

*Second Edition*

# *Principles of* **Dental Imaging**

*Olaf E. Langland  
Robert P. Langlais  
John W. Preece*



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# Principles of Dental Imaging

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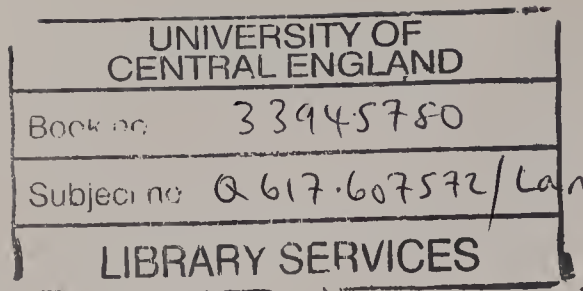
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*To my wife, Gwendolyn Stokes Langland, whose encouragement,  
help, and sacrifices made this book possible.*

*—Olaf Langland*

*To Denyse Paré Langlais. Once again, merci beaucoup!*

*—Robert Langlais*

*To my wife Lorna and children Jon and Elizabeth  
for their patience, love, and encouragement;  
to my students who make each day a challenge and joy.  
Thank you.*

*—John Preece*





# Preface to the First Edition

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Make no mistake: The principles described herein must be understood by all dental health care workers whose goal is to learn and perfect the techniques of dental imaging. The skills required to expose and process radiographs are exactly the same for all types of dental professionals. Additionally, the risks of radiation exposure are the same for all. Therefore, this text is meant to be used by all students who are required to learn dental imaging techniques.

**ORGANIZATION:** This text is organized into five sections, and each section is subdivided into several chapters. With the material subdivided into these smaller packages, students will find that their learning goals are more easily achieved. Course directors may wish to alter the order of the various sections to conform with different subject sequencing by various instructors. Section 1 is concerned with the concepts of radiologic imaging; Section 2 deals with radiographic techniques and procedures; Section 3 discusses panoramic and special imaging techniques; Section 4 involves radiation biology and radiologic health; and Section 5 describes radiologic imaging interpretation.

**LEARNING/TEACHING DEVICES:** The authors of this textbook have used numerous pedagogic methods to enhance the learning process and to stimulate student interest in this sometimes difficult and confusing subject. The resulting content helps students correlate classroom and laboratory learning with assigned clinical experiences. For example, the first nine chapters (1 through 9) and Chapter 11 include laboratory/workshop sessions to enhance the learning of concepts and clinical techniques; Chapters 10 and 12 through 18 contain case-based questions to further the cognitive skills necessary to assess and interpret the images. The full complement of these teaching devices is as follows:

**Chapter Learning Objectives:** At the beginning of each chapter, a list of objectives defines what the student should learn upon completion of the chapter. These objectives also emphasize the goals of the instructor.

**Key Terms and Phrases:** Key terms and phrases used within the text are listed at the beginning of each chapter. This list can be used as a quick reference to the material learned.

**Illustrations and Tables:** In many instances, concepts are illustrated with a combination of line drawings,

clinical photographs, and radiographs, as well as tables where applicable. The authors have made extensive use of these aids to help the student visualize principles more clearly and to clarify complex ideas or to summarize important areas of the narrative, such as a series of steps in a technique. This book contains many

publisher.

**Boxed Information:** Lists of key points, steps in a technique, or short paragraphs, set off in boxes, appear within the text throughout the book. These boxes will help apply information and ideas to clinical situations and also serve to highlight important information for future reference or review and study.

**Practical Laboratory Workshops:** (Application of Knowledge): Workshops are found at the end of the first nine chapters (1 through 9) and Chapter 11 to allow the student to practice a technique in a clinical setting, visualize a concept, or solve a problem. These practical applications are used to reinforce the previously presented information, which may have been only partially assimilated by the student in reviewing class notes and textbook information.

questions are presented at the end of each chapter. Some questions are constructed so that answers will require only recall of simple concepts or facts. Other questions require more complex understanding and may have more than one correct answer. Other testing formats are added from time to time, including matching columns or basing questions on a diagram, a radiograph, or a case-based question. Many of the questions will help the student gain experience in applying information to clinical situations and will test their preparedness in answering examination questions.

National Board/State Board Certifying Examination, which is based on the content of the whole book. All of these questions may serve as topics for discussion with other students or with the instructor. Answering these questions correctly, however, does not necessarily test for problem-solving skills.

**PROBLEM SOLVING:** Problem solving is the mental process that we use to arrive at a “best answer” to an un-

known, subject to a set of constraints. The problem situation is usually one that has not been encountered before, and the student must mentally process learned information to obtain the “best” answer. Our *first* objective in teaching problem solving is that the student acquires an essential body of knowledge in dental imaging. This has two dimensions: what the students should learn and how the body of knowledge should be learned. It is later retrieved as useful information to perform clinical tasks. Our *second* objective concerns the students’ ability to apply that knowledge effectively to assess, understand, and evaluate dental imaging problems. Students with only encyclopedic information are less effective, if not unsafe, because they do not have problem-solving skills necessary to approach dental imaging problems. Problem-solving skills encompass the skills needed to (a) evaluate the problem, (b) decide what is wrong, and (c) make decisions to manage the problem with appropriate actions. Our *third* objective in problem solving is to ensure that students are able to extend their knowledge base to remain contemporary in the field and be able to provide appropriate solutions for new or unique problems they may face in the future.

**READABILITY:** Readability is one of the highest priorities of the authors. We have therefore engaged the services of some of our colleagues, whose names appear in the contributors list. It has been our intent to make this book more readable so that a student may begin to learn without the added confusion created by a complex narrative format. This is one of the most important duties of our valued contributors.

**APPROPRIATENESS OF CONTENT:** To ensure appropriate content, we consulted the Oral and Maxillofacial Radiology guidelines published by the American Association of Dental Schools (AADS). We also studied the survey responses of 95 instructors of dental imaging to help us achieve the best design for the book. This book has not been diluted to create an artificial separation between the various types of dental professionals aspiring to learn oral and maxillofacial radiologic imaging.

**FORMAT:** Apart from the use of bold headings and fonts of various sizes to clearly delineate subheadings from major headings, the authors have used individual boxed subject highlights to further enhance divisions in the subject material and readability. All of these format variations are designed to stimulate the student in the learning process, to give the student a feeling of comfort and ease in reading the book, and to impart a feeling of satisfaction as the material is being learned in an organized fashion.

**GLOSSARY:** A glossary of pertinent terms and definitions is included at the end of the book. Review of the glossary is a helpful tool to identify weak areas requiring further study in preparing for examinations.

**INDEX:** The text contains a complete and “user-friendly” index for students and teachers to use in searching for specific information.

Olaf E. Langland  
Robert P. Langlais



# Preface to the Second Edition

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Firstly, we would like to welcome our new co-author, John W. Preece. He has been teaching dental hygiene and dental assisting for many years and has achieved national prominence in oral and maxillofacial radiology, in dental hygiene standards and accreditation, and in dental assisting radiology qualification curriculum development and course presentation. Dr. Preece has completely revised and updated Chapter 12, "Radiation Biology," to a much more readable and easily understood format.

The preface to the first edition explains our original plan for the design and presentation of this book to the reader. The wide acceptance and overall success of the first edition has afforded us the opportunity to do a second edition. We thank each and every instructor and student for giving us this support.

The overall theme of the second edition of this textbook is to maintain the style and format of the first edition but with refinements. We are happy to say that many of our course directors were kind enough to supply us with feedback and many suggestions for improvement.

This second edition has two major additions: "Chapter Zero" ("Introduction to Dental Radiology") and a very comprehensive chapter section on digital imaging by our newest contributor, William S. Moore (Chapter 11, "Special Imaging Techniques"). "Introduction to Dental Radiology" is an example of the authors' response to a perceived need and the vivid use of our imaginations in its unique designation as "Chapter Zero." It consists of a brief general introduction to dental radiography for the student who, after maybe one lecture in the course, will now proceed to the laboratory or clinic and begin to learn the clinical techniques. Therefore, information such as some basic definitions of commonly used terms or words, the parts of the machine, how to turn on the x-ray machine and adjust the settings, some safety and infection control tips, procedures on processing and mounting of the x-ray films, and examples of common technique errors are included in a few brief pages. Digital imaging is here to stay and will in a few short years surely replace

film-based radiography. Although a small percentage of dental offices (about 7%) are currently equipped with digital imaging, the numbers increase every day. The new chapter section on digital imaging is one of the simplest and most complete we have seen. All of the new clinical photographs and prints of radiographs in this edition were done digitally.

Some of the more minor (but much needed) changes include: improvement and simplification of some of the diagrams, several new diagrams, and replacement prints of some radiographs. We have also tried to more perfectly match photographs, diagrams, and prints of radiographs to the same side of the patient and anatomic region for better visualization of a technique described. With the exception of chapters 14 and 16, the review section at the end of each chapter has been expanded to include at least 15 review questions. All review questions have been checked to ensure that the correct answer can indeed be found within the chapter. We have also expanded the list of key words

tional Board/State Board Certifying Examination has been expanded slightly with several new cases. Some of the folks who helped to make the above changes include the inimitable photographer extraordinaire, Lee Bennack; some of the world's finest photographic technicians, Thurman Hood and April Cox, whose computer skills have outmatched and outdone their photographic expertise; and our extremely talented artist who is a true genius, David Baker. This book could not have been ready without the precise and skilled word processing provided by Gwen Langland, who redid the entire manuscript several times over for the second edition. We also wish to thank our publisher, editors, and production staff for their dedication to making this the best publication in the field.

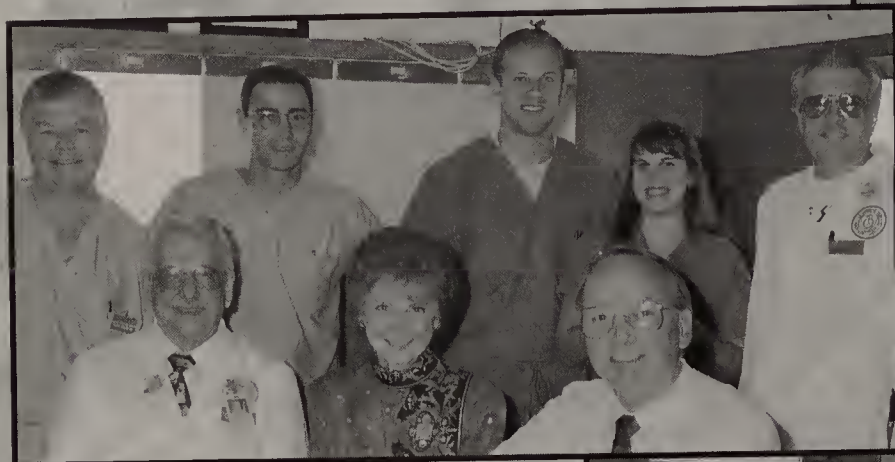
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John W. Preece

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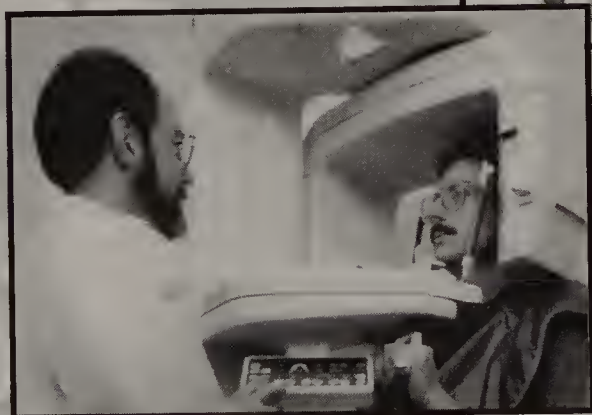


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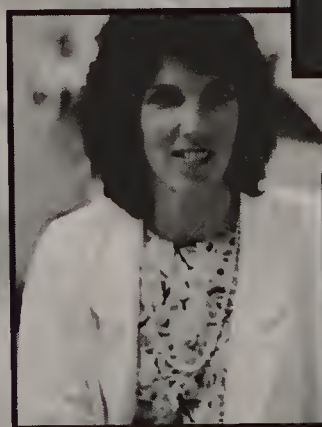
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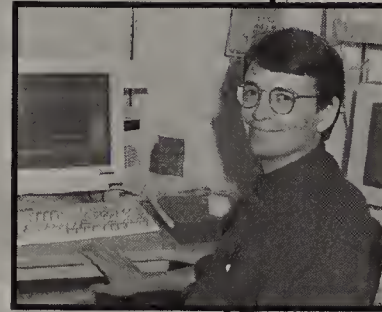
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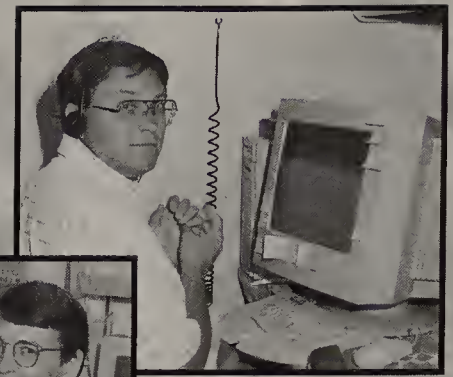
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We, Olaf Langland (1), Robert Langlais (2), and John Preece (5), would especially like to recognize Gwen Langland (3) for the endless amount of word processing and editing she did during the preparation of the manuscript, and the dozens of little things needed to get the job done. We welcome our new and valued contributor, Bill Moore. We are also grateful to some of our favorite students who acted as models for the photographs of the various techniques. These include Mike Suhler (4), Brad Revering (6), Heidi Ritsco (8), Isabel Britain (9), Stacy Morgan (10), and David Tasch (13). Other persons who were photographed include Dr. Scott Makins (11), University of Texas at Houston, TX; Dr. Michael McNally (12), University of Nebraska; Dr. Craig Miller, University of Kentucky at Lexington; Dr. Manon Paquette, University of Montreal; Dr. Raghunath Puttaish, Baylor University, Dallas, TX; Dr. Cliff Thornell; David Greer (7), computer technologist at UTHSCSA; and Michelle Kirby, radiology technician at UTHSCSA. We also had the invaluable input of our two collaborators, Dorothea Cavallucci (14), Harcum College, Bryn Mawr, PA, and Joan Gibson-Howell (15), West Virginia University at Morgantown, WV, who judiciously read and reread the manuscript several times, offered suggestions relating to terminology, assessed the comprehensibility of the text, critiqued the stated objectives, suggested the case-based questions, and provided multiple other inputs which made the book better. Also, we are deeply indebted to those 95 wonderful dental radiology educators from every corner of the United States who answered our Dental Radiology Survey and offered us so many marvelous suggestions and advice. We are totally indebted to Lee Bennack (16), photographer extraordinaire, who created the skull photos and the other special effect photos, and just about all of the other photos in the text. We also had the support of Al Julian (17), director of photography; April Cox (18), the photo lab technician who personally critiqued just about every photo and x-ray print in the text; and Thurman Hood (19), the photographic technician who was responsible for the lab work resulting in the exquisite illustrations, many of which were drawn by Nick Lang (20), who also designed and drew the cover illustration and the unfolding panoramic image drawings of technique errors. Other medical illustrators who helped include David Baker (21), Brian Neuenschwander, and Chuck Whitehead, who drew the first illustrations depicting the unfolding of the panoramic image. We are also grateful to Nancy Place (22), Medical Illustrator, and Kris Doyle (23), Publishing Coordinator. There are many others who helped with the book and we thank them also, including the editors and production team at Lippincott Williams & Wilkins. Finally, we acknowledge Denyse Langlais, who has had numerous textbooks dedicated to her for her unfaltering support of Robert Langlais' book projects, and Lorna Preece for her encouragement and understanding throughout the many years of John Preece's administrative and teaching activities.

OEL, RPL, and JWP





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*And all other persons who answered the dental radiology educational survey sent out by Drs. Langland and Langlais. You are the educators who make this textbook possible.*





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# Concepts of Radiologic Imaging

- CHAPTER 0      Introduction to Dental Radiology
- CHAPTER 1      Production of X-Rays
- CHAPTER 2      The X-Ray Machine, Attenuation, and Recording of Radiographic Images
- CHAPTER 3      Diagnostic Quality of Dental Radiographs





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# Introduction to Dental Radiology

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## A WORD TO INSTRUCTORS

### PURPOSE OF THIS CHAPTER

The authors recognize that in a perfect world, students would be able to have all, or most, of the related didactic instruction before using x-ray equipment; exposing, processing, and mounting radiographs; and identifying and correcting various technique errors. In the imperfect world we live in, the semester or quarter starts and we begin immediately with both lecture and laboratory activities, with students using equipment and procedures not yet covered in lecture. The purpose of this chapter is to provide a “crash course” in basic radiographic procedures and terminology to help facilitate early entrance into the preclinical laboratory.

---

### CRITICAL BASIC ASSUMPTIONS

Students beginning in the preclinical laboratory should begin to use proper terminology associated with the radiographic process—initially at a superficial level, with greater detail and understanding to follow. Due to the availability of several intraoral radiographic procedures such as the paralleling and bisecting-angle procedures using various types of instruments and/or biteblocks, we feel it desirable that students start the preclinical laboratory using only one of the available intraoral periapical and bitewing methods. Once this introductory method is mastered, then other intraoral radiographic principles and procedures may be introduced, time permitting. All students must learn where to place the film in the mouth for each area and what interproximal space to open. Students must be able to process the film and recognize sufficient anatomy or tooth shapes to mount the radiographs properly. Students can learn other anatomical landmarks later as an aid to distinguishing normal anatomical structures from abnormalities. Students should be able to recognize the most common radiographic technique errors before learning about less common technique and processing errors.

---

## NONCRITICAL BASIC ASSUMPTIONS

Beginning students will be using technique mannequins. A knowledge of aseptic technique may not be critical during the first few laboratory sessions; this will be introduced once students have become more efficient in film placement and tubehead alignment. Subjects concerning “patient history” and “history of radiology” can be covered later, and so can discussions on “how the x-ray unit and processing chemicals work.” Radiation biology and safety can be covered after students learn “what x-rays are and how they are absorbed.” Radiographic contrast will be covered later, because it is better to discuss “film characteristics and film processing” first. We will start with the paralleling principle, and the bisecting-angle principle can be integrated later.

---

## GETTING STARTED—STUDENTS, THE REST IS UP TO YOU

### FIRST PRINCIPLE

X-ray exposure is potentially harmful. You **must** stand behind the leaded barrier or outside the x-ray cubicle in the hall, or behind a wall, during every exposure. **Absolutely no one** is to stand close to the x-ray tubehead or in a direct line with the x-ray beam during an exposure. There are **no exceptions** to this rule—ever. Begin practicing good radiation hygiene now! In addition, place the leaded apron and thyroid collar on the mannequin.

### SECOND PRINCIPLE

X-ray film is sensitive to x-rays—**always** keep your film behind the barrier or outside the room. Set up your work area with the unexposed film in one area; deposit exposed film into a paper cup that is positioned away from the unexposed film.

### THIRD PRINCIPLE

Please do as your instructors tell you for now; we promise to explain the specific reasons for doing certain things later.

## BASIC DEFINITIONS

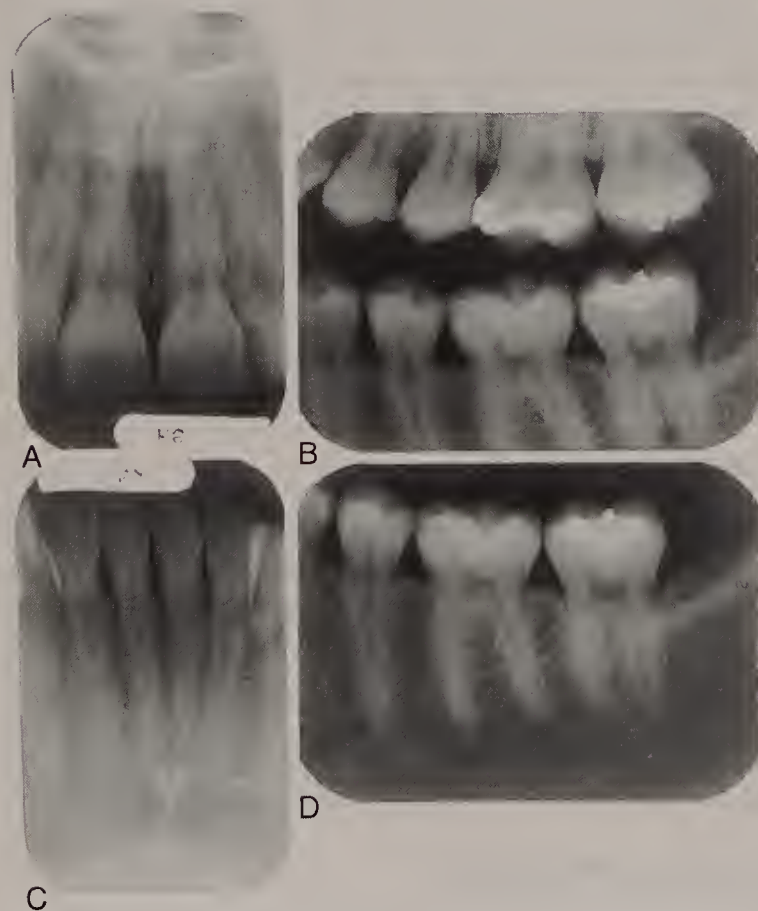
### TERMS ASSOCIATED WITH DENTAL RADIOGRAPHY

Dental radiography is the art and science of making shadow pictures of the teeth and surrounding structures.

Dental radiograph is a shadow picture of the teeth and its surrounding structures.

Periapical radiograph includes the entire tooth crown, root, and at least 4 mm of bone above or below the apex of the tooth (Fig. 0-1A, C, and D).

Interproximal/bitewing radiograph shows equal portions of the crowns of upper and lower teeth, in addition to one-third of the alveolar bone closest



**Figure 0.1 Dental Radiographs.** (A) Maxillary anterior periapical radiograph. (B) Posterior interproximal (bitewing) radiograph. (C) Mandibular anterior periapical radiograph. (D) Posterior mandibular periapical radiograph.



**Figure 0.2 Intraoral Film Sizes.** (Top row) No. 2 film, correct side (white, smooth) faces x-ray tubehead. No. 2 film, wrong side (tab side). (Bottom row) No. 1 film, correct side (white, textured) faces x-ray tubehead. No. 1 film, wrong side (tab side).

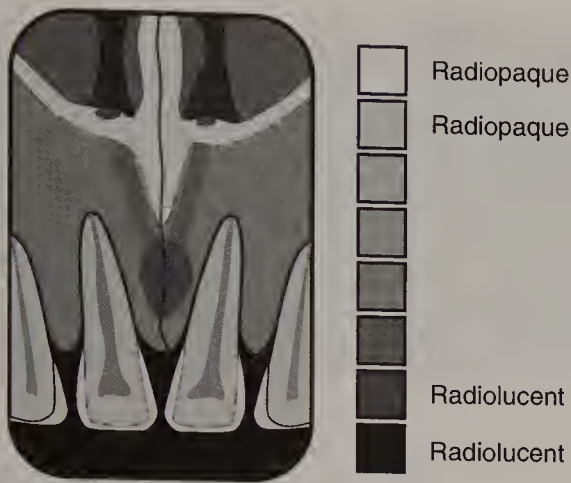
to the crowns (referred to as the “alveolar crest” or “crestal alveolar bone”) (Fig. 0-1B).

**Film.** The shadows of the teeth are recorded on a film, similar to the kind used in a camera but specially designed for x-rays. When the film is placed inside the mouth, it is called an intraoral film and it is used to produce intraoral radiographs. The film we use comes in several sizes. For starters you will typically be using small and big films. The small ones we refer to as No. 1 size film (Fig. 0-2, bottom row); the bigger one is a No. 2 size film (Fig. 0-2, top row); they may be used either vertically (long side up) or horizontally (long side: horizontal/flat) (Fig. 0.1).

### TERMS ASSOCIATED WITH THE RADIOGRAPH: RADIOLUCENT/RADIOPAQUE AREAS ON THE RADIOGRAPH (FIG. 0-3)

**Radiolucent**—black or dark gray areas on the radiograph.





**Figure 0.3 Radiolucent/Radiopaque Areas on Radiograph.** White areas represent enamel and cortical bone. Gray areas represent dentin and bone. Dark areas represent air, pulp, and foramina.

**Radiopaque**—white or light gray areas on the radiograph.

**Density**—overall darkness or lightness of the processed radiograph. A radiograph may be too dark, too light, or just right. If it is too light, we say the radiograph exhibits “insufficient (low) density;” if it is too dark, we say it exhibits “excessive (high) density” (Fig. 0-4).

## THE X-RAY UNIT

### KEY PARTS

The control panel (Fig. 0-5) contains the following:

**On/off switch**—a light comes on when the machine is switched to the “on” position.

**Exposure timer**—set the exposure time according to the exposure chart posted on the wall next to the control panel.

**Milliamperage (mA) switch**—set the mA switch according to the exposure chart (some machines do not have this switch).

**Exposure switch**—this switch (hand or foot operated) causes the x-ray unit to produce x-rays. You **must** hold the button down for the full length of the exposure, until the beeping stops. Taking your finger/foot off too quickly will stop the production of x-rays instantly, and the processed radiograph will be “underexposed” and appear too light.

## X-RAY ROOM AND INFECTION CONTROL (FIG. 0-6)

**X-ray arm**—mounts the tubehead to the wall and permits moving the tubehead up and down and front to back around the patient’s head.

**Yoke**—attaches the tubehead to the arm. The yoke permits the tubehead to rotate in a horizontal direction (side to side).

**Tubehead**—attaches to the yoke and rotates in a vertical direction (up and down). The tubehead contains the **x-ray tube** that creates the invisible x-ray beam of energy we use to take radiographs (pictures of teeth). The x-ray tube is referred to as the “source” of radiation.

**Beam indicating device (BID)**—the BID is attached to the tubehead and may be rectangular; most commonly, it is a round cylinder of varying length.

**Central ray (CR)**—the CR is an imaginary beam of x-rays in the exact center of the BID; the CR is used to define the position of the beam of radiation vertically (up and down) and horizontally (long side: front to back/left to right).

**Exposure chart**—is a critical element in any radiographic procedure and is essential to minimize patient exposure and reduce the possibility of retakes due to improper exposure. Each x-ray unit should have its own exposure chart. You must adjust the x-ray unit to radiograph each area of the mouth. Do not use a different setting unless specifically requested by your supervisor.

### Exposure Chart

Dental Clinic                      Kodak E+ Speed Film  
X-Ray Exposure Chart            70 kVp, 7 mA

Average Patient/Dexter

|               |               |                |               |
|---------------|---------------|----------------|---------------|
| Max. Central  | = 28 impulses | Mand. Central  | = 22 impulses |
| Max. Premolar | = 36 impulses | Mand. Premolar | = 28 impulses |
| Max. Molar    | = 40 impulses | Mand. Molar    | = 32 impulses |

|                                              |                                              |
|----------------------------------------------|----------------------------------------------|
| Interproximal Radiographs                    | Occlusal Radiographs                         |
| Premolar                      = 36 impulses  | Maxillary                      = 36 impulses |
| Molar                          = 40 impulses | Mandibular                   = 36 impulses   |

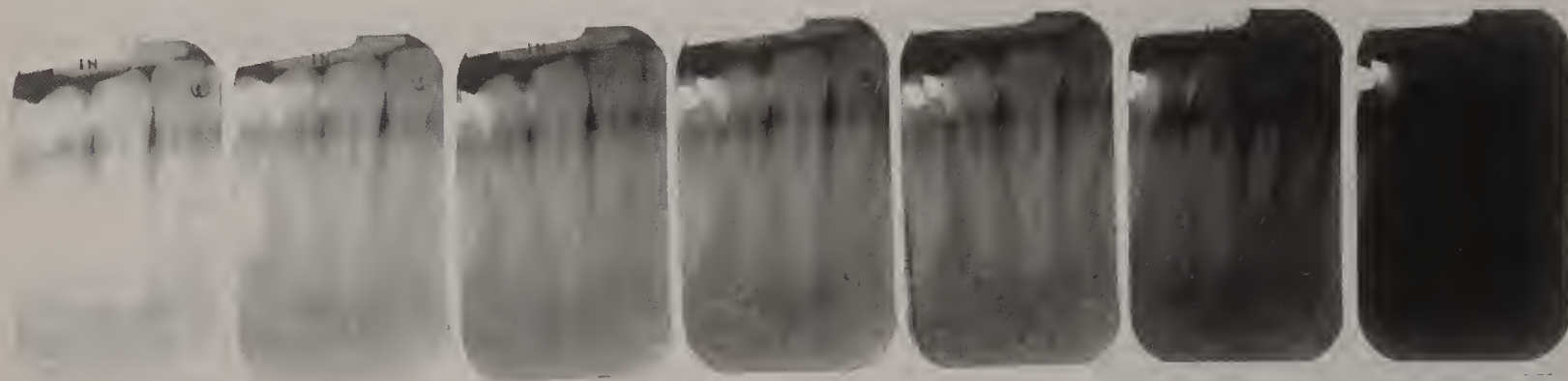
**Procedure:** Expose **one film**, process and verify acceptable density with faculty member.

Acceptable Exposure Modifications

Children/Petite Adults—decrease above settings by 4 impulses

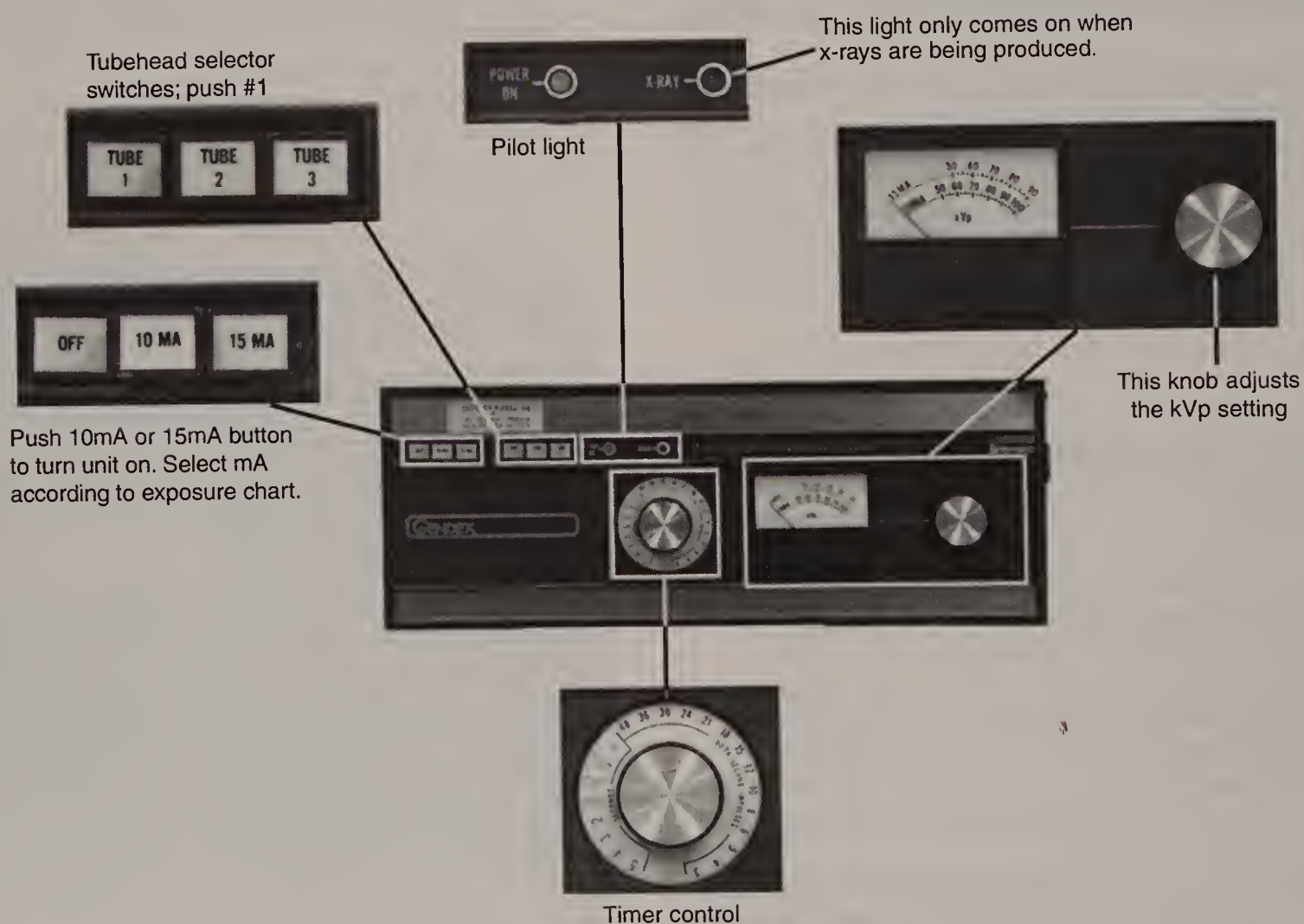
Large Adults—increase above settings by 4 impulses

Faculty member must authorize any increased exposure more than +4 impulses. Note exposure variation in radiography record in the patient’s chart.



**Figure 0.4 Differences in Densities.** Beginning on the left, the first two images are low density, which is insufficient for interpretation. The next three images are medium density and acceptable for interpretation. The last two images on the right have excessive density and are not acceptable for interpretation.

## X-ray Unit Control Panel



**Figure 0.5 X-Ray Unit Control Panel.** Beginning clockwise from the left: off switch, mA selector button, tubehead selector button (one control panel can operate several tubeheads), pilot light (which indicates when power is activated), x-ray light, kVp adjustment knob and dial, and timer control knob with exposure times indicated.



### Clinic Rules Concerning Radiographic Exposure

1. No radiographs will be exposed with a person standing or walking in the hallway between cubicles.
2. The student exposing the radiographs will stand directly behind the wall to activate the "touch pad" exposure switch. The operator should never stand in a position where they can see the x-ray tubehead at the time of exposure.
3. During patient exposures, the patient will be observed "indirectly" by means of a mirror positioned appropriately on the wall.
4. Preclinical radiology "partners" will not remain in the cubicle during exposure of the film.
5. Students will place leaded apron and thyroid collars on all patients.

## GENERAL INSTRUCTIONS: PARALLELING PRINCIPLE

### LONG AXES OF TEETH

Every tooth has a long axis. For anterior (front) teeth, it is a line drawn from the incisal (biting) edge to the apex of the tooth root. Identify the long axis of the tooth or teeth you intend to radiograph. Normally, the teeth are not straight up and down in the mouth, thus their long axis is not usually vertical. The teeth have a long axis such that they are usually tipped one way or another (Fig. 0-7).

### PARALLELING TECHNIQUE

The film is placed in a film holder to hold the film in a stable, secure position covering the teeth you are attempting to radiograph. Position the film parallel to the long axis of the tooth closest to the middle of the film. Position the CR of the BID perpendicular to the long axis of the tooth and film (vertical angulation) (Fig. 0-8). To prevent overlapping of adjacent teeth, the CR should be directed parallel to the specified interproximal space (horizontal angulation) (Fig. 0-9). Finally, center the beam of radiation over the film without changing either the vertical or horizontal inclination of the CR or BID.

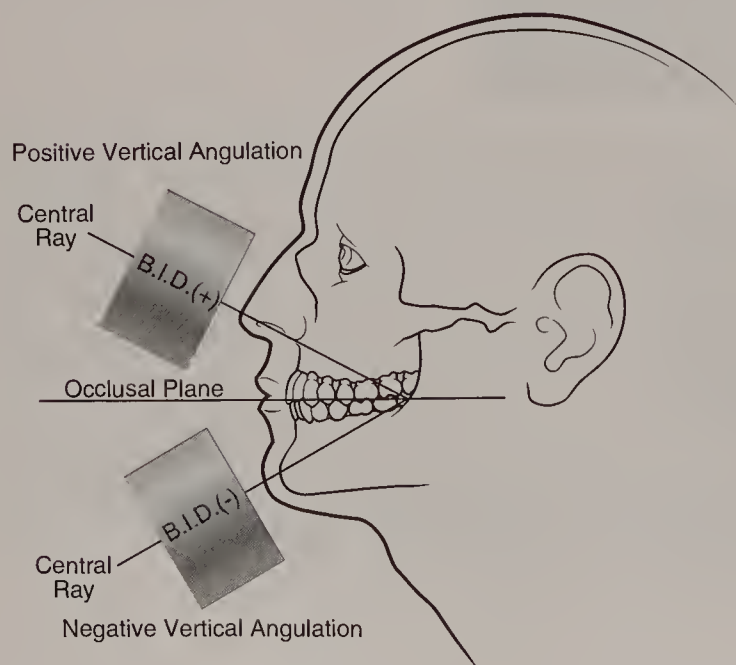
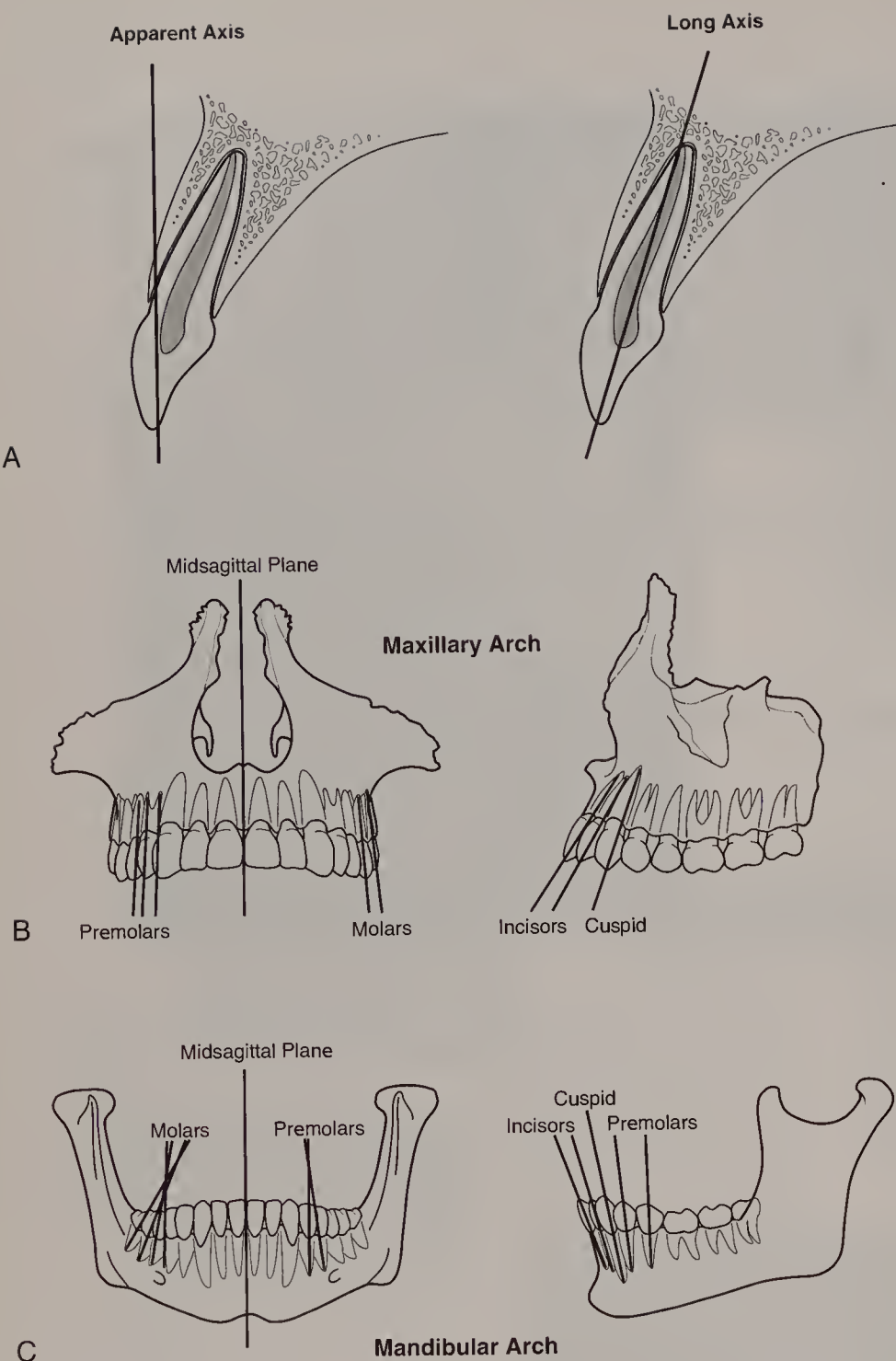
### IMPORTANT NOTE

When using the **paralleling principle**, the goal is to position the film as **parallel** as possible to the **long axis** of the

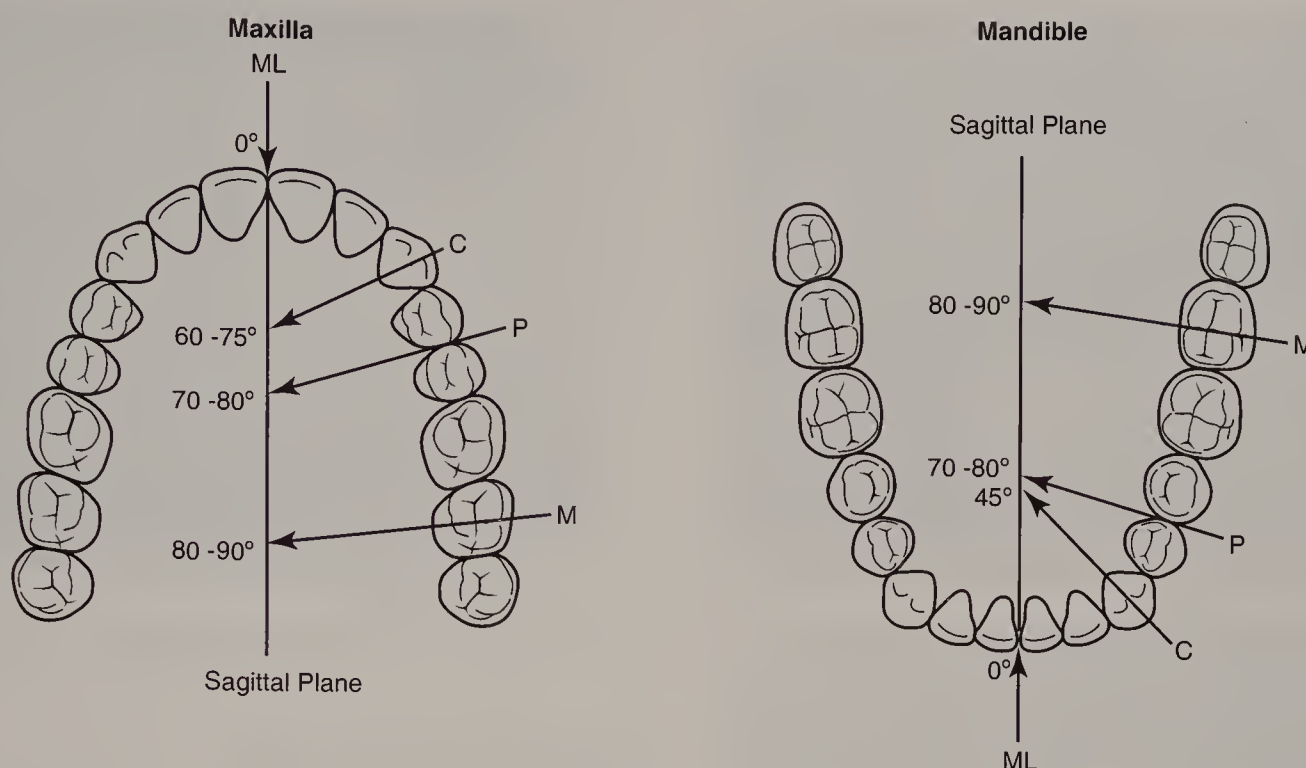


**Figure 0.6 X-Ray Room and Infection Control Equipment.** (1) X-ray arm. (2) Yoke with clear plastic wrap for infection control. (3) Tubehead and plastic wrap. (4) Rectangular BID and plastic wrap. (5) Head rest and plastic wrap. (6) Chair arm and plastic wrap. (7) Seat of x-ray chair. (8) Protective thyroid collar. (9) Leaded apron. (10) Operator apparel including scrubs, disposable long-sleeve gown, and latex examination gloves. (11) Leaded barrier wall. (12) Leaded glass window so operator may view patient during x-ray exposure. (Courtesy of Manon Paquette, DMD.)

tooth to be radiographed. Your ability to do this will be determined by the depth and width of the hard palate (maxilla) and the height of the muscle attachments in the floor of the mouth of the patient. When using a biteblock of any type for periapical radiographs of the maxilla and anterior mandible, always seat the film holder against the incisal edge or buccal cusp **first**, and then rotate the film up into contact with the hard palate or down into the floor of the mouth of the patient. This action will keep the film holder stabilized against the tooth while the film is rotated to be as parallel as possible to the long axis of the tooth.







**Figure 0.9 Horizontal Angulation of BID.** To position the horizontal angulation of the BID correctly, the CR of the beam should be directed at an angle to the sagittal plane, as specified by the anatomical region. C, canine; M, molar; ML, midline; P, premolar.

## PLACING THE FILMS IN THE MOUTH (FIG. 0-10)

### PROPER PLACEMENT OF FILM IN A PARALLELING TECHNIQUE FULL-MOUTH SURVEY

**Central incisor region (maxilla/mandible)**—center the film directly behind the two central incisors. The “key” interproximal space for this radiograph is the contact between the two central incisors.

**Lateral incisor region (maxilla only)**—center the film directly behind the lateral incisor. The “key” inter-

proximal space for this radiograph is the contact between the central and lateral incisor.

**Canine region (maxilla/mandible)**—center the film directly behind the canine. The “key” interproximal space for this radiograph is the contact between the lateral and canine. The canine region is also known as the “cuspid” region.

**Premolar region (maxilla/mandible)**—position the film forward in the mouth (mesial) to include the distal (back) one-half of the canine. The “key” interproximal space for this radiograph is the second premolar–first molar interproximal space and it should not be overlapped. The premolar region is also known as the “bicuspid” region.



**Figure 0.10 Proper Film Placement for a Full-Mouth Survey of the Parallelizing Technique.**

**Molar region (maxilla/mandible)**—position the film toward the back of the mouth (distal) to include all of the third molar. The “key” interproximal space for this radiograph is first–second molar interproximal space and it should not be overlapped.

**Premolar interproximal radiograph**—position the film forward (mesial) to include the distal (back) one-half of the mandibular cuspid. The “key” interproximal space for this radiograph is the maxillary second premolar and first molar interproximal space.

**Molar interproximal radiograph**—position the film backward (distal) to include the last erupted tooth in the arch. The “key” interproximal space for this radiograph is the maxillary first and second molar interproximal space.

Note: Refer to Figures 5-22 to 5-32 in Chapter 5 for Dentsply/RINN XCP positioning.

## SEQUENCE OF ACTIVITY TO EXPOSE A RADIOGRAPH

1. Set the x-ray control panel: (Exposure time, kVp, mA as appropriate.)
2. Select an appropriate size film and place it into the film holder with the embossed dot in the groove/slot of the film holder.
3. Place the film into the mannequin’s mouth as indicated above for each area with the film as parallel as possible to the long axis of the tooth.
4. Set the vertical (up/down) relationship of the CR perpendicular to the long axis of the tooth and film.
5. Position the horizontal (front to back) relationship

of the CR so that it is parallel to the “key” interproximal space indicated above. (You need to do this without changing the vertical direction of the CR.) Use the yoke of the machine to do this.

6. Center the beam of radiation over the film.
7. Make sure you are standing behind the barrier and no one else is in the room or in line with the beam of radiation.
8. Warn the patient not to move by saying, “Please don’t move. I’m going to expose the film now.”
9. Expose the radiograph. Keep your finger on the exposure switch until the “beep” and the exposure light go off by themselves.
10. Remove the film from the mouth and place it in an area away from the unexposed film—a paper cup works great.
11. Take all radiographs assigned. When finished, process (develop) your films.

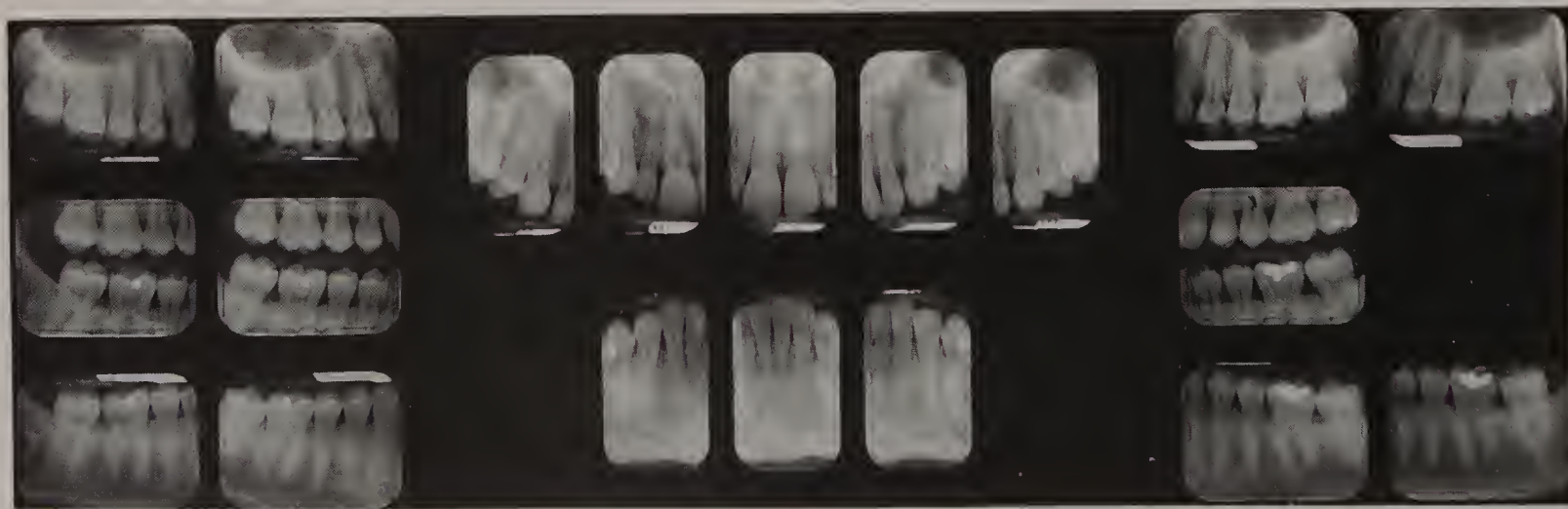
## PROCESSING THE RADIOGRAPH(S)

Refer to Figures 4-12 to 4-14 in Chapter 4 for infection control guidance in processing films.

## MOUNTING THE RADIOGRAPHS

Use the shape of the teeth as a guide. Your supervisor will tell you whether he or she wishes you to mount the radiographs with the embossed dot up (facing out) or down (facing in) (Fig. 0-11).

Refer to Figures 6-10 to 6-16 in Chapter 6 for guidance in processing and mounting films.



**Figure 0.11 Normal Anatomical Landmarks for Mounting a Full-Mouth Survey.** Some of these landmarks include: maxillary sinus for maxillary posterior teeth; the “inverted Y” for maxillary canine; the nasal fossae for maxillary anterior teeth—Curve of Spee for correct positioning of bitewings; mandibular canal for mandibular molar region (not seen here); mental foramen for mandibular premolar region; and genial tubercles for mandibular incisor region (not seen here).



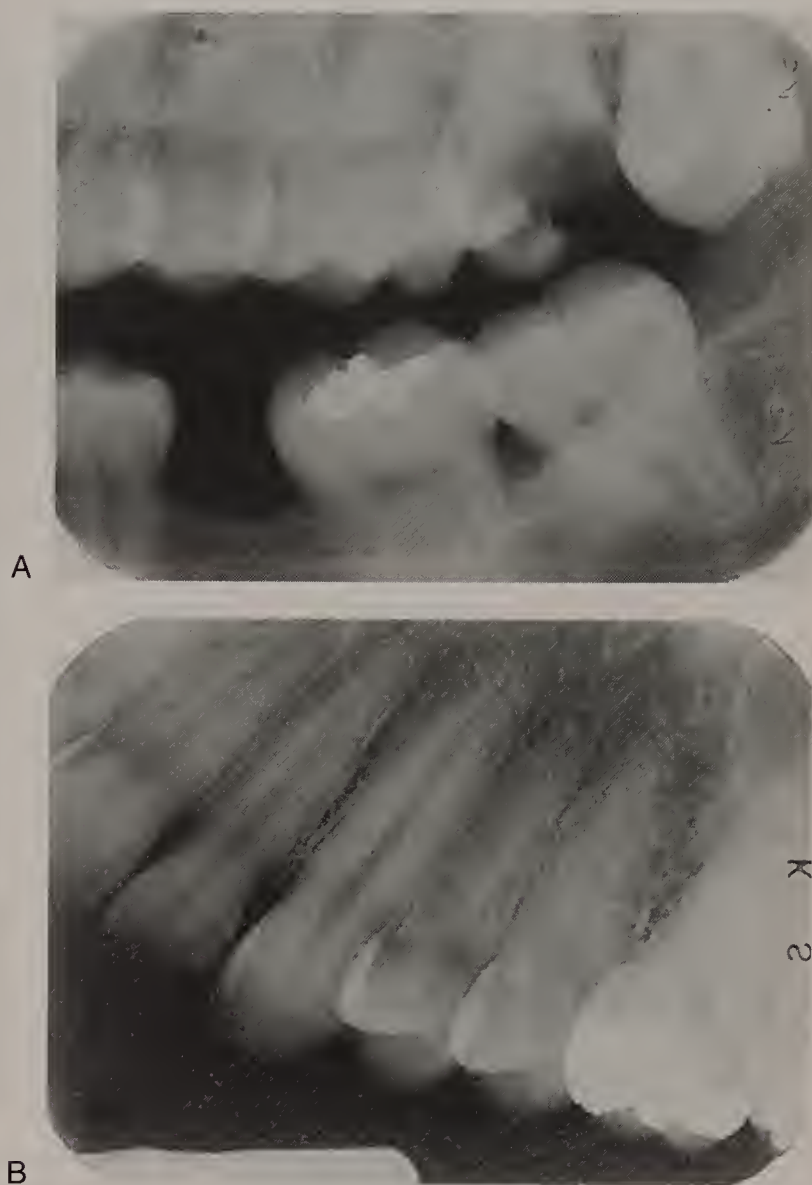


**Figure 0.12 Incorrect Film Packet Placement for Molar Radiograph.** Third molar not shown properly.

## PICTORIAL GUIDE TO RECOGNIZING ERRORS

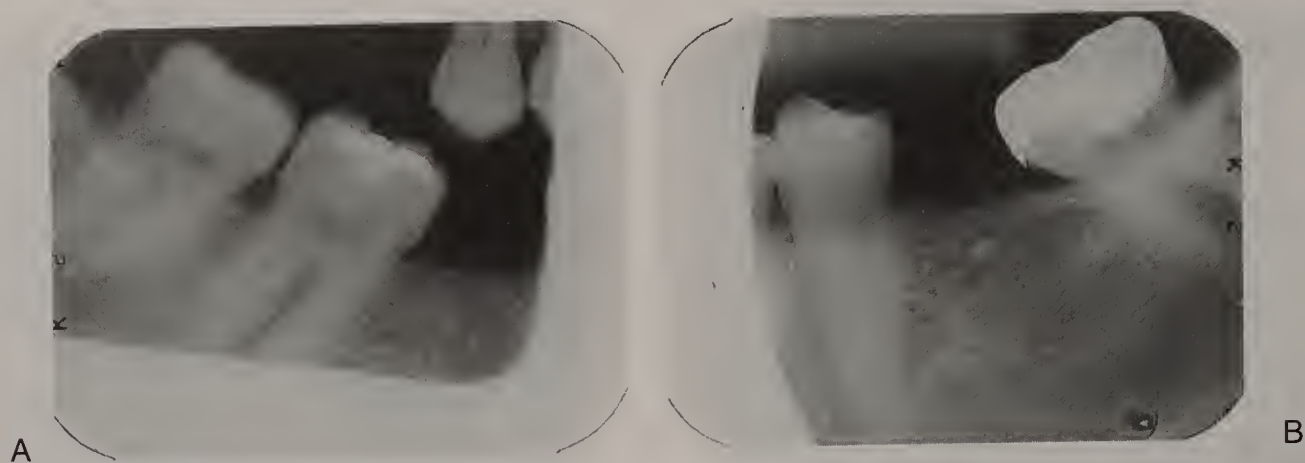
The following technique errors (no processing errors) are probably the most common ones you will encounter as you begin working with your preclinical technique mannequin and patients.

1. **Incorrect packet placement** results in the correct teeth not being included in the image—errors of this type generally involve not centering the film behind the correct tooth, inability to position the film mesial to include the distal one-half of the canine on premolar periapical and interproximal radiographs, and inability to position the film distal enough to include all of the third molar, etc. (Fig. 0-12).
2. **Incorrect horizontal angulation (overlapping)**—CR was not parallel to the “key” interproximal space (Fig. 0-13).
3. **Cone-cut (partial image)**—did not center the beam over the film and part of the film is clear (Fig. 0-14A and B).
4. **Bent film**—“patient” bit down too hard; distortion

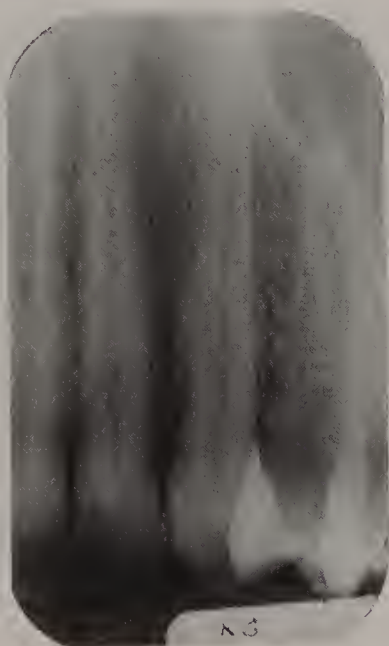


**Figure 0.13 Overlapping.** (A) Bitewing film overlapping. (B) Posterior periapical film overlapping.

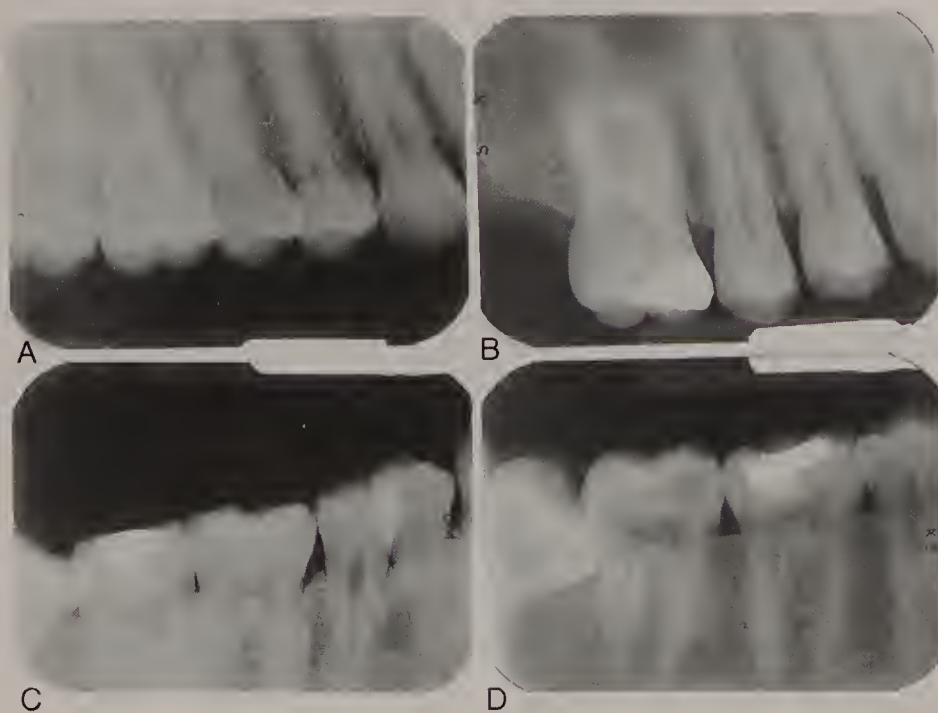
- of root apex and bone or the operator bent the film on purpose (Fig. 0-15).
5. **Missing root apices**—may be produced by poor film placement or inadequate vertical angulation (Fig. 0-16).
6. **Backward film**—film placed backside facing to the front. Backward films should be rejected and not used, because there is a danger of interpreting the wrong side of the patient (Fig. 0-17).



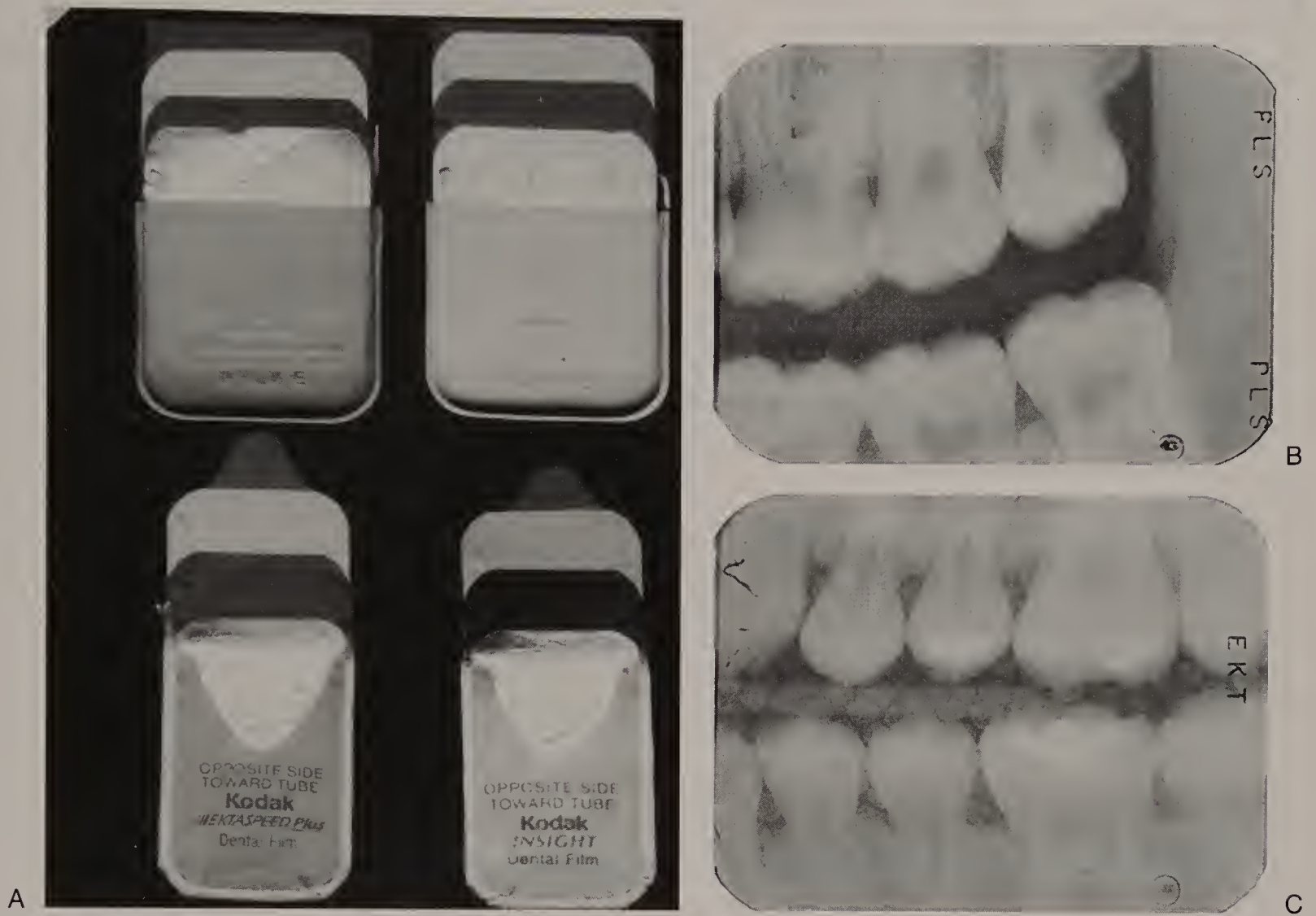
**Figure 0.14 Partial Image (Cone-Cut).** (A) "Cone-Cut" with rectangular BID. (B) "Cone-Cut" with round BID.



**Figure 0.15 Bent Film.**



**Figure 0.16 Missing Root Apices.** (A) Due to poor film placement, maxilla. (B) Due to inadequate vertical angulation, maxilla. (C) Due to poor film placement, mandible. (D) Due to inadequate vertical angulation, mandible.



**Figure 0.17 Backward Film.** (A) A backward film is identified by embossed patterns on the lead foil, called a "tire track" pattern (*top*), or "ping-pong ball" pattern (*bottom*). (B) Radiograph with "tire track" pattern. (C) Radiograph with "ping-pong" ball pattern.





# Production of X-Rays

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Identify the components of the x-ray tube on a diagram.
2. Discuss the steps that take place to produce radiation.
3. List and identify the 10 properties of x-rays.
4. Identify by written description and discuss bremsstrahlung and characteristic radiation.
5. Discuss the wave concept of electromagnetic radiation.
6. Identify the two types of ionizing radiation.
7. Discuss briefly the history of radiology.
8. State examples of electromagnetic radiation.
9. Discuss the components of an atom.
10. Complete a workshop demonstrating the properties of x-rays.
11. Learn the basic parts of the x-ray machine and how it works in a workshop format.
12. Complete a workshop/laboratory exercise regarding basic radiation safety.
13. Test his or her knowledge by solving a problem dealing with the properties of x-rays, including radiation protection.
14. Test his or her knowledge by answering the review questions.

## KEY WORDS/PHRASES

|                              |                                   |                          |                          |
|------------------------------|-----------------------------------|--------------------------|--------------------------|
| alpha particle               | electron orbits                   | ionization               | radiograph               |
| angstrom unit                | electron volt (eV)                | kiloelectron volts (keV) | radiography              |
| anode                        | element                           | kilovoltage peak (kVp)   | radiology                |
| atom                         | energy (work)                     | kinetic energy           | radionuclide             |
| beam indicating device (BID) | excitation                        | line focus principle     | Roentgen, Wilhelm Konrad |
| beta particle                | filament                          | megaelectron volts (MeV) | roentgenology            |
| binding energy               | focal spot                        | nanometer                | target                   |
| bremsstrahlung radiation     | focusing cup                      | negatron                 | thermionic emission      |
| cathode                      | frequency                         | neutrons                 | useful beam              |
| cathode rays                 | gamma radiation ( $\gamma$ -rays) | nucleus                  | valence electrons        |
| characteristic radiation     | general radiation                 | orbital electrons        | Walkhoff, Otto           |
| corpuscular radiation        | hertz (Hz)                        | particulate radiation    | wave propagation         |
| dental radiography           | heterogeneous radiation           | photon                   | wavelength               |
| electromagnetic radiation    | homogeneous radiation             | propagate                | x-ray                    |
| electron                     | ion                               | proton                   | Z number                 |
|                              | ion pair                          | quantum                  |                          |

## HISTORICAL BACKGROUND

### DISCOVERY OF X-RAYS

X-rays were discovered on November 8, 1895, by **Wilhelm Konrad Roentgen** (pronounced "Rentken"), Professor of Physics and Director of the Physical Institute of the University of Wurzburg in Bavaria, Germany. After Roentgen discovered x-rays, he determined that x-rays could darken a photographic plate. By placing objects between the source of the rays and the plate, he took permanent x-ray photographs, exploiting the differing abilities of materials to transmit the rays. In taking these photographs, he pioneered three key areas of x-ray imaging. First, an x-ray photograph of his closed wooden box of weights clearly revealed its contents, thus presaging the security application found at every **airport check-in**. Second, an x-ray image of his hunting rifle revealed a flaw inside the metal of the gun. This was the first time a **hidden structural flaw** had been exposed without destroying the object. Third and most startling, he took a permanent x-ray photograph of his wife Bertha's left hand, revealing the bones and the rings that she was wearing. To produce this image, Bertha held her hand still against the plate for about 15 minutes, which gave her a dose of x-rays that dangerously exceeded the limits set in modern health and safety standards. In recognition of his outstanding contribution to science, Roentgen was awarded the first Nobel Prize for Physics in 1901.

### EARLY DENTAL RADIOGRAPHY

Supposedly, the first dental radiograph ever made was completed by **Otto Walkhoff, DDS, MD**, of Braunschweig (Brunswick), Germany, on January 14, 1896, 14 days after the publication of the experimental results of the discovery of x-rays by Roentgen. Walkhoff made the first dental radiograph by placing in his own mouth an unexposed photographic glass plate that was wrapped in black paper and covered with a rubber dam. He lay on the floor, submitting

himself to 25 minutes of x-ray exposure. When Roentgen announced to the world the discovery of a new kind of ray in 1895, he called it the "X-ray" after the algebraic symbol for unknown quantity. The scientific world, for the most part, called it the "roentgen ray" in honor of the discoverer, and **roentgenology** is the study of x-rays.

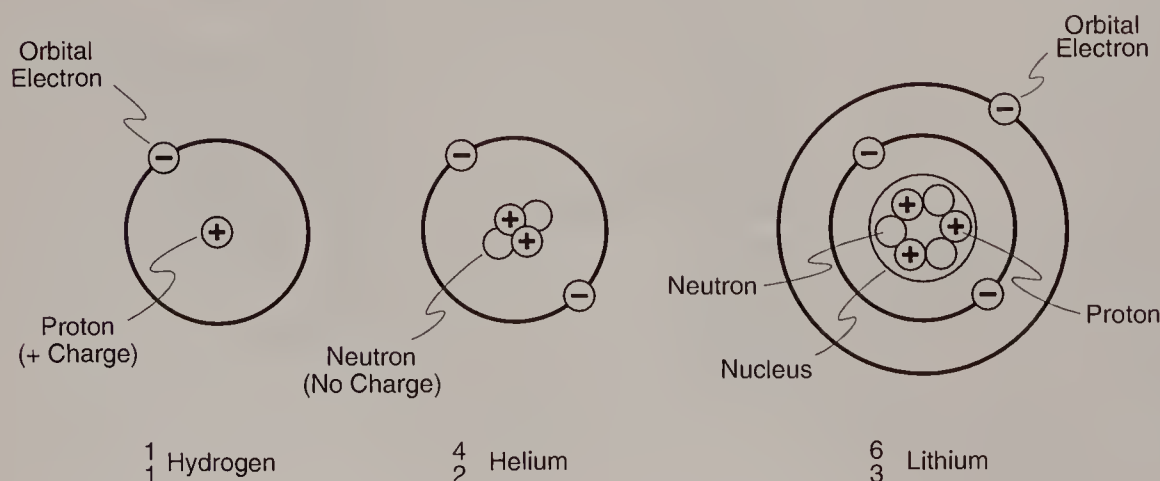
## NATURE OF THE ATOM

To understand the nature of x-rays, it is important to be familiar with matter and the structure of the atom. Matter is a physical manifestation possessing mass (occupies space and has weight) and having form or shape. Matter is composed of substances, which are any materials that have a definite constant composition, such as pure salt. Simple substances are called **elements** and cannot be decomposed by ordinary means. At present, there are 105 known elements. The **atom** is the smallest particle of an element that has characteristic properties of that element.

The structure of the atom can be described as a miniature solar system. Each atom consists of a small **nucleus**, which has a positive charge, and a number of lighter particles with negative charges called **electrons**, which move around the nucleus in definite orbits. The atom is said to be electrically neutral when the net number of positive charges of the nucleus (protons) equals the negative charges of the orbital electrons. The electrons are kept in their orbits by the balance between (1) the electrostatic attraction of unlike charges and (2) the centrifugal forces of the fast-moving electrons.

### COMPOSITION OF THE NUCLEUS

The nucleus is composed of protons and neutrons. These particles are called **nucleons**. Protons carry a positive charge (+), which is equal in size, but opposite in sign to the charge carried by the electrons (-). The neutrons carry no electrical charge ( $\pm$ ) and are similar in size and mass to a proton (Fig. 1-1).



**Figure 1.1 Structure of the Atom.** Note the structure of the first three atoms of the periodic table.



## ATOMIC NUMBER

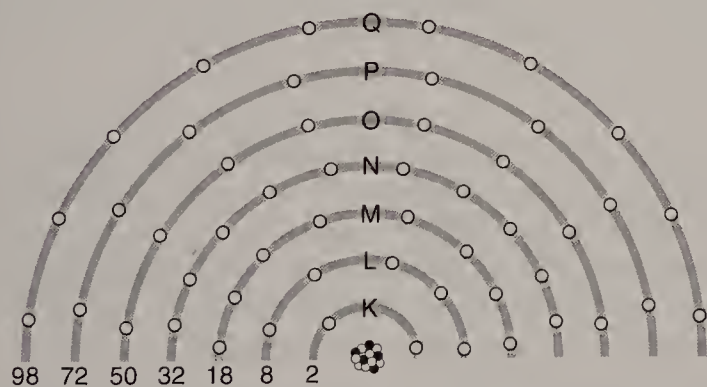
Atoms differ from one another in the constitution of their nuclei and in the number and arrangement of their electrons. The atomic number, or **Z number**, is the number of protons in the nucleus or the number of electrons outside the nucleus. Z numbers range from 1 for the simplest atom (hydrogen) to 105 for the most complex atom yet discovered (hahnium). The chemical properties of an atom are determined by the atomic number.

## ORBITAL ELECTRONS

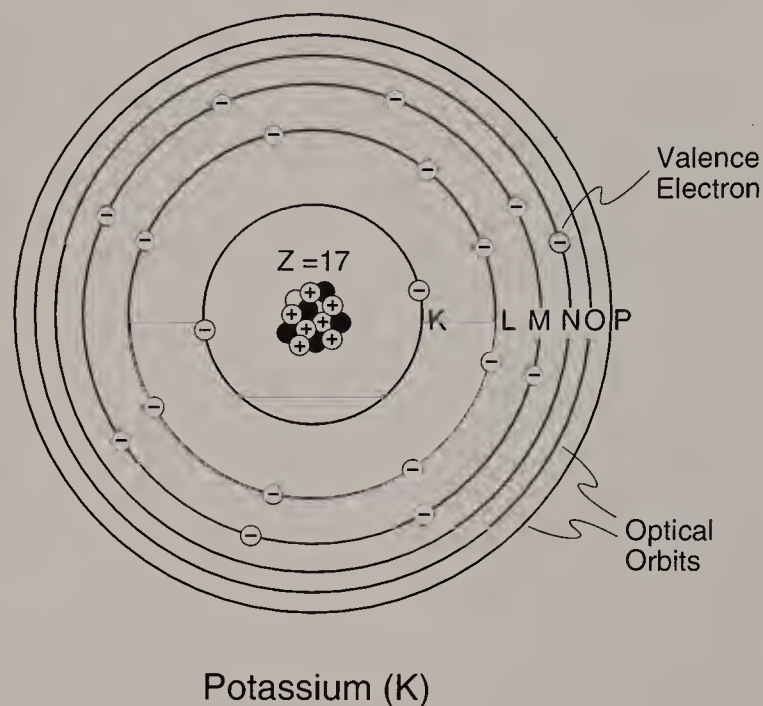
Electrons are very small particles carrying 1 unit of negative electric charge. They revolve around the nucleus in well-defined shells that exist at varying distances from the nucleus. The arrangement of the electrons around the nucleus determines the way atoms interact with each other. A maximum number of seven potential electron-containing orbits or shells exists. No known atom contains more than seven shells. These seven shells are designated as K, L, M, N, O, P, and Q in order of increasing distance from the nucleus (Fig. 1-2). Electrons in the outermost shell are termed **valence electrons** and determine the chemical properties of the atom (Fig. 1-3).

## ELECTRON ORBITS OR SHELLS

The electrons in an atom do not spontaneously fly off from the nucleus by centripetal force or, on the other hand, drop into the nucleus by electrostatic attraction (unlike charges attract), because in the normal atom there is a balance between centripetal force and electrostatic force. This balance results in a definite electron path or orbit for each electron around the nucleus. Each shell has a different energy level, which is dependent on the atomic number of the atom and the distance the electron is from the nucleus. For each element, these orbital energy levels are different and characteristic. Because the nucleus carries a positive charge, it exerts an electric force of attrac-



**Figure 1.2 Maximum Number of Electrons That Can Exist in Each Orbital Shell.**



**Figure 1.3 Electron Orbits of Potassium (Z = 17).** For x-ray purposes, the motion of the tightly bound K, L, and M shells is important. The motion of the outer electrons is important in determining the chemical properties and optical spectrum of the atom.

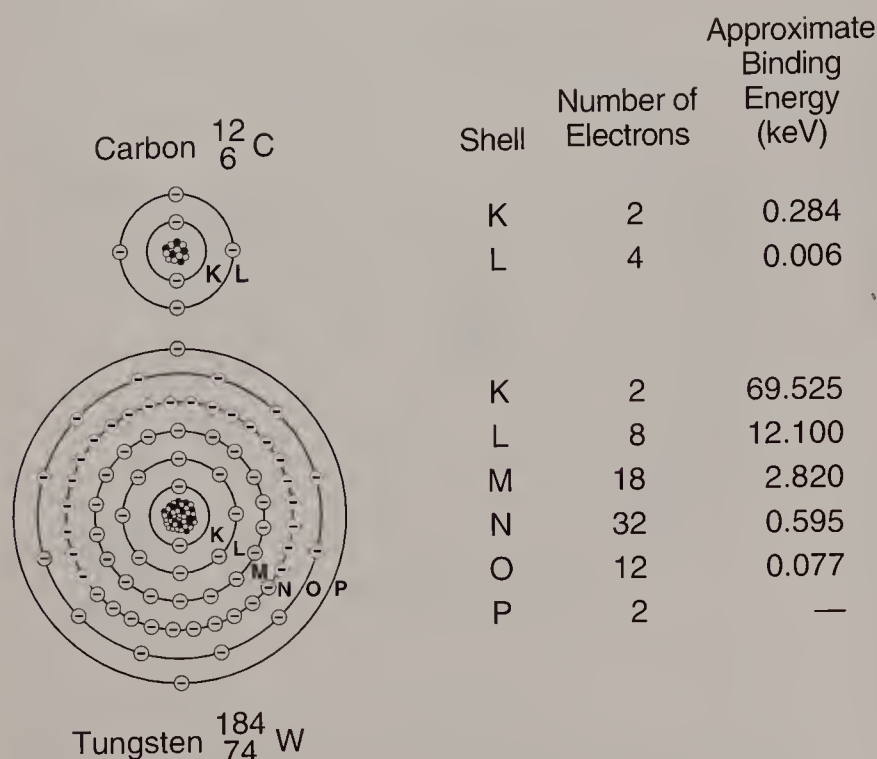
tion on orbital electrons. The attraction force is greater when the electron shell is nearer the nucleus. Thus, it would require **more work (energy)** to remove an electron from the K shell than to remove an electron from one of the outer shells.

## BINDING ENERGIES

The energy required to remove an electron from a particular shell is designated as **binding energy** of that shell. The binding energy is largest for the K shell, because of its proximity to the positively charged nucleus, and decreases progressively for successive shells. The binding energy is characteristic of a given element and shell. Because of the relatively large amount of energy needed to remove an electron from the inner shell, the electron is said to be bound more tightly than the electrons of the outermost shells.

## ELECTRON VOLT

Energy is measured by the amount of work done or the amount of work capable of being done. The most useful unit of energy for our purposes is the electron volt. This is the kinetic (motion) energy of an electron accelerated through a potential difference of 1 volt. Larger multiple units of the electron volt are frequently used: keV for 1000 or kiloelectron volts, and MeV for 1 million or megaelectron volts.



**Figure 1.4 Binding Energies of Tungsten and Carbon (Two Important Elements in Radiology).** Note that binding energies are greater for each element for the inner shell electrons. Also, tungsten is a more complex element than carbon and has higher binding energies in each shell.

## BINDING ENERGIES IN ELECTRON VOLTS

The binding energies of the K, L, and M shells of tungsten are 70 keV, 12 keV, and 3 keV, respectively. To remove a K shell electron from tungsten would require an energy of 70 keV (Fig. 1-4). Because the electrons in the inner shells have greater binding energies, it takes x-rays, gamma rays, or high-energy particles to remove electrons from these shells. Electrons in the outer shells are not held so tightly to the nucleus and therefore can be affected by lesser energies, such as visible light rays and ultraviolet rays.

## IONIZATION

**Ionization** is the process by which a neutral atom or molecule acquires either a positive or a negative charge. When an atom loses or gains an electron, it is said to be ionized. An ionized atom (called an ion) is not electrically neutral but carries a charge equal to the difference between the number of protons and electrons. Many elements have incompletely filled outer shells, which tend to capture electrons quite readily from adjacent atoms. Of course, when this occurs, the atom has more electrons than it should and it becomes a negative atom. When atoms lose electrons, they become deficient in negative charges and therefore will behave as positively charged atoms. An atom that is not electrically balanced is called an ion. In any ionization process, **ion pairs** are formed; it is this process that elicits chemical changes in matter.

X-rays are a form of energy that can form ion pairs in atoms. When an x-ray transfers its energy to an orbital electron, it ejects it from the atom, and an ion pair is formed. The atom becomes a positive ion (+1 charge) be-

cause it has lost an electron, and the ejected electron has a negative charge (−1). Thus, an ion pair has been formed (Fig. 1-5).

## IONIZING RADIATION

### TYPES OF IONIZING RADIATION

There are two forms of ionizing radiation: (1) **corpuscular or particulate radiation** and (2) **electromagnetic radiation**.

#### Particulate Radiation

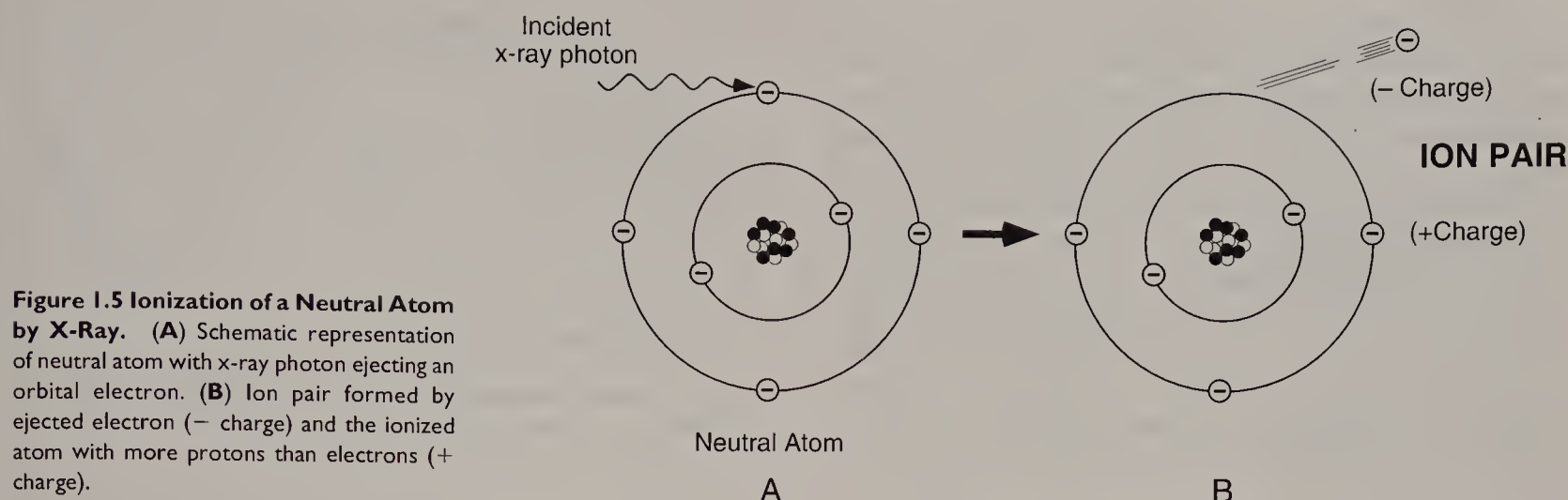
Particulate radiations are actually minute particles of matter that travel in straight lines at high speeds from their sources. Although incredibly small, they possess mass. All are charged electrically, except the neutrons, and they all move extremely fast—sometimes almost as fast as light. Examples of particulate radiation follow.

**Alpha Particles.** Alpha particles are composed of a combination of two protons and two neutrons. It is the helium nucleus without orbital electrons. Alpha particles are emitted only from the nuclei of heavy metals. Compared with the other particles, the alpha particle is enormous and exerts a large electrostatic attraction. They have little ability to penetrate tissue and give up their large energies within a very short distance in air (5 cm) and in soft tissue (100 μm).

**Electrons.** Electrons have a very small mass compared with protons. Electrons abound in nature. We are interested in the following two: beta particles (negatrons) and cathode rays (electrons).

**Beta Particles (Negatrons).** Beta particles (negatrons) are emitted from the nucleus of radioactive atoms and





possess 1 unit of negative charge. They have very small atomic masses. Beta particles are more penetrating than alpha particles and may penetrate 10 to 100 cm of air and approximately 1 to 2 cm of soft tissue.

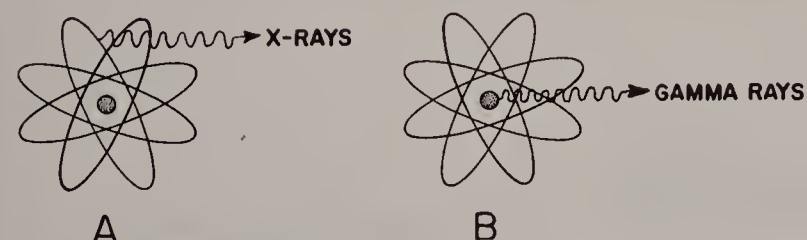
**Cathode Rays (Electrons).** Cathode rays are streams of electrons passing from the hot filament of the cathode to the target of the anode in an x-ray tube. They differ from beta particles in their place of origin. Beta particles come from the nucleus of radioactive atoms, whereas cathode rays originate from the orbital electrons of the atoms of the filament material of an x-ray tube.

**Protons.** Protons are accelerated hydrogen nuclei. They are approximately 2000 times the mass of the electron. Because protons are heavy, charged particles, they lose kinetic energy rapidly as they penetrate matter.

**Neutrons.** Neutrons carry no electrical charge and have nearly the same mass as a proton. The characteristic of being electrically neutral has proved of great importance in nuclear physics, because such a particle can penetrate into the nucleus of an atom without being subjected to the enormous forces of repulsion that resist the entrance of a positively charged particle.

### Electromagnetic Radiation

called electromagnetic radiations. Electromagnetic radiation is the propagation of energy through space accom-

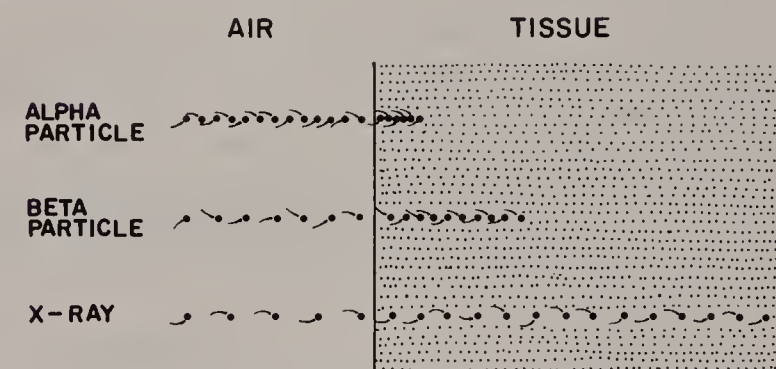


**Figure 1.6 X-Rays and Gamma Rays.** (A) X-rays are produced outside the nucleus of stable atoms. (B) Gamma rays are emitted from the nucleus of radioactive atoms.

panied by electric and magnetic force fields (hence the name electromagnetic radiation). X-rays and gamma rays are identical except for their origin. X-rays are produced outside the nucleus in the electron orbital system. Gamma rays are emitted from the nucleus of a **radionuclide**, which is a species of atom that disintegrates with the emission of corpuscular and electromagnetic radiations (Fig. 1-6). In nuclear medicine, alpha particles, beta particles, and gamma rays are of importance. In diagnostic radiology, x-rays are of prime importance because they do not deposit their energy in highly localized concentrations the way particulate radiation does, and x-rays penetrate tissue for long distances (Fig. 1-7).

### NATURE OF X-RAYS

As mentioned previously, x-rays are a form of electromagnetic radiation. To understand the production of a radiograph, we must first understand the nature of x-rays.



**Figure 1.7 Particulate and Electromagnetic Radiation.** Particulate radiation ionizes matter differently than electromagnetic radiation. An alpha particle has an enormous electrical charge and mass that ionizes matter rapidly and penetrates tissue for very short distances. A beta particle does not ionize matter as readily as an alpha particle and penetrates tissue farther than an alpha particle. X-rays have no electrical charge or mass and do not ionize matter rapidly. This allows x-rays to penetrate matter for long distances.



The interactions of electromagnetic radiations are difficult to understand. Some interactions are best explained by the theories of wave propagation, whereas other interactions are only explained if they are assumed to be particles or bundles of energy called “quanta” or “photons.” It is necessary to discuss electromagnetic radiations as if the radiations were both waves and particles. The method used to detect x-rays or the way x-rays are being used determines which aspect (waves or photons) is the more useful concept. The wave concept of electromagnetic radiation explains why it may be reflected, refracted, diffracted, and polarized. The particle concept is used to describe the interactions between radiation and matter.

## WAVE CONCEPT OF ELECTROMAGNETIC RADIATION

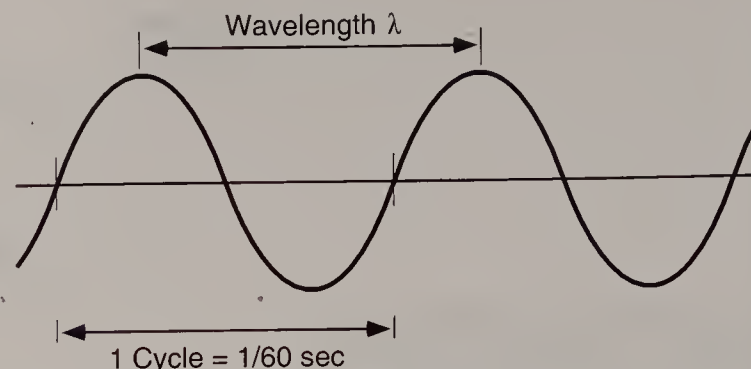
Electromagnetic radiation is the propagation of wave-like energy through space or mass at the speed of light (186,000 miles/sec or  $3 \times 10^8$  m/sec). A wave can be defined as a variation or disturbance that transfers radiant energy progressively from point to point in a medium. (Energy is the capacity to perform work.) It is called electromagnetic radiation because the energy that is radiated is accompanied by oscillating electric and magnetic fields.

Each field is in phase with and perpendicular to each other and perpendicular to the direction of wave propagations (Fig. 1-8).

### Examples of Electromagnetic Radiation

1. The radio waves that we hear.
2. The light waves we see.
3. The infrared waves that can take pictures in the dark.
4. The ultraviolet rays that cause sunburn.
5. The x-rays studied in this text.
6. The gamma rays of the atomic bomb.
7. The cosmic rays that hinder travel in space.

The waves we are familiar with are like waves traveling down a stretched rope while one end of the rope is moved up and down in rhythmic motion. Sound waves traveling in water or air must be propagated in a medium.



**Figure 1.9 Wave Concept of Electromagnetic Radiation.** Wave diagram illustrating wavelength and frequency.

Electromagnetic waves need no such medium, as they can be propagated within and transmitted through a vacuum. All waves have an associated wavelength and frequency. The wavelength of a wave is the distance between two successive crests, or valleys, and is given the symbol  $\lambda$  (the Greek letter lambda, the symbol for length) (Fig. 1-9).

The number of waves passing a particular point during a specific time interval is called the frequency and is given the symbol  $\nu$  (the Greek letter nu, the symbol for number). It is usually identified as oscillations per second or cycles per second. The unit of frequency measurement is the hertz (Hz). One hertz equals 1 cycle/sec, and 60 Hz is the standard 60 cycle/sec alternating electrical current used in North America. Other parts of the world use 50-cycle current. Because the velocity is always known, the wavelength of the radiation can be determined if the frequency is known; conversely, the frequency can be determined if the wavelength is known. It also holds true that if the frequency of the wave is high, the wavelength will be short; if the frequency is low, the wavelength will have to be long (Fig. 1-10).

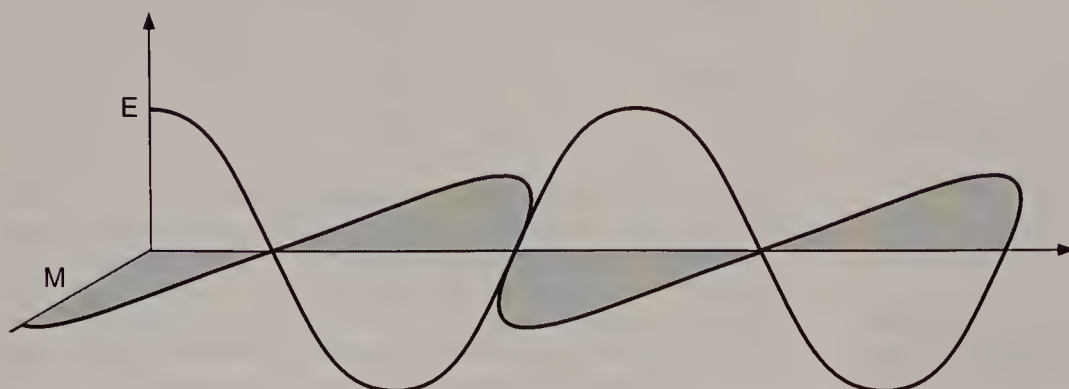
The relationship among velocity, frequency, and wavelength can be expressed in the following formula:

$$c = \lambda \nu \text{ (lambda} \times \text{nu)}$$

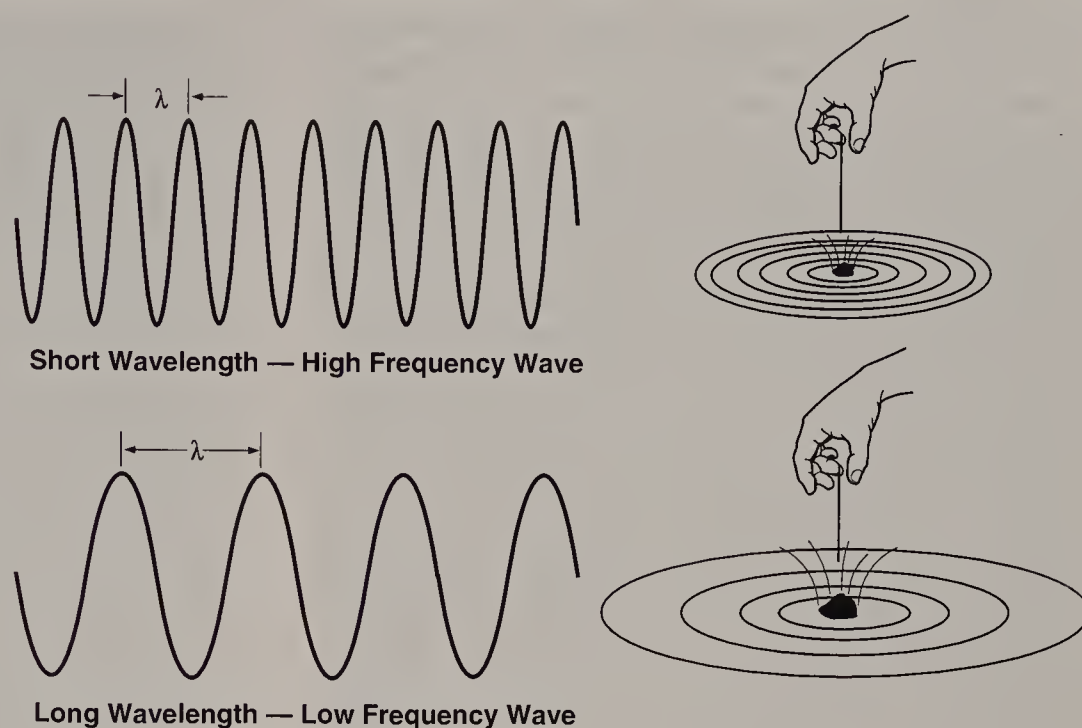
where  $c$  = velocity of light ( $3 \times 10^8$  m/sec)

$\lambda$  = wavelength in meters

$\nu$  = frequency in hertz (cycles per second)



**Figure 1.8 Electromagnetic Waves.** Simplified diagram of electromagnetic waves. The electric (E) and magnetic (M) force fields are at right angles to each other and perpendicular to the direction of the wave propagations (movement).



**Figure 1.10 Frequency of Wave Motion.** Note the two energies with different wavelengths. The shorter the wavelength, the higher the frequency.

## PARTICLE CONCEPT OF ELECTROMAGNETIC RADIATION

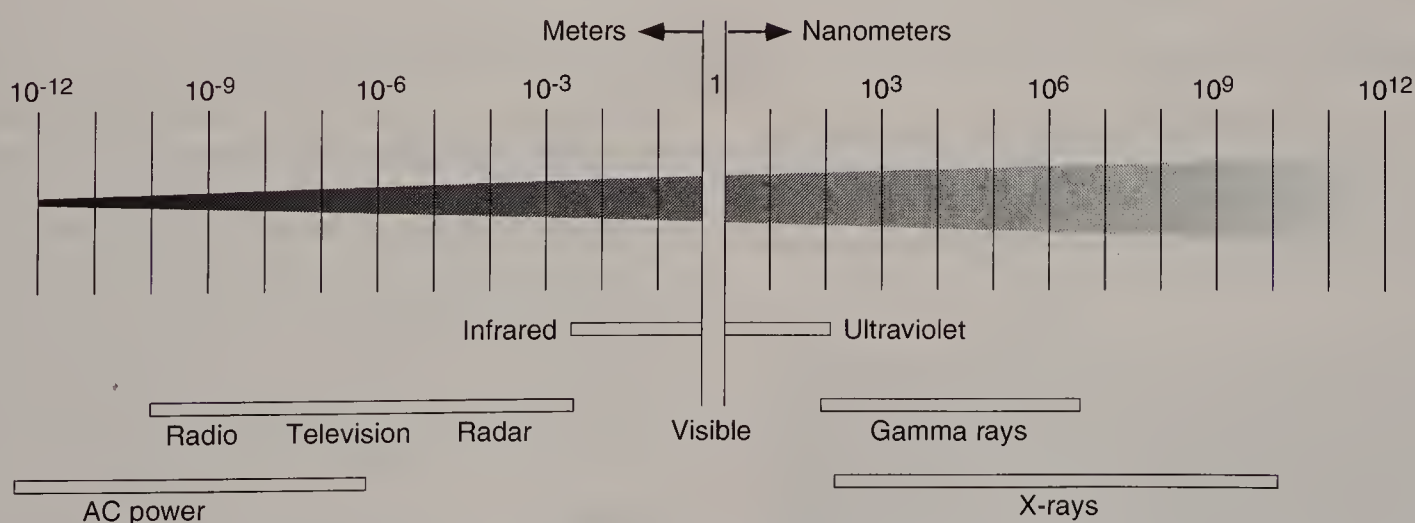
Short electromagnetic waves, such as x-rays, may react with matter as if they were particles rather than waves. These particles are actually discrete bundles of energy having no mass, and each of these bundles of energy is called a **quantum** or **photon**. These photons travel at the speed of light. The dual natures (waves and particles) are inseparable. For instance, the amount of energy carried by each quantum or photon depends on the frequency ( $\nu$ ) of the radiation. If the frequency (vibrations per second) is doubled, the energy of the photon is doubled. The unit used to measure the energy of photons is the electron volt (eV), as mentioned previously. If a photon has 15 eV or more of energy, it is capable of ionizing atoms and molecules and

is called “ionizing radiation.” An atom is ionized when it loses an orbital electron. Gamma rays, x-rays, and some ultraviolet rays are all types of ionizing radiation.

## ELECTROMAGNETIC SPECTRUM

Electromagnetic energy is all around us. X-rays, gamma rays, radio waves, and light waves are forms of electromagnetic energy within the spectrum that we encounter every day. The only fundamental differences among them are their wavelengths (or frequency) and the energy of their photons. All these forms of electromagnetic radiation

of their photons in what is called the electromagnetic spectrum (Fig. 1-11). Figure 1-11 shows their location in



wavelength in what is called the electromagnetic spectrum



the spectrum and some of their common uses. When the wavelengths (or frequency) and the energy of the photons change, so do the properties of the different types of radiation. The wavelength of a radio wave may be 100 yards long, whereas the typical x-ray is only one-billionth of an inch in length. For example, the length of electromagnetic waves generated by 60 Hz (cycles/sec) alternating electrical current is approximately the distance from coast to coast of the United States. The wavelengths of the standard broadcast portion of radio waves are as long as a football field and have a frequency of 3 million Hz. The wavelengths used in television are about equal to the height of an average man and have a frequency of 300 million Hz. The wavelength of diagnostic x-rays is extremely short and is usually expressed in **nanometers (nm)**, one of which is equal to one-millionth of a millimeter. The useful range of x-rays in medical and dental radiography is approximately 0.01 to 0.05 nm. In the earlier literature, wavelengths of electromagnetic radiation were often given in **angstrom units (Å)**. One angstrom unit is equal to one-tenth of a nanometer. The wavelength of light in the center of the visible spectrum is about 550 nm, whereas the x-rays used for radiography—those near the center of the medical and dental x-ray spectrum—have a wavelength of approximately 0.05 nm or approximately 1/10,000th that of visible light. Short wavelengths correspond to high energies and frequency. X-rays generated by a 100 keV current will be very short (0.05 nm) and have frequencies of  $2.42 \times 10^{19}$  Hz (cycles/sec).

## WHAT ARE X-RAYS?

X-rays are weightless packages of pure energy (photons) that have no electrical charge and travel in waves with specific frequency at a speed of  $3 \times 10^8$  m/sec. Their energies depend on the frequency of their wavelengths. The greater the frequency of the wavelength, the greater the energy of the photon. The greater the energy of the photon, the more readily it will penetrate matter.

## PROPERTIES OF X-RAYS

To gain more understanding of x-rays, it is necessary to know a little more about how they act and what they do. Fundamentally, x-rays obey all the laws of light. Among their special properties, some of the following are of interest to the student of dental radiology.

### Properties of X-Rays

1. X-rays are invisible and weightless; they cannot be seen, heard, felt, or smelled.
2. X-rays travel in straight lines; they can be deflected from their original direction, but the new trajectory is linear.

3. X-rays travel at the speed of light ( $3 \times 10^8$  m/sec).
4. X-rays have a wide range of wavelengths, 0.01 to 0.05 nm, in length.
5. X-rays cannot be focused to a point; over distance the beam diverges much like a beam of light.
6. Because of their extremely short wavelengths, they are able to penetrate materials that absorb or reflect visible light.
7. X-rays are differentially absorbed by matter; this absorption depends on the atomic structure of the matter and the wavelength of the x-rays. It is this property that produces an image on a photographic film, which in turn can be made visible by chemical development.
8. X-rays cause certain substances to fluoresce, that is, to emit radiation of longer wavelength (e.g., visible and ultraviolet radiation). It is this property that makes it possible to use intensifying screens in radiography.
9. X-rays produce biologic changes that are valuable in radiation therapy but necessitate caution when used for diagnostic purposes.
10. X-rays can ionize gases, that is, remove electrons from atoms to form ions, which can be used for measuring and controlling exposure (ionization chambers).

These special properties have applications in dental, medical, and industrial radiography; radiation therapy; and research.

## PRODUCTION OF X-RAYS

X-rays are generated when fast-moving electrons (small particles, each bearing a negative electrical charge) collide with matter in any form (Fig. 1-12). X-ray production is a process of energy conversion when electrons are suddenly decelerated (speed is reduced) in the target of the x-ray tube.

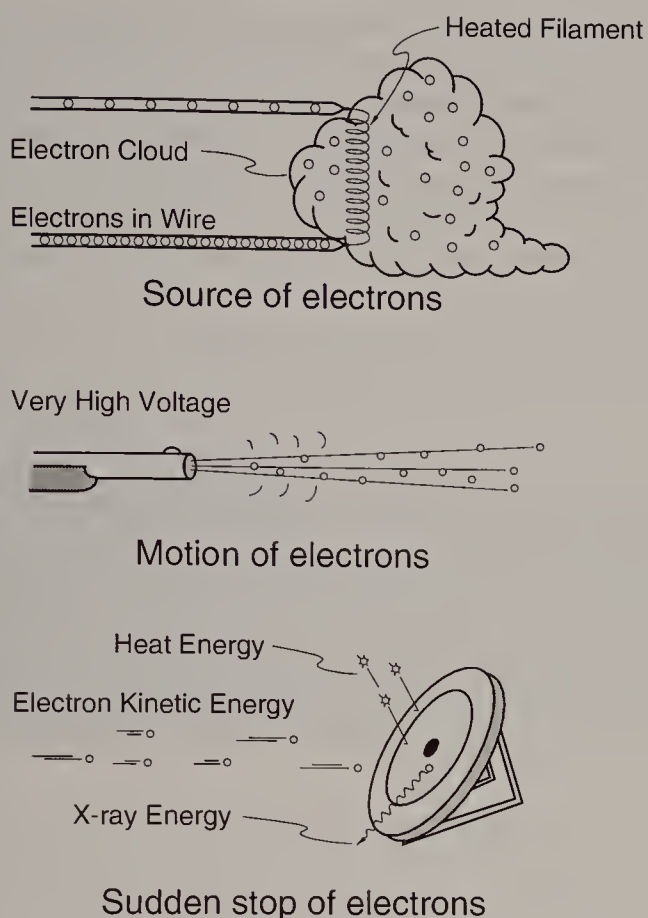
### X-RAY TUBE

The x-ray tube is only a few inches long. It is contained within the tubehead of the x-ray machine, which is the much larger outer housing to which the **beam indicating device (BID)** is attached. The most efficient means of generating x-rays is an x-ray tube, and the simplest form of an x-ray tube is a sealed leaded glass envelope from which air has been evacuated. The x-ray tube is made of Pyrex (heat- and chemical-resistant glass) and contains two electrodes in a vacuum. The electrodes are designed so that electrons produced at the cathode (negative electrode or filament) can be accelerated to a high potential difference (voltage) toward the anode (positive or target electrode) (Fig. 1-13).

### Cathode

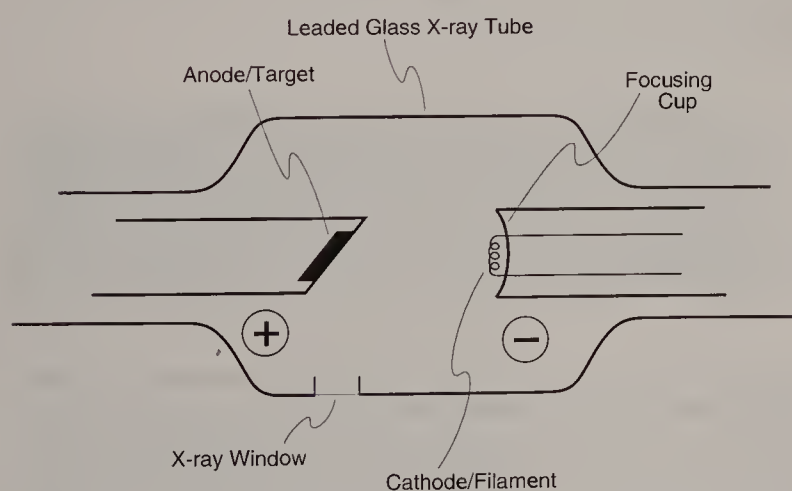
The cathode of the x-ray tube is the negative terminal of the tube and consists of a tungsten wire (filament) wound





**Figure 1.12 Production of X-Rays.** Three things are needed to produce x-rays: (1) source of electrons, (2) motion—high-voltage potential to move electrons, and (3) sudden stop. Electrons striking an anode target of high atomic number causes sudden deceleration or stoppage of rapidly moving electrons, which produces heat energy and x-ray energy.

in the form of a spiral set in a molybdenum cup-shaped holder (called a focusing cup) and positioned approximately 1 inch away from the anode (positive terminal). Tungsten is used for the filament because it has a high melting point (3370°C or 6098°F) and can be drawn into a thin wire (0.2 mm in diameter) and still remain quite strong. The filament electrical circuit (low-voltage circuit) provides a source of electrons that are emitted from the



**Figure 1.13 Simple X-Ray Tube.** Diagram shows the relation of the anode (target) and the cathode (filament) to each other.

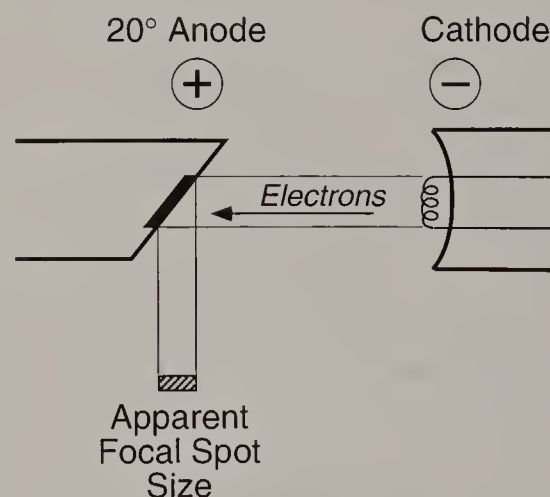
hot wire of the filament and forms a “cloud” of electrons around it.

### Anode

The **anode** (positively charged to attract electrons) is usually made of copper because of its good heat conductivity. A block of tungsten is set in the face of the copper anode at the center of the tube. This block of tungsten is referred to as the **target**. The **focal spot** is an area on the target that electrons strike to generate x-rays. The electrons at the filament are set in motion toward the target by activating the high voltage circuit (kVp) as the timer switch is pressed. As the stream of electrons strikes the target, most of the kinetic energy is converted to heat (99%); however, a small amount of energy is converted to x-rays (1%).

The size of the focal spot has a very important effect on the sharpness of the x-ray film image. The smaller the focal spot, the sharper the x-ray image. However, the smaller the focal spot becomes, the less heat the focal spot will be able to absorb at one time without being damaged. Some method had to be found to obtain a practical size of the focal spot that would provide image detail without excessive heating of the anode.

**Line Focus Principle (Anode).** The Benson line focus principle developed in 1918 is a method of reducing the effective focal spot size and is used in dental x-ray tubes. The target face is placed at an angle of 15 to 20° to the cathode, as shown in Figure 1-14. As the angle of the target face is made larger, the projected focal spot becomes smaller. When the rectangular focal spot is viewed from below—where the film would be located—it appears more nearly square. This is called the “effective focal spot,” which is only a fraction of the size of the actual target. By using x-rays that emerge at this angle, radiographic definition is improved while the heat capacity of



**Figure 1.14 Benson Line Focus Principle.** Diagram showing how the line focus principle works. By placing the target/anode at a 20° angle to the cathode, the effective focal spot produced is only a fraction of the size of the actual target. (The smaller the effective focal spot, the sharper the x-ray image.)

the anode is increased, because the electron stream is spread over a greater area. The effective focal spot of most dental x-ray tubes measures approximately 0.5 to 1.2 mm<sup>2</sup>, depending on the manufacturer's specifications. The smaller the effective focal spot, the sharper the x-ray image.

## CONDITIONS NECESSARY FOR THE PRODUCTION OF X-RAYS

There are four conditions required for the production of x-rays in an x-ray tube. They are as follows:

1. Generation of electrons.
2. Production of high-speed electrons.
3. Focusing of electrons.
4. Stopping of high-speed electrons at the target.

### Generation of Electrons

In referring to an x-ray tube, the terms cathode and filament may be used interchangeably. The filament is the source of electrons (called cathode electrons) in the x-ray tube. As mentioned previously, the filament is made of tungsten because tungsten has a high melting point of 3370°C or 6098°F and can be drawn into a thin wire 0.2 mm in diameter. Tungsten has orbital electrons circulating around a central nucleus. How can these electrons be liberated from individual atoms within the tungsten filament? The filament current (average of 10 V and 3-5 A) that supplies the tungsten filament causes it to become glowing hot, or incandescent, in the same way as the filament in an ordinary light bulb. However, the filament is not heated to produce light but to act as a source of electrons that are emitted from the hot wire. When the tungsten is heated, its atoms absorb thermal energy, and some of the outer orbit electrons in the metal acquire enough energy to allow them to move a small distance from the surface of the metal. Their escape from the metal is referred to as the process of **thermionic emission** (boiling off electrons), which is the emission of electrons resulting from the absorption of thermal energy. The separation of electrons from the tungsten filament will form a small cloud of electrons in the immediate vicinity of the filament. The temperature of the filament (at least 2200°C or 3992°F) controls the quantity of electrons emitted from it. As the temperature is raised by increasing the milliamperes (mA), more electrons are emitted, and the flow of electrical current through the x-ray tube (mA) increases. The x-ray tube current, measured in milliamperes (1 mA = 0.001 ampere), refers to the number of electrons flowing per second from the filament to the target of the anode. For example, in a given unit of time, the x-ray tube current of 15 mA is produced by 1.5 times as many electrons as a current of 10 mA. The number and the quan-

tity of x-rays produced in a unit of time depend entirely on the number of electrons that flow from the filament to the target (anode) of the tube. The number of electrons can be varied by altering the exposure time, the mA, or both. Dental x-ray machines use a 7-mA, 10-mA, or 15-mA current. The higher the mA, the more electrons that will be available, and of course the more x-rays produced, in a unit of time.

### Production of High-Speed Electrons

When a large potential difference (e.g., 90 kVp) is applied across the tube electrodes, it causes the electrons at the cathode filament to accelerate at very high speeds (approximately half the speed of light) across the 1- to 3-cm gap from the filament to the target. The electric current across an x-ray tube is always in one direction only (cathode to anode). The higher the potential (voltage), the greater the speed of these cathode electrons as they strike the target. This produces more energetic x-ray photons that have shorter wavelengths, higher frequencies, and greater penetrating power.

### Focusing of Electrons

As stated previously, the electron stream always crosses the x-ray tube in one direction, from cathode (−) to anode (+). Because of the forces of mutual repulsion between electrons, the electron stream tends to spread out and bombard an unacceptably large area on the anode tungsten target of the x-ray tube. This is prevented by a structure called the **cathode focusing cup**, which surrounds the filament. The focusing cup is designed so that its electrical forces cause the electron stream to converge onto the target or anode in the required size and shape. The small area of the target that the electrons strike is called the **focal spot** and is the source of the x-radiation. The smaller the focal spot, the sharper the image.

### Stopping of High-Speed Electrons at the Target

When the fast cathode electrons enter the target of the x-ray tube, their kinetic energy (energy in motion) changes to other forms of energy.

The efficiency of ordinary radiographic equipment is such that at 90 kVp, only approximately 0.6% of this energy is converted to x-rays, while the remaining 99.4% is converted to infrared radiation or what we simply report as heat.

This interaction, responsible for the generation of heat, is primarily one of excitation rather than ionization interaction. In excitation, the high speed cathode electrons interact with the outer shell electrons of the tungsten target but do not transfer sufficient energy to these outer shell electrons to eject them from their orbits. Rather, the outer



shell electrons are simply raised to an excited or higher energy level. When the outer shell electrons drop back to their normal state, there is an emission of infrared (heat) radiation. This constant excitation and restabilization of the outer shell electrons of the tungsten atoms of the anode generates an enormous amount of heat. In fact, only about one part in a thousand of the kinetic energy of the electrons eventually results in radiologically useful x-rays! X-rays from the target are emitted in all directions, but only those leaving the window of the x-ray tube comprise the **useful beam**.

If you are confused, you should avoid confusing the cathode electrons flowing in the tube with the x-rays emerging from the tube. Imagine throwing stones at and hitting the side of a barn. The stones are analogous to the electron beam that hits the target in the x-ray tube, whereas the emerging sound waves are analogous to the x-rays that come from the target when struck by cathode electrons.

### Kinetic Energy of High-Speed Electrons

To review, x-rays are produced when fast-moving electrons from the cathode filament of the x-ray tube (cathode electrons) interact with the anode (target). The kinetic energy (energy of motion) of a cathode electron released at the target will depend on the voltage being applied to the tube at that moment. The higher the speed of the electrons, the higher penetrating power of the x-rays produced at the anode.

### kVp and keV

First, we must clearly distinguish between kVp (kilovoltage peak) and keV (kiloelectron volts). The expression

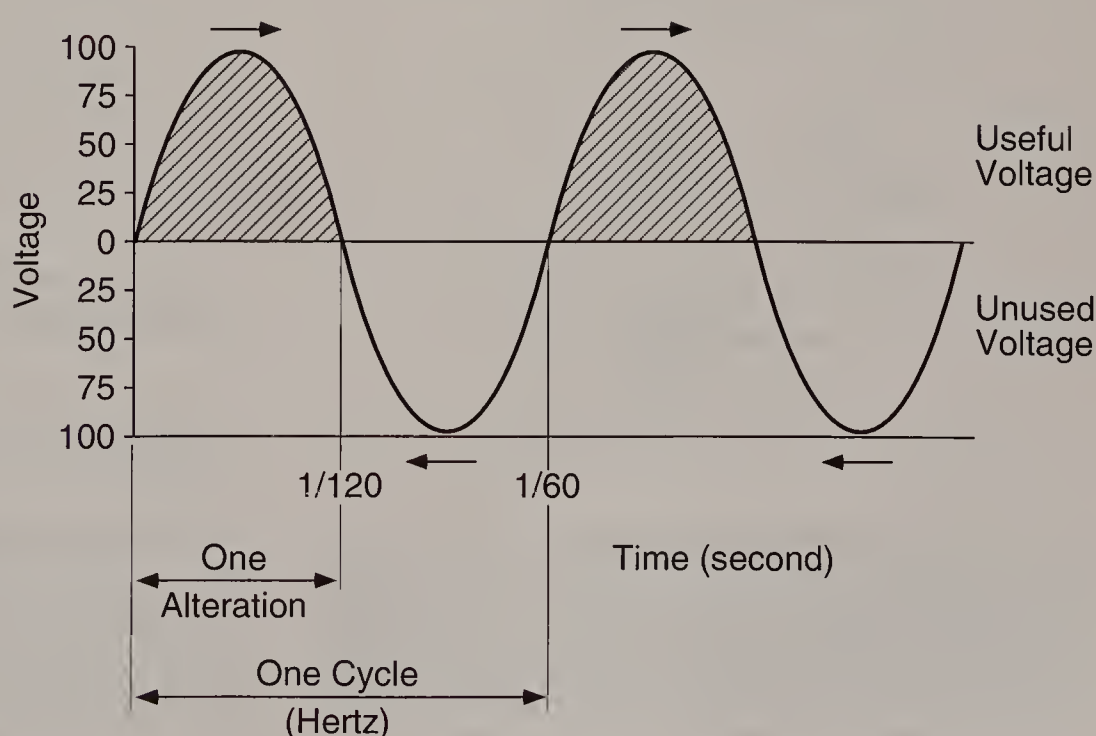
100 kVp means that the maximum voltage across the tube causing acceleration of electrons is 100,000 volts. The expression keV denotes the energy of any individual cathode electron in the beam (100 keV = 100,000 electron volts). When the dental x-ray tube is operated at 100 kVp, few cathode electrons acquire a kinetic energy of 100 keV. This is because in the dental x-ray machine generator, the useful voltage of the single phase, half-wave, self-rectified circuit will pulsate from 0 to a maximum 100 kVp and back to 0 at the rate of 60 times/sec (Fig. 1-15). Each cathode electron will acquire a certain kinetic energy (eV), depending on the applied voltage across the tube at that particular instant (see Fig. 1-18). Therefore, the high-speed cathode electrons striking the target do not all have the same kinetic energies, because the voltage (V) across the tube that provides the potential to accelerate the cathode electrons is variable. In other words, the energy (eV) of the individual cathode electrons that encounter the target (anode) covers a broad range of kinetic energies.

### TWO PROCESSES OF X-RAY PRODUCTION

When the fast-moving cathode electron stream strikes the tube target, the cathode electrons interact with target atoms producing x-rays by the following two processes: **general radiation** and **characteristic radiation**.

#### General Radiation (Bremsstrahlung)

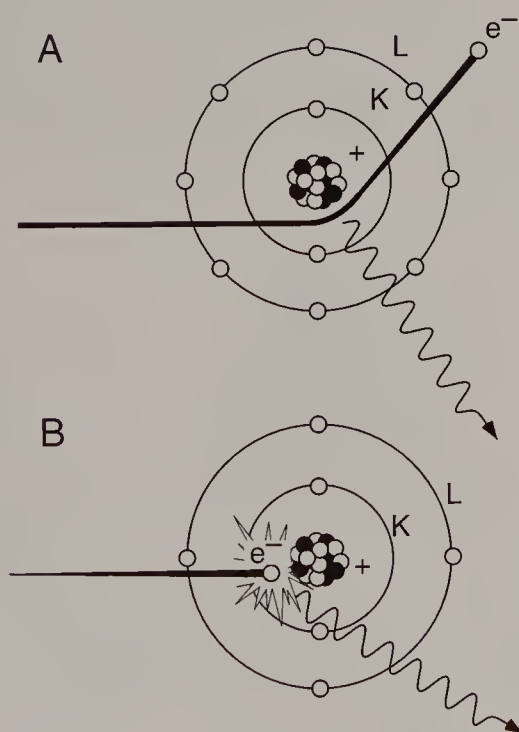
Most of the x-rays produced by dental x-ray machines are called bremsstrahlung, brems, white, or general radiation. *Bremsstrahlung* is derived from two German words: *bremse*, meaning "brake" and *strahl*, meaning "ray." It is called "braking radiation" because the radiation is pro-



**Figure 1.15 Voltage and Kinetic Energy of Electrons Vary.** During the positive (useful) phase of the alternating current cycle the voltage will vary continuously from a low value (0 volts) to a peak value and back to zero. The kinetic energy of the cathode electrons will thus vary according to the voltage being applied the instant the electrons are "boiled" out of the filament (cathode) and attracted toward the target/anode.



duced by “braking” or decelerating of high-speed electrons. A cathode electron that completely avoids the orbital electrons of an atom of the tungsten target may come sufficiently close to the nucleus to come under its influence. Because the cathode electron is negatively charged and the nucleus is positively charged, there is an electrostatic attraction between them. As the cathode electron approaches the tungsten atom’s nucleus, it is influenced by a nuclear force, which is stronger than the electrostatic attraction between the electron and the nucleus. As a result, the projected electron slows down and is deflected from its original course, thereby losing some of its kinetic energy (energy of motion). The kinetic energy lost by the electron is emitted directly in the form of photons of radiation (x-radiation) (Fig. 1-16). Most of the cathode electrons that strike the target will give up their kinetic energy by interactions with many atoms before coming to rest. Each time a cathode electron is decelerated, it gives off only a small part of its energy; the projected electron will penetrate many layers of atoms of the target material before giving up all its energy. Therefore, not all the x-ray photons are produced on the surface of the target; a fraction of the projected electrons approach the nucleus head-on and are completely stopped by the electrostatic field. In this collision, all the energy of the electron is converted to a single x-ray photon.



**Figure 1.16 Bremsstrahlung (Brems Radiation).** Generation of general or white radiation (bremsstrahlung) produced by interaction of a high speed cathode electron with a tungsten atom nucleus of the target (anode). (A) Cathode electron deflected and decelerated by the nucleus of a tungsten atom producing an x-ray photon. (B) Occasionally, the total kinetic energy of a cathode electron is converted into x-ray photon energy by a direct collision with the nucleus of the tungsten atoms of the target (anode).

### Characteristic Radiation

The other process by which x-rays can be produced in an x-ray tube is when a cathode electron has sufficient energy to ionize (remove an electron) from a tungsten atom within the target (focal spot) by ejecting an inner orbital electron (e.g., in K or L shell) from the tungsten atom. To eject a K shell electron, work has to be done to overcome the attractive force of the nucleus of an atom of tungsten. The binding energy of an orbiting electron in the K shell of tungsten is about 70 keV. Therefore, the cathode electron must have energy of more than 70 keV to eject a K shell electron. When such an event occurs, both the K shell electron and the cathode electron leave the atom. (A 60 keV electron beam will not contain any electrons that will eject a K shell electron from tungsten.) The tungsten atom is now unstable because it is now ionized (an electron missing from an atom) and in an excited state (an electron vacancy in a shell). For the atom of tungsten to return to a normal state again, the ionized atom of tungsten must get rid of its excess energy. Immediately, the space or “hole” vacated by the ejected electron in the K shell is filled by an electron from one of the outer shells, usually from the adjacent L shell. When an L electron drops down into the K shell, the L electron must give up its excess energy. This energy given off by the L shell electron is a single photon of x-radiation of 59 keV. This is the difference between the binding energies of the K shell (about 70 keV) and the L shell (about 11 keV). The x-ray photon of 59 keV is the characteristic radiation of the K shell of the tungsten atom. The energy emitted is termed a characteristic x-ray because its energy is characteristic of the target element (tungsten) (Fig. 1-17). What contribution does the characteristic radiation make to the total x-ray production by a standard x-ray tube? Below 70 kVp, there is no K shell characteristic radiation. With 80 kVp, characteristic radiation (K shell characteristic) contributes approximately 10% of the useful x-ray beam. It is important to distinguish the differences between cathode electrons striking the target, orbital electrons of individual tungsten atoms within the target, and ejected electrons from individual orbital shells of tungsten atoms.

### HETEROGENEOUS AND HOMOGENEOUS X-RADIATION

X-Radiation used in dentistry can be heterogeneous or homogeneous, depending on the varying wavelengths in the x-ray beam.

#### Heterogeneous Radiation

Brems radiation is heterogeneous or polyenergetic; that is, it is not uniform and has a variety of energies and wavelengths (Fig. 1-18). There are two factors that produce this wide variation in the energy of radiation produced by the braking phenomenon. First, the cathode electrons will

Schematic representation of the K and L shells of an atom of tungsten of the target (anode).

**Figure 1.17 Characteristic Radiation.**

(Event 1) The incoming cathode electron collides with a K shell electron of tungsten. (Event 2) Both cathode electron and K shell electron leave the atom. The atom now is in an excited state. (Event 3) An electron from the L shell jumps into the K shell, giving off K-characteristic radiation with photon energy of 59 keV. (Event 4) The L shell electron space is filled by the M shell electron, and L-characteristic radiation with photon energy of 9 keV is emitted.

EVENT #1  
Incident electron "A"  
from the filament (cathode).

EVENT #3  
L shell electron  
fills vacancy  
in the K shell.

EVENT #4  
Photon of  
characteristic  
radiation generated  
by the combined action  
of the incident electron "A"  
and the filling of the  
vacancy in the K shell  
by an electron from  
the L shell.

EVENT #2  
Ejected electron  
from the K shell.

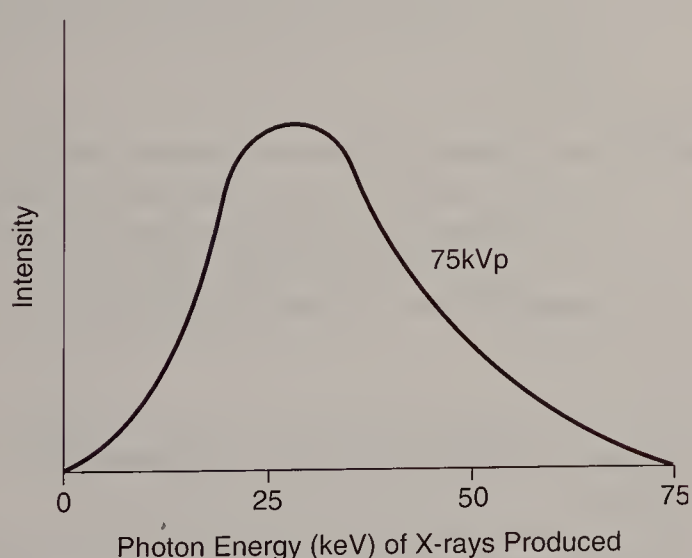
Deflected incident  
electron "A".

undergo many interactions before coming to rest in the majority of cases. With each deceleration of a cathode electron, a corresponding amount of kinetic energy (energy in motion) is converted to x-ray photons of equivalent energy. As the deceleration or braking varies, so does the energy of the x-ray photons produced. **Second**, the cathode electrons have widely different kinetic energies (speed). As the applied kVp varies, so will the kinetic energy of the cathode electrons. In general, the highest-energy x-ray (short wavelengths) photons are determined by the selected kilovoltage peak (kVp) used (i.e., 90 kVp). The lowest-energy x-ray (long wavelength) photons pro-

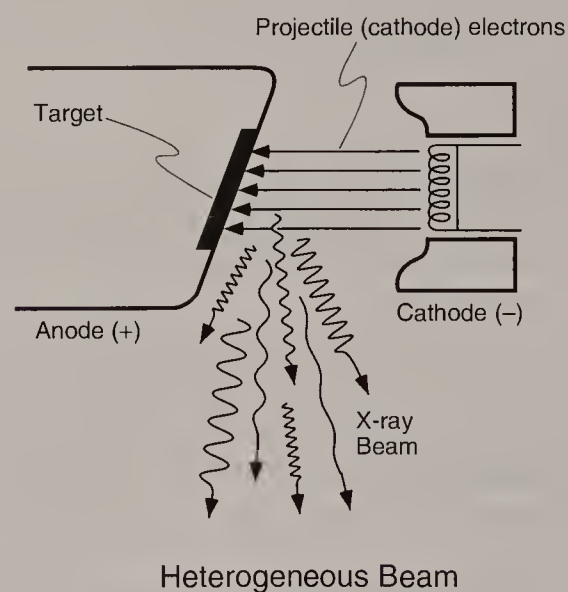
duced will probably never reach the patient because they will be filtered out either within the x-ray tubehead (target material, glass, and oil insulation) or by the added aluminum filter placed outside the tubehead exit window (see Fig. 13-1, Chapter 13). Nevertheless, the x-radiation that does emerge from the x-ray machine is still, in most instances, heterogeneous; that is, the x-ray beam will contain photons of varying wavelengths (Fig. 1-19).

### Homogeneous Radiation

In some x-ray machines, the alternating current (AC) is converted to direct current (DC). When a DC current is



**Figure 1.18 Brems Radiation Spectrum.** The Brems spectrum (distribution curve) shown here compares the intensity (number of x-rays) with the photon energy of the x-rays produced at a particular kVp. The maximum number of x-rays produced is at approximately the 25 keV level, as shown on this continuous spectrum of Brems Radiation at 75 kVp.



**Figure 1.19 Brems Radiation Is Heterogeneous.** Brems radiation is heterogeneous or polyenergetic, that is, it is not uniform in energy and wavelengths. In this diagram, projectile (cathode) electrons of widely different kinetic energies (keV) produce an x-ray beam of x-ray photons of various energies (wavelengths).



applied to an x-ray generator, the kilovoltage rapidly rises to its peak and remains there throughout the x-ray exposure. Thus, all the cathode (projected) electrons will have the same keV, and the resulting radiation is more homogeneous. (That is, the x-ray photons will have less variation in wavelengths compared to bremsstrahlung radiation.) Thus, the emerging x-ray beam will contain fewer low-energy (longer wavelength) x-ray photons that are not sufficiently penetrating. In a heterogeneous beam, these long-wave photons are absorbed by the patient's soft tissues; thus, they do not penetrate the teeth and bone and do not contribute to the image. In DC machines, most of the x-ray photons penetrate the patient's soft tissues to eventually create the image. Thus, when a DC-type dental x-ray machine is used as compared to a conventional self-rectified dental x-ray machine using similar kVp-mA factors, the same quality image can be produced with 20% less radiation dose to the patient.

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 1.1. PROPERTIES OF X-RAYS DEMONSTRATED WITH A RARE EARTH SCREEN

#### Materials and Equipment Needed

1. Intraoral x-ray machine.
2. Preferably rare earth screen (Kodak Lanex Regular; Eastman Kodak, Rochester, NY) or older calcium tungstate screen.
3. Small piece of pine board.
4. Small piece of Sheetrock/plasterboard.

Note: Rare earth screen can be obtained from a dental supply house. Pine board and Sheetrock can be obtained as waste from most construction sites or contractors, a plumber, or a construction supply store.

#### Instructions

- Step 1:** Set up the fluorescent screen as follows: place an opened cephalometric or panoramic cassette vertically on a counter top near the intraoral x-ray machine.
- Step 2:** Set up the x-ray machine as follows: turn it on and set the exposure time at 60 impulses or 1 second, depending on the machine. If there is a kVp dial, set it at 90 kVp. If there is an mA switch, set it at 15 mA or the highest mA setting.
- Step 3:** Align the x-ray machine and fluorescent screen. Grasp the tubehead and move it toward the screen so that the tip of the BID is about 1 inch away from the screen and perpendicular to it

(i.e., aim the BID directly at the screen) (see Figures 2-5 and 2-6 in Chapter 2).

- Step 4:** Observe the fluorescence of the screen. Turn off the lights in the room and stand behind either a shield or door with a leaded glass panel or stand at least 6 feet away from the tubehead and in the safe quadrant. (The instructor will explain.) Depress and hold down the timer or exposure switch (note the sound while x-rays are being emitted).

Now look at the green or blue light being emitted by the screen. Note the size of the fluorescent spot being just a bit bigger than the size of the BID opening.

- Step 5:** Back the BID tip away from the screen. Grasp the tubehead and move the tubehead and BID back so it is about 6 inches away from the screen, but still pointing directly at it.

- Step 6:** Repeat Step 4. Do this with the lights on and also with the lights off. Now the fluorescent spot will be somewhat larger than before and not as bright/intense as during the first exposure when the lights were off. When the lights are on, it is harder to see the fluorescent light. When the lights are on or off, the beam of x-rays cannot be seen.

- Step 7:** Place a piece of wood between the BID tip and the screen. Obtain a small length of 3/4-inch pine board and tape it to the BID tip, so that the BID tip is completely covered. Place the BID tip about 1 or 2 inches away from the screen as before. Depress and hold down the timer or exposure switch. Observe the green or blue light being emitted by the screen. Note the presence or absence of the fluorescent spot and its relative brightness.

- Step 8:** Place a piece of Sheetrock between the BID tip and the screen. Obtain a small piece of 3/4-inch or 5/8-inch Sheetrock. Remove the piece of wood from the BID tip and replace it with the piece of Sheetrock. Using the Sheetrock only, repeat Step 7.

### CASE-BASED QUESTIONS FOR LABORATORY EXERCISE

1. Name as many properties of x-rays you were able to observe by performing this experiment.
2. What did you learn about the x-ray machine?
3. What did you learn about radiation safety?



## CASE-BASED PROBLEM-SOLVING

You need to go home and explain to a boyfriend, girlfriend, spouse, or parent how:

1. X-rays are similar to light.
2. X-rays are different from light.
3. Easy it is to protect oneself from radiation exposure.

**Clue:** Use a small pocket-sized flashlight, a piece of clear plastic or glass, and a piece of cardboard from a note pad.

## REVIEW QUESTIONS

1. In the x-ray tube, x-rays originate from the:
  - A. Filament.
  - B. Cathode.
  - C. Anode.
  - D. Focusing cup.
2. The electrons that revolve in shells around the nucleus:
  - A. Have a positive charge.
  - B. Have no charge, either positive or negative.
  - C. Have a negative charge.
  - D. Have either a positive or negative charge.
3. X-rays belong to which of the following radiation categories?
  - A. Particulate radiations.
  - B. Hygroscopic radiations.
  - C. Alpha radiations.
  - D. Corpuscular radiations.
  - E. Electromagnetic radiations.
4. An x-ray photon is:
  - A. A small particle able to penetrate matter.
  - B. A small bundle of pure energy with wave-like properties.
  - C. An electron that has been accelerated to 186,000 miles/sec.
  - D. An electrical current that has been magnified by 1000 V or 1 kV.
5. X-rays are actually produced in the x-ray tube by:
  - A. Radioactive decay of particulate matter.
  - B. Electrical current passing through a mixture of oil and gases, creating minute explosions.
  - C. High-speed electrons interacting with the nucleus of the target atoms giving off radiation.
  - D. High-speed photons colliding with the electrons in the oil mixture and target area.
6. The target material (in the anode) for diagnostic tubes is:
  - A. Copper.
  - B. Tungsten.
  - C. Lead.
  - D. Samarium.
7. At diagnostic levels, what percentage of the electron energy is converted to x-radiation at the anode?
  - A. Less than 1%.
  - B. 2%.
  - C. 10%.
  - D. More than 99%.
8. Increasing the kVp of an x-ray machine increases the:
  - A. Number and energy of photons generated.
  - B. Mean wavelength of the photons generated.
  - C. Focal spot size of target.
  - D. Filament temperature.
9. The dental x-ray beam consists of photons of many different wavelengths, with the shortest wavelength photons determined by:
  - A. Milliamperage (mA).
  - B. Kilovoltage peak (kVp).
  - C. Filtration.
  - D. Coefficient of attenuation.
10. Which of the following statements most adequately describes the radiation produced by high kilovoltage?
  - A. Short wavelengths of low frequency.
  - B. Long wavelengths of high frequency.
  - C. Short wavelengths of high frequency.
  - D. High penetrating waves of low frequency.
11. In a standard dental x-ray unit, the quality of x-radiation produced during exposure energization is controlled primarily by:
  - A. Exposure time.
  - B. Kilovoltage (kV).
  - C. Milliamperage (mA).
  - D. Inherent filtration.
12. In a standard dental x-ray unit, the quantity of x-radiation produced during exposure energization is controlled primarily by:
  - A. Exposure time and kilovoltage (kV).
  - B. Exposure time and milliamperage (mA).
  - C. Exposure time and inherent filtration.
  - D. kV and mA.

13. Ionization occurs:
  - A. When atoms lose electrons; they become deficient in negative charges and therefore behave as positively charged atoms.
  - B. When atoms gain electrons; they become positively charged.
  - C. When an atom loses its nucleus.
  - D. Only when a K orbit electron is ejected and replaced by an L orbit electron.
14. Which electron has the greatest binding energy to the nucleus?
  - A. J shell electron.
  - B. K shell electron.
  - C. L shell electron.
  - D. Q shell electron.
15. Select the correct statement:
  - A. X-rays cannot be focused to a point.
  - B. X-rays can be focused to a point.
  - C. X-rays cannot increase the electrical conductivity of a gas.
  - D. X-rays do not always travel in a straight line.
16. The mean penetrability of an x-ray beam is **not** related to which of the following?
  - A. kVp.
  - B. Filtration.
  - C. Wavelength.
  - D. Frequency.
  - E. mA.

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# The X-Ray Machine, Attenuation, and Recording of Radiographic Images

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *Identify two types of electric current.*
2. *Describe and discuss the purpose of transformers.*
3. *Define the half-value layer.*
4. *Define self-rectification and half-wave.*
5. *Define milliamperere-second.*
6. *Identify the effect mAs have on the x-ray beam.*
7. *Define leakage and scattered radiation.*
8. *Identify the types of interactions that occur when matter is exposed to radiation.*
9. *Discuss the inverse square law.*
10. *Recognize radiographic film sizes and the appropriate uses for each of the sizes.*
11. *List the four components of radiographic film and discuss the purpose of each component.*
12. *Discuss the relevance of film speed to radiation safety.*
13. *Define latent image.*
14. *Observe the differential absorption of x-rays by matter through the Workshop/Laboratory Exercises.*
15. *Observe the components of the intraoral film packet through the Workshop/Laboratory Exercises.*
16. *Learn the essentials of x-ray processing through the Workshop/Laboratory Exercises.*
17. *Apply the Workshop/Laboratory Exercises knowledge to solve three common problems occurring with bitewing radiography.*
18. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

aerial image  
alternating current  
ampere (A)

attenuation  
autotransformer  
characteristic radiation

coherent scattering  
Compton scatter radiation  
(scatter radiation)

conductor  
control panel  
current



|                         |                         |                          |                       |
|-------------------------|-------------------------|--------------------------|-----------------------|
| developer               | filament circuit        | latent image             | screen type film      |
| differential absorption | film sensitivity        | photoelectric absorption | self-rectifying tubes |
| direct current          | fixer                   | potential difference     | sensitivity speck     |
| direct exposure film    | half-value layer (HVL)  | radiolucent              | silver halide         |
| electricity             | heterogeneous radiation | radiopaque               | step-down transformer |
| electrovalence forces   | high-voltage circuit    | rectification            | step-up transformer   |
| emulsion, film          | intensity               | remnant x-rays           | x-ray generator       |
| filament                | inverse square law      | resistant                |                       |

## X-RAY MACHINE

X-rays used in dental radiography are electronically produced. The major components of the x-ray system are the wall switch, control panel, generator, and x-ray tube. An x-ray generator receives standard alternating current from the wall switch. The control panel is used to select predetermined settings of x-ray exposure and to initiate the exposure. The generator provides high-voltage wave-forms according to the factors of exposure selected that will energize the x-ray tube.

## X-RAY GENERATOR

The x-ray generator supplies an electrical source of energy (usually 110 or 220 V) and 60 Hz (cycles/sec) alternating current to the x-ray tube and then modifies it to supply the needs of the x-ray tube. The tubehead is the outer housing that is attached to the arm by the yoke. The beam indicating device (BID) is attached to the tubehead (see Fig. 2-5). To understand how the generator works, we should first review some basic electrical physics, because x-rays are produced by the use of electricity.

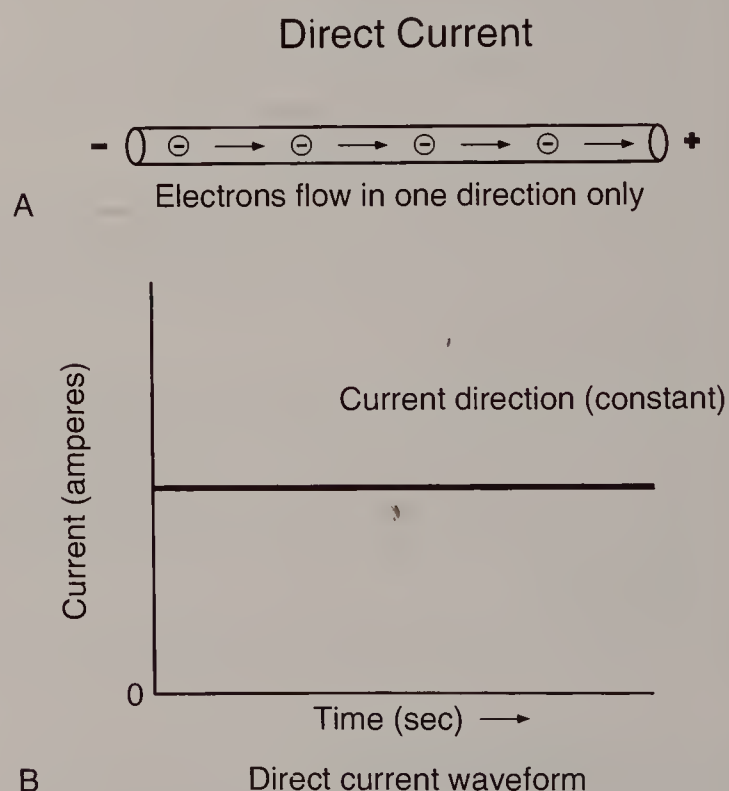
## ELECTRICITY

Electric current, or electricity, is the flow of electrons through an electric conductor very much like water flowing through a pipe. If the electrons are made to flow in one direction along a conductor, the electrical current is called **direct current** or DC (Fig. 2-1). Most applications of electricity in radiology require the electrons to flow first in one direction and then in the opposite direction. Current in which electrons oscillate back and forth is called **alternating current** or AC (Fig. 2-2). The term "cycle" in AC refers to the curve above and below the horizontal line. Each cycle consists of two alternations; that is, the voltage starts at 0, rises gradually to the maximum in one direction called the kV peak, and finally returns to 0. There are 120 alternations/sec with 60-cycle current. However, only 60 alternations/sec are usable in dental self-rectified x-ray tubes. This is because only half of the available cycle is used to produce x-rays (Fig. 2-3). Recti-

fication is a process of changing AC into DC. Dental x-ray tubes are called **self-rectifying tubes**, in that they act as a simple rectifier in changing AC into DC while producing x-rays.

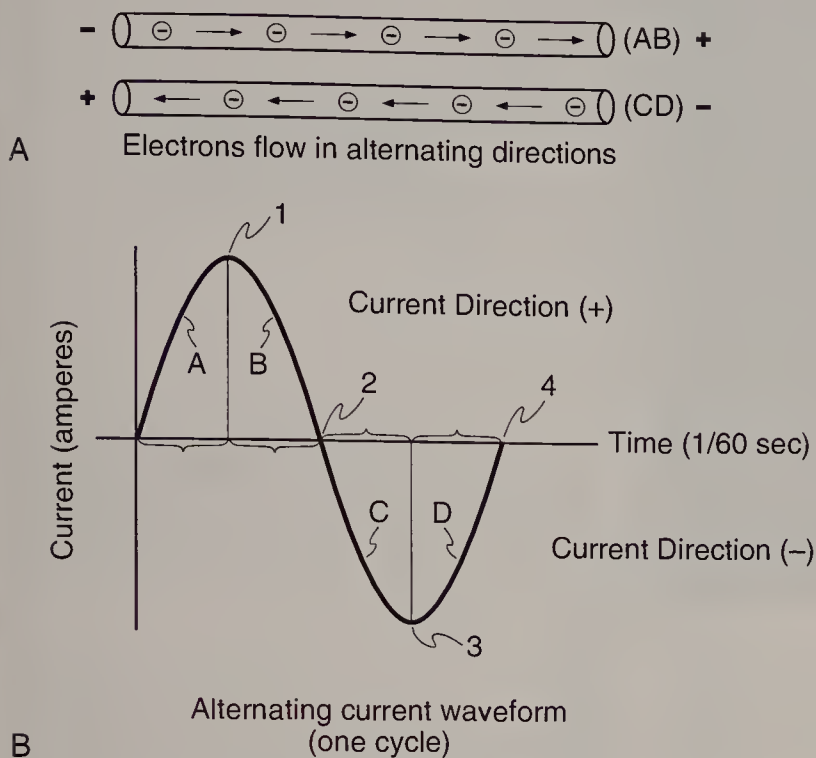
## COMPONENTS OF THE X-RAY GENERATOR

The x-ray generator consists of two separate compartments: the control panel and the tubehead assembly. The control panel contains the main off-and-on switch, the exposure button, mA selector control, kVp selector control, time selector, x-ray emission light, and pilot light (Fig. 2-4). The tubehead assembly of the x-ray generator (Fig. 2-5) contains a low-voltage transformer, high-voltage transformer, and x-ray tube. Because the potential difference in these circuits may be as high as 100,000 V,



**Figure 2.1 Direct Current (DC).** (A) In DC, electrons flow in one direction only. (B) Graph of associated wave-form of direct current. The distance between the horizontal line and the time axis represents the magnitude or velocity of the electrons.

## Alternating Current

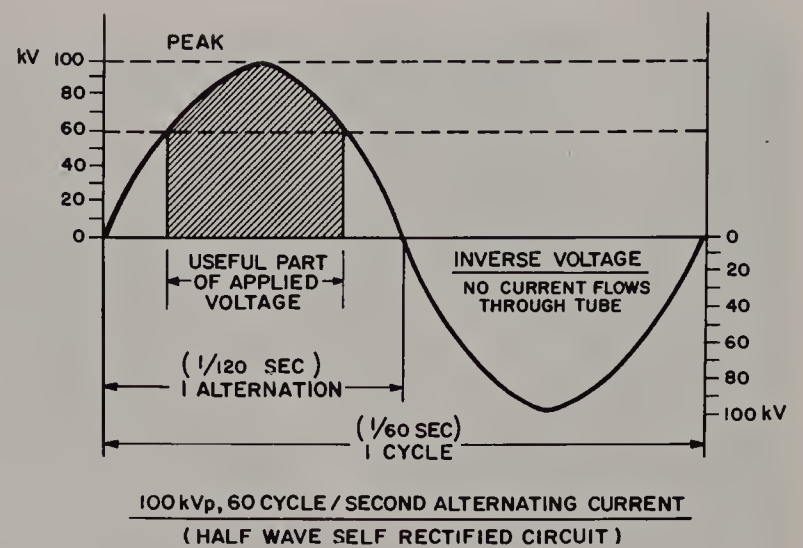


**Figure 2.2 Alternating current (AC).** (A) In AC, electrons flow in one direction and alternately in the opposite direction, always from the negative to the positive pole. (B) Example of a sine wave (represents periodic oscillations) of alternating current. Note that electrons flow first in a positive direction and then in a negative direction (below the 0 axis). At point 0, the electrons are at rest and increase in velocity during segment A. When they reach maximum velocity they are at point 1, where the electrons begin to slow down in segment B. They come to rest again at point 2. They then reverse motion, and the flow of the electrons begins again in a negative direction. At point 4 the cycle ends, which takes 1/60 second in 60 hertz (cycles/sec) current.

the transformers and x-ray tube are immersed in oil (Fig. 2-6). The oil functions as an insulator and prevents sparking from one electrical component to another in the tube-head.

### Step-Up and Step-Down Transformers

By definition, a transformer is an electromagnetic device that changes AC from low voltage to high voltage or from high voltage to low voltage without loss of an appreciable amount of energy (less than 10%). A transformer is composed of two wire coils wrapped around the opposite ends of an iron core. The first coil circuit is called the primary circuit or input side, and the second coil circuit is called the secondary circuit or output side. When current flows through the primary circuit and coil (transformer), it produces a magnetic field within the magnetic core, and the magnetic field induces a current in the secondary coil and circuit. However, current will not flow in the secondary or output circuit unless the magnetic field is changing (either decreasing or increasing); the current will not flow if the magnetic field is in a stable state, such as with DC. AC is used for transformers because in AC the voltage



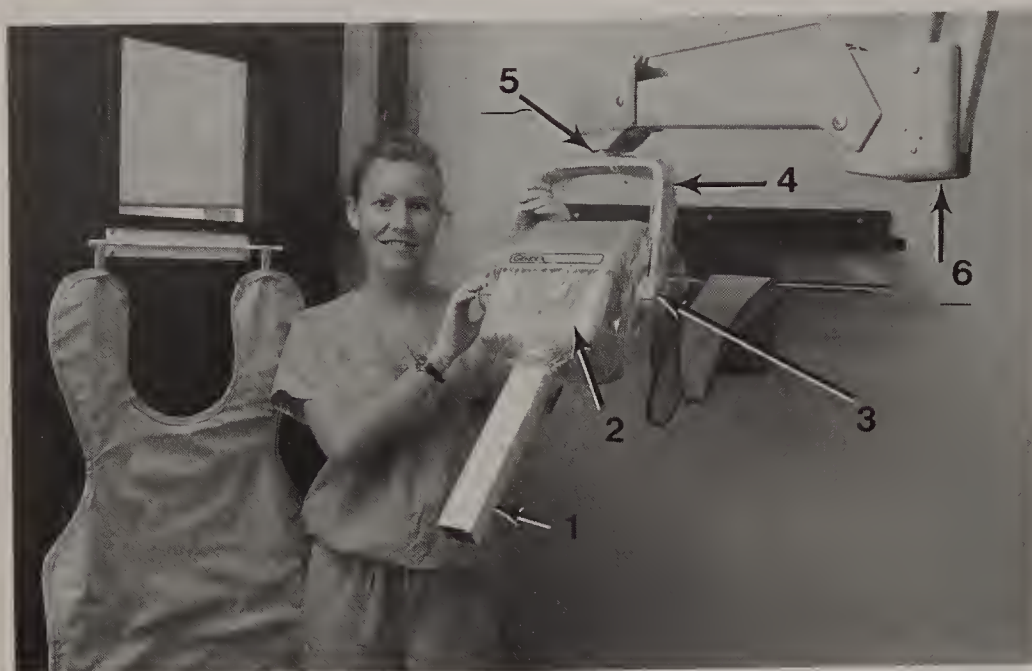
**Figure 2.3 Dental Self-Rectified X-Ray Tubes.** AC used in dental radiography is a 60-cycle current—it flows first in one direction and then flows in the opposite direction, changing directions every 1/120 second. It makes a complete cycle every 1/60 second. In the dental x-ray tube, the anode is first positive and then negative with respect to the cathode during each half-cycle (1/120 second). When the anode is positive, the electrons flow by attraction to the anode; when the anode is negative, the electrons are not attracted to the anode. Hence, no current flows in the tube. Therefore, the dental x-ray tube in essence changes AC into DC (self-rectification) while producing x-rays.

changes continuously, thus producing a continuously changing magnetic field. Voltage is induced in the secondary coil when AC current is applied to the primary coil. The voltages in the two coils are directly proportional to the number of turns of wire in each, assuming a theoretical 100% efficiency. This means that if the number of turns in the secondary coil is twice the number in the primary coil, then the voltage in the secondary coil will be twice the voltage in the primary. A step-up transformer has more turns in the secondary coil than the primary coil (Fig. 2-7). A transformer with fewer turns in the



**Figure 2.4 Control Panel of a Gendex Dental X-Ray Machine.** (1) Holder for exposure button, (2) main switch off, (3) mA selector and main switch on, (4) x-ray tube selector, (5) power on light, (6) x-ray/emission light, (7) exposure timer, (8) kVp-mA meter, and (9) kVp selector (auto transformer).





**Figure 2.5 X-Ray Tubehead Assembly and X-Ray Room Infection Control.** (1) Beam indicating device (BID). (2) X-ray tubehead. (3) Tubehead angulation indicator and vertical rotation axis. (4) Yoke. (5) Horizontal rotation axis. (6) X-ray arm.

secondary coil than in the primary coil decreases the voltage and is called a **step-down transformer** (Fig. 2-7).

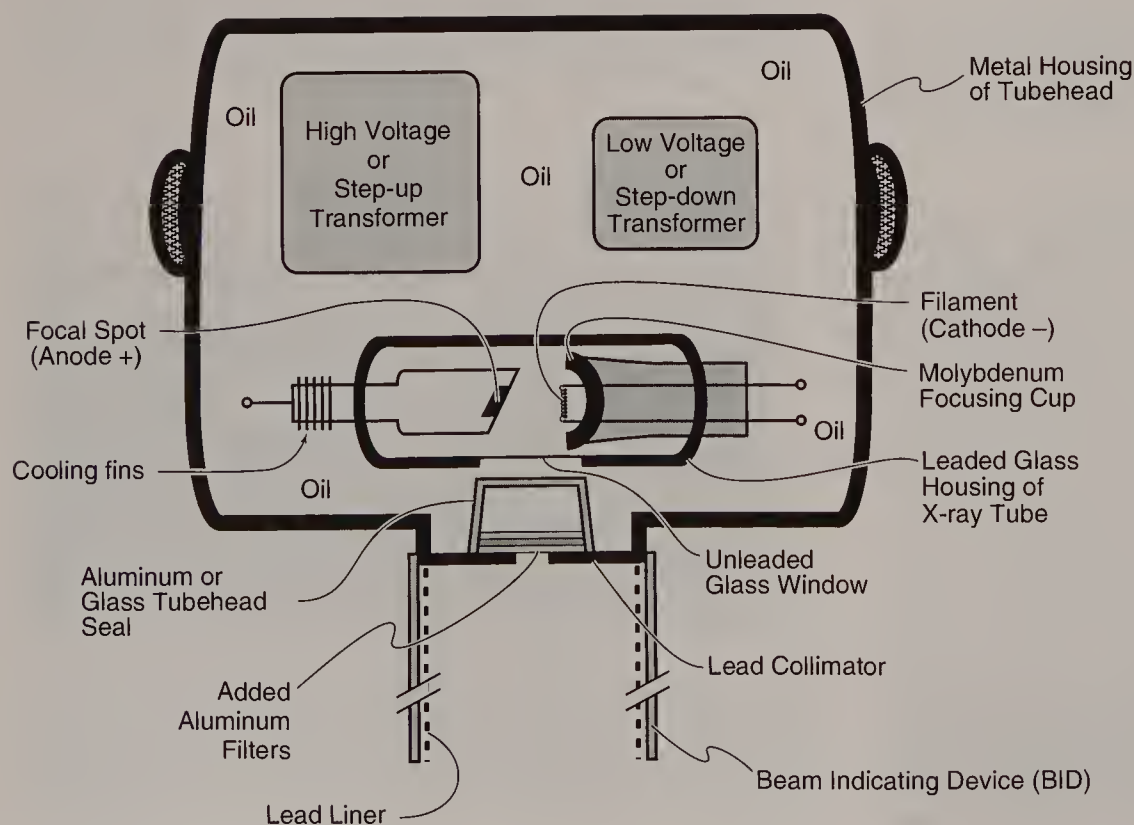
#### Autotransformer

Although in dental radiography there are x-ray machines with fixed kVp (such as 65 or 70 kVp), it is advantageous to have an x-ray machine in which the kilovoltage can be varied. The kilovoltage can be varied by the use of an **autotransformer**. The autotransformer has a single coil of insulated wire wound around a large iron core, which serves as both the primary and secondary coil, with the number of turns being adjustable. At regular intervals along the coil, the insulation is interrupted and the bare

points connected to metal buttons. By moving a metal conductor to various metal buttons on the wire, the number of turns included in the secondary circuit of the autotransformer is varied, which in turn varies the output voltage. Therefore, when the autotransformer is varied, it in turn varies the output voltage. The autotransformer serves as a kVp selector dial and varies the kVp available to the primary coil of the step-up transformer (Fig. 2-7).

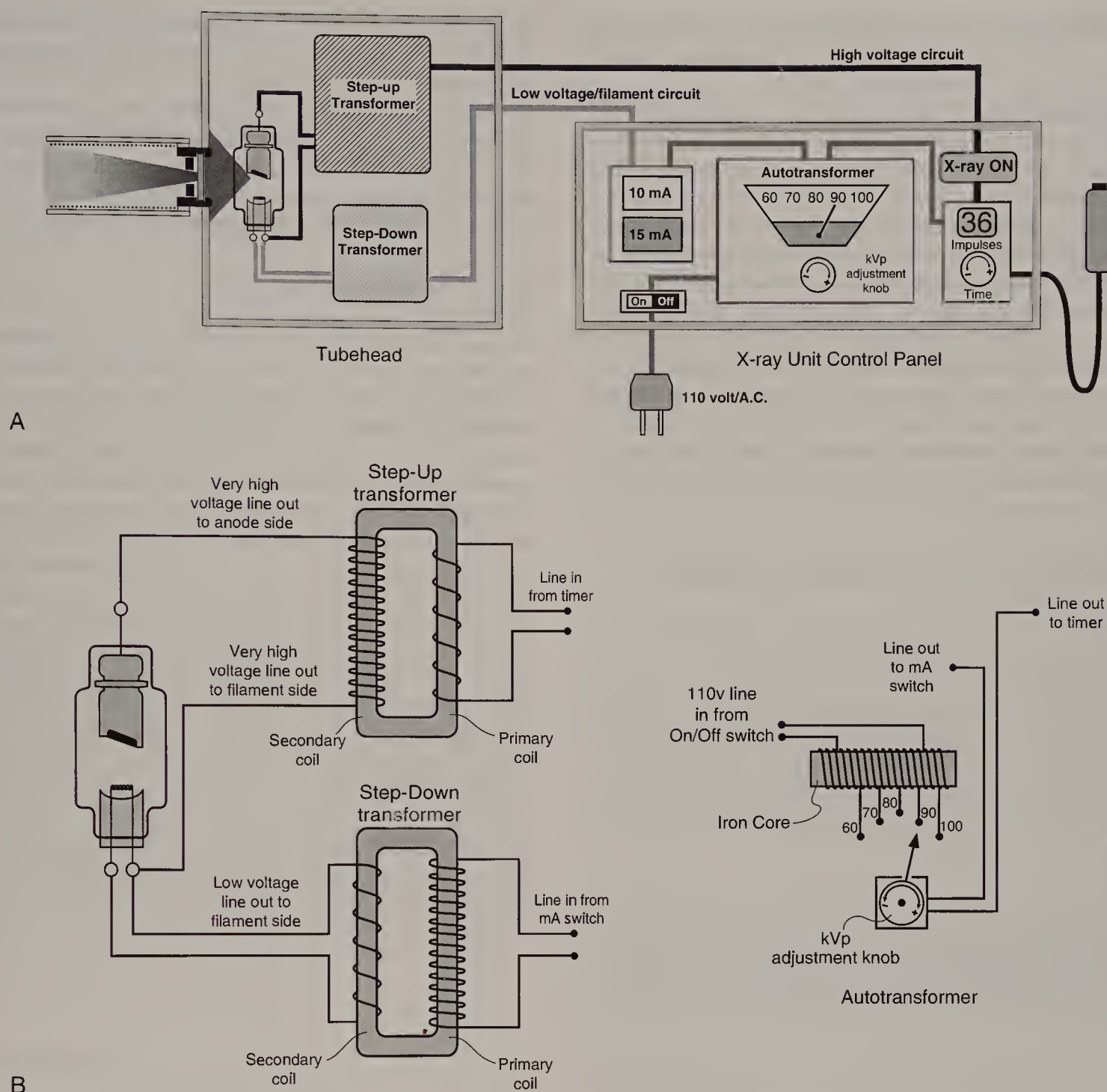
#### Filament and High-Voltage Circuits

There are two electrical circuits necessary in the x-ray machine to produce x-rays in the x-ray tube. The first is the filament circuit, which provides a source of electrons by



**Figure 2.6 Dental X-Ray Head, Tube, and BID.** The x-ray tube is immersed in oil to prevent sparking from one electrical component to another and to disperse the heat from the copper sleeve of the anode.





**Figure 2.7 Transformers.** (A) General configuration of components shows location of the step-up, step-down, and autotransformers within the tubehead and x-ray unit control panel. (B) A step-up transformer has more turns in the secondary coil than in the primary coil. In dental x-ray machines, a step-up transformer takes 110- or 220-V current and increases this voltage to 65,000 to 90,000 V (65 to 90 kVp). This provides the high voltage necessary to accelerate the cathode electrons toward the anode at high speeds. Step-down transformer: In dental x-ray machines, the primary coil of the step-down transformer has more turns than the secondary coil. This decreases the voltage from 110 or 220 V to 8 to 12 V in the secondary coil, which provides a high current of 3 to 6 A to heat the filament. (C) Autotransformer (kVp Selector): The autotransformer varies the voltage input into the primary coil of the step-up transformer, which in turn varies the kVp of the machine.

heating the filament to incandescence to “boil off” the electrons from the filament of the cathode. The second circuit is the **high voltage** circuit which is necessary to accelerate the cathode electrons from the cathode toward the anode at high speeds.

**Filament Circuit.** This regulates the current flow to the filament. The step-down transformer in the filament circuit reduces the voltage (110 or 220 volts) in the primary

coil to 8 to 12 volts in the secondary coil, which results in a high current of 3 to 6 amperes to heat the filament. Although the current (amperes [A]) in the filament circuit only heats the filament and does not represent the current created by the cathode electrons flowing between the cathode and anode of the x-ray tube (mA). The high current flow in the filament actually increases the x-ray tube current (cathode to anode electrons) by increasing the fil-

ament temperature. A hotter filament emits more electrons and adds electrons to the current electrons (milliamperes [mA]) across the x-ray tube.

**High-Voltage Circuit.** This circuit has two transformers: a step-up transformer and an autotransformer. The **step-up transformer** takes 110- or 120-V current and increases this voltage to 65,000 to 100,000 V (60 to 100 kVp), thereby providing the high voltage necessary to attract the cathode electrons in the x-ray tube at high speed from the cathode to the anode. At the same time it decreases the current to 10 to 15 thousandths of an ampere (10 to 15 mA). As previously stated, although there are x-ray machines with fixed kVp (such as 65 or 70 kVp—kilovoltage), it is an advantage to be able to vary the kilovoltage. The kilovoltage can be varied by the use of an autotransformer. The **autotransformer** is an electromagnetic device that operates as a kVp selector because it varies the voltage available to the primary coil of the step-up transformer.

## INTENSITY OF THE X-RAY BEAM

Because the x-ray beam is composed of photons with many energies (**heterogeneous radiation**), it is common to speak of quality and quantity of a beam of photons. **Quality** refers to the energy of particular photons; **quantity** refers to the number of photons in the beam, each with a particular energy. Quality and quantity are described together in a concept known as **intensity**, defined as the total energy contained in the beam (quality times quantity) per unit area per unit time.

Intensity

$$= \frac{(\text{no. of photons in beam}) \times (\text{energy of each photon})}{(\text{area}) \times (\text{exposure rate})}$$

The area referred to is the cross-sectional area of the beam at a particular point in space. Because most photons spread out as they move away from the source, it is important to specify where the intensity is being calculated (distance from source). The intensity of the x-ray beam varies with the target material, the mA (current), exposure time (rate), and distance of film from source (inverse square law) (see Fig. 2-10). In the use of modern dental x-ray units, the variables that are under the operator's control are the kVp, mA, exposure time, and source-to-film distance. The target material (usually tungsten) in the anode electrode of the x-ray tube has already been placed in the x-ray machine by the manufacturer before the practitioner purchases it from the dental supply dealer.

## TUNGSTEN AS THE TARGET MATERIAL

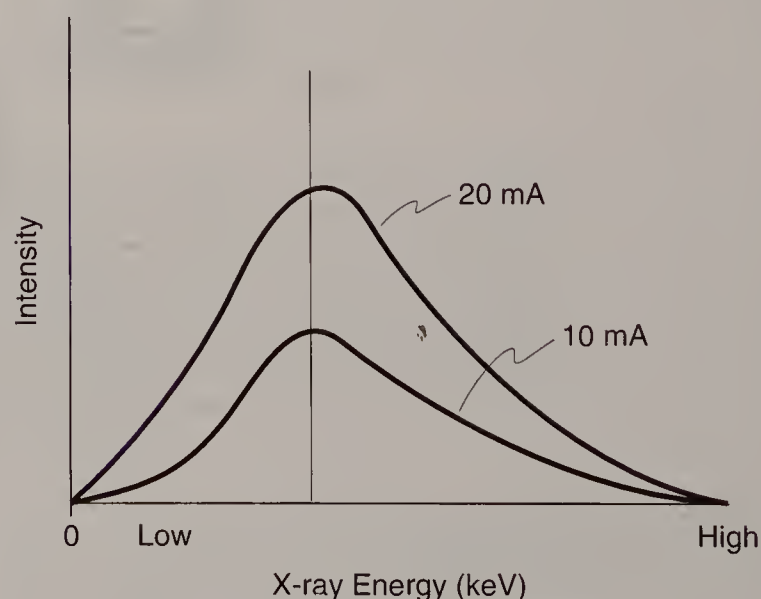
Tungsten was chosen for the target of the anode because it has a high atomic number (74), which makes it more ef-

ficient in the production of x-rays. This is because the K shell binding energy is high and there are a large number of planetary electrons. Also, it has a high melting point (3370°C) to withstand the high temperature produced in the production of x-rays. Tungsten is a relatively poor thermal conductor for the absorption and dissipation of heat from the target area and is embedded in copper to permit rapid dissipation of heat from the target.

## X-RAY EMISSION SPECTRUM

Because the x-ray beam is heterogeneous in wavelength

a high degree of precision by sorting out the x-rays by wavelength, according to energy. This can be done by a spectral distribution curve or spectrum of x-rays of various wavelengths or photon energies. Graphically, the general shape of the x-ray emission spectrum is the same for all dental x-ray machines, but the relative position of the axis can change. The farther to the right the spectrum is, the higher the effective energy of the photons or **quality** of the x-ray beam. The greater the area under the curve, the higher the intensity (total energy contained in the beam) of the x-ray beam. The number of x-rays produced depends on the number of electrons emitted by the filament. The number of electrons emitted by the filament depends directly on the tube current or mA used. If the operator changes the mA from 10 to 20 while other factors remain constant, twice as many electrons will flow from cathode to the anode. A change in the mA will make a proportionate area change in the x-ray emission spectrum (change in intensity of x-ray beam) (Fig. 2-8).



**Figure 2.8 The Relation of Milliampere to Intensity of the Beam.** A change from 10 to 20 mA, while other factors remain constant, will make a proportionate area change in the x-ray emission spectrum shown above. The intensity (total energy of the beam) of the 20 mA x-ray beam is twice that of the 10 mA beam.



## INFLUENCE OF EXPOSURE TIME ON INTENSITY

Exposure time is the interval during which x-rays are being produced. The more exposure time used, obviously the more x-rays produced. In dental radiography, the exposure time is the factor that is most commonly used to compensate for anatomical variables of patients. The most popular exposure technique is the “fixed kVp and mA technique,” which varies only the exposure time.

Traditionally, timer intervals in dentistry have been in fractions of a second and whole numbers such as 1/4, 1/2, 3/4, 1, and 2. Most of the exposure time designations for less than 1 second are timer impulse intervals of 48, 38, 30, 24, 18, 15, 12, 10, 8, 6, 5, 4, 3, 2, and 1. With a 60 Hz (cycle) AC and a half-wave self-rectified dental x-ray tube, there are 60 impulses/sec of electrical energy. Therefore, 1 impulse equals 1/60 of a second. Any number greater than 60 is designated in seconds (for example, 120/60 = 2 seconds).

### Relationship of mA and Exposure Time

The mA and the exposure time have a direct effect on the quantity or number of photons produced in an x-ray beam. When these two factors (mA and seconds) are multiplied together, a common factor, mAs, is formed. When impulses are used instead of seconds for the exposure time, the common factor (mAs) becomes the milliamperere impulses (mAi). Milliamperere seconds or milliamperere impulses determine the total number of x-ray photons produced in the beam but do not indicate the energy of each photon in the beam. The effective energy of each particular photon in the x-ray beam depends on the kVp applied across the cathode to the anode.

### mAs or mAi Rule

The milliamperage required for a given exposure time is inversely proportional to the exposure time. That is, the higher the milliamperage, the shorter the exposure time. Some examples of mAs and mAi are given to show how the factors may be varied without influencing the quantity of radiation produced.

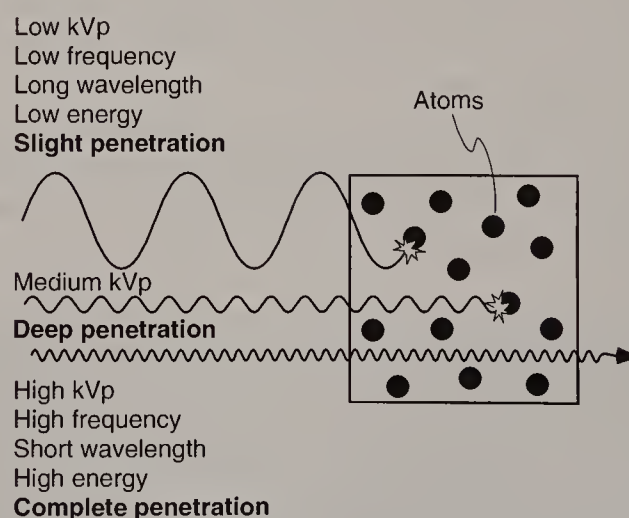
|                                            |                                            |
|--------------------------------------------|--------------------------------------------|
| $\text{mA} \times \text{sec} = \text{mAs}$ | $\text{mA} \times \text{imp} = \text{mAi}$ |
| $10 \times \frac{1}{2} = 5$                | $10 \times 30 = 300$                       |
| $15 \times \frac{1}{3} = 5$                | $15 \times 20 = 300$                       |

Because the mAs and mAi in the above examples remain the same, the quantity of the radiation produced remains the same. Note that 1/2 second is the same as 30 impulses, and 1/3 second equals 20 impulses. There are 60 impulses in 1 second.

## INFLUENCE OF TUBE POTENTIAL (KVp) ON INTENSITY

The higher kVp techniques will (1) increase the amount of radiation produced (quantity) and (2) determine the maximum energy (quality) of the x-rays produced. Kilovoltage controls the speed (kinetic energy) of each electron, which in turn has important effects on the photon energy of the x-rays produced. Radiation produced in the higher kilovoltage range (85 to 100 kVp) has more x-rays with greater energy, higher frequency, and shorter wavelengths. Such x-rays are much more penetrating and are called “hard” x-rays. Radiation produced in the lower kilovoltage range (60 to 65 kVp) has more x-rays with less energy, lower frequency, and longer wavelengths; such x-rays are less penetrating and are called “soft” x-rays. In addition to controlling the penetrating power (quality) of the x-ray beam, kilovoltage also influences x-ray quantity. If the kVp were doubled from 50 to 100, the x-ray intensity increases by a factor of 4. This will increase the darkness (density) on the film. Actually, to double the x-ray intensity by kVp manipulation alone, one would only have to increase the kVp by 41%. This helps to explain the x-ray “rule of thumb” used by x-ray technologists to make kVp and mAs changes to produce constant density (darkness) on the film. The rule states that, “an increase of 15% in kVp should be accompanied by a reduction of one half in mAs.” In dentistry, an increase of 15 kVp usually requires halving the exposure time, and a decrease of 15 kVp necessitates doubling the exposure time to maintain the same density (darkness) on the radiograph.

In summary, because kVp controls the speed of the electrons traveling from the cathode to the anode, more x-ray photons are produced per unit of time. Also, the higher speed of the cathode electrons colliding with the target produces more short wavelength or more penetrating photons of x-radiation (Fig. 2-9). Because of the greater number of photons of x-radiation at higher kVps, the exposure time will always need to be decreased when using higher kVps to avoid over-exposing the film.



**Figure 2.9 Influence of kVp on Penetration.** The higher the kVp, the greater the penetration.



### Varied kVp Technique

Many operators with x-ray machines in which the kVp can be varied use the **varied kVp exposure technique**. In this technique, the mA and exposure times (mAs) are fixed, and the kVp is varied according to differences in the thickness and density of anatomical structures in a particular region of a patient's jaw.

### Half-Value Layer

In radiology, the quality or penetrating power of the x-ray beam is controlled by the kVp and is measured by its **half-value layer (HVL)**. The HVL of an x-ray beam is the thickness of absorbing material (usually aluminum) necessary to reduce the x-ray intensity to one half its original value. In dentistry, a diagnostic x-ray beam has an HVL of 1.5 mm of aluminum for machines 69 kVp and below; machines capable of 70 to 90 kVp have an HVL of 2.5 mm of aluminum. These thicknesses of aluminum are standards set by the federal government (for more on this, see Chapter 8).

### INFLUENCE OF SOURCE-FILM DISTANCE ON INTENSITY

Because x-rays are created at the focal spot of the tungsten target of the anode of the x-ray tube, they act like visible light waves in that they radiate from the source in all directions unless stopped by an absorber. The x-rays of the primary beam emerge from the protective tube housing not as parallel waves but as divergent rays. The primary beam, then, is shaped very much like a cone or a megaphone. Therefore, the intensity of the beam decreases as the distance from the source increases. This can be proven by a simple demonstration. In a darkened room, move a single light source nearer to and farther away from a printed page. As the light source is moved away from the page, the light falling on it is less and less bright. Exactly the same thing happens with x-rays. As the distance from the object to the source of radiation is decreased, the x-ray intensity at the object increases; as the distance is increased, the radiation intensity at the object decreases.

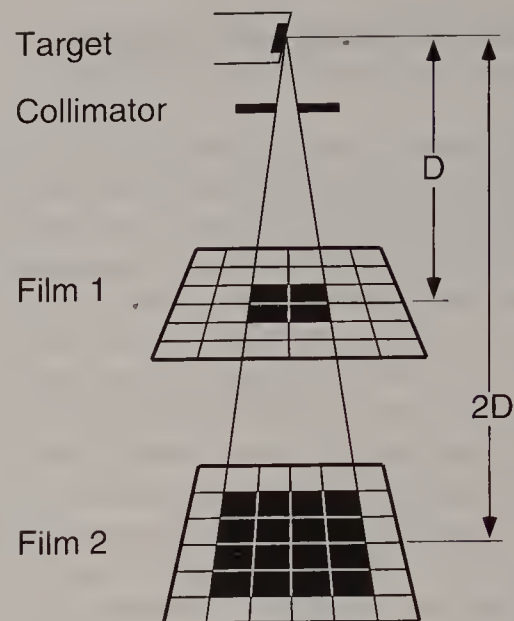
### Inverse Square Law

The relationship between distance and intensity of radiation is called the **inverse square law** because the intensity of radiation varies inversely as the square of the source-film distance (SFD) (Fig. 2-10).

A practical formula to use in adjusting the exposure factor is as follows:

$$\frac{\text{Original mAs}}{\text{New mAs}} = \frac{\text{Original SFD}^2}{\text{New SFD}^2}$$

where SFD = source-film distance and  
mAs = milliamperere/seconds



$$\text{Inverse Square Law: } I = \frac{1}{d^2}$$

**Figure 2.10 Inverse Square Law.** Diagram showing how the x-ray intensity is altered by changing the source-film distance. Increasing the distance by two times decreases the intensity by four times ( $1/d^2$ ).

Many times the kVp and mA will be fixed in dentistry, and the practitioner may want to change from a short-BID to a long-BID technique, perhaps from 8-inch SFD to 16-inch SFD. This is doubling the SFD distance, so the exposure time will have to be increased by the square of the distance or by a factor of 4 to maintain the same density (blackness) on the film. The intensity of the beam at 16-inch SFD would be one-fourth the intensity as that at 8-inch SFD. Because the photons spread out as they move away from the source, the SFD is an important factor in determining the intensity of the beam.

By now, the astute reader would be able to figure out that if the original BID length were 16 inches and the exposure time was 1 second and now an 8-inch BID was going to be used, the exposure time would be cut down to 1/4 second to maintain the same intensity of the radiation beam.

### INTERACTION OF X-RAYS WITH MATTER

When x-ray photons arrive at the patient with energies produced by dental x-ray machines, three things can happen:

1. Some x-ray photons are merely scattered,
2. Some x-ray photons are absorbed completely in the patient, and
3. Some x-ray photons can pass through the patient without interacting with the tissue atoms.

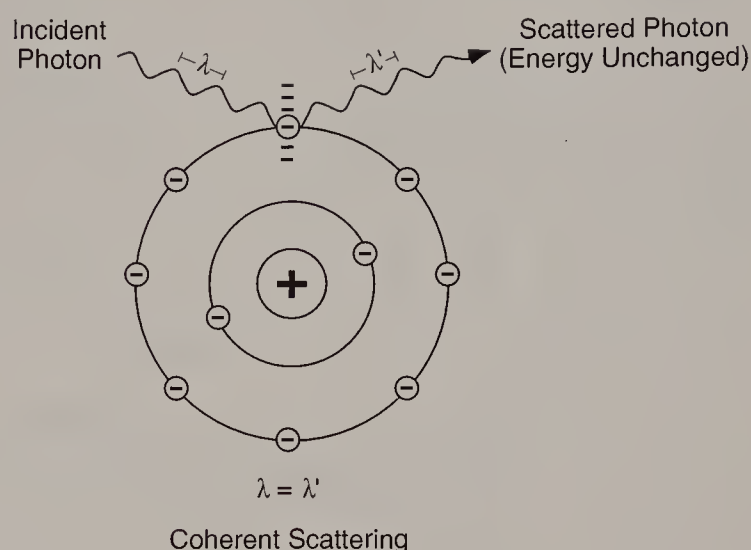
When the x-ray photons are transmitted through the patient without an interaction, they produce densities (blackness) on the film. The photons that are absorbed are completely or partially removed from the x-ray beam and produce opacities (whites or grays) in the film. When the x-rays are scattered, they are deflected in all directions and therefore contribute no useful information to the film. Scattered radiation that reaches the film is called film fog (unwanted darkness) and can completely obscure the film image (Fig. 2-11).

## SCATTERED RADIATION

When x-rays (called incident photons or primary photons) strike any form of matter, such as body tissue, scattered x-ray photons are produced that usually possess longer wavelengths than the primary radiation. Because scattered radiation is unfocused and may come from any direction, its action on the film may cover the entire image with a veil or fog unless it is controlled. Radiographically, this fog tends to make the visualization of the image details more difficult. Almost all scatter radiation in dental radiography comes from Compton scattering.

### Unmodified (Coherent) Scattering

Coherent or Thompson scattering is when low-energy x-rays (below 10 keV) interact with matter and the x-rays undergo a change in direction without a change in wavelength. For this reason the name **unmodified** is sometimes used. In this type of interaction between x-rays and matter, no energy is transferred and no ionization occurs. Its only effect is to change the direction of the incident radiation (Fig. 2-12). Most coherent scattering is in a forward direction. It is of little importance in dental radiography because it primarily involves low-energy x-rays that contribute little to the radiograph. However, there is some coherent scattering throughout all the ranges of energies in the beam. At 70 kVp, perhaps less than 5% of the radiation undergoes coherent scattering, which contributes

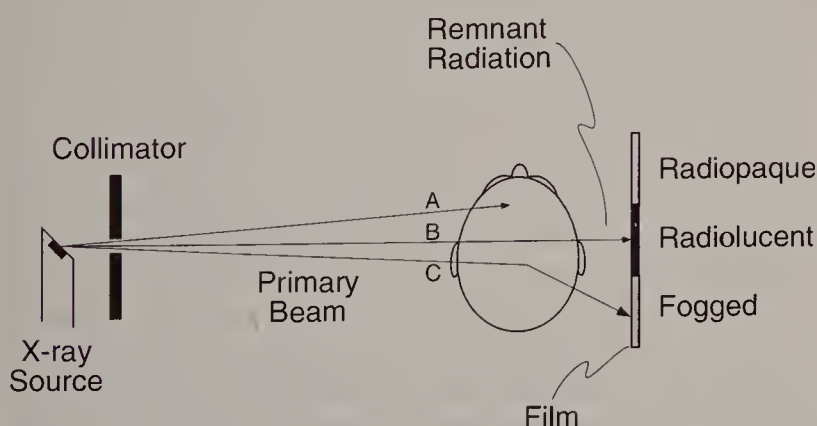


**Figure 2.12 Unmodified (Coherent or Thompson) Scattering.** An incident photon (usually of low energy) interacts with one of the outermost electrons. They are essentially free because they are so loosely bound. The electron starts to vibrate at the frequency of the incident photon. Because the electron is a charged particle, it emits radiation with the same frequency of the incident radiation and the atom returns to its stable state again.

only slightly to film fog. It is too small to be of any importance in diagnostic radiology.

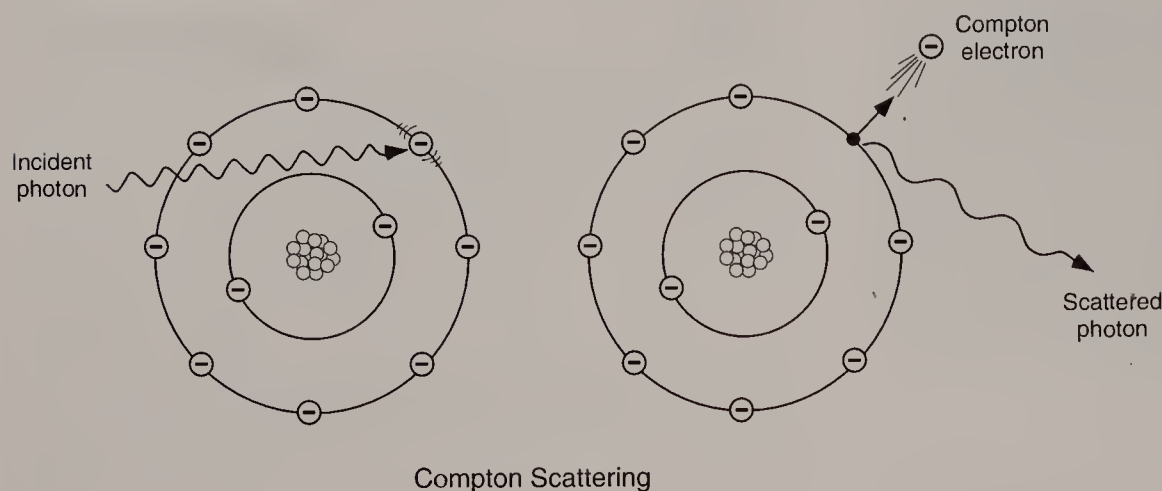
### Compton (Incoherent) Scattering

An x-ray with relatively moderate to high energy strikes a loosely bound (free) outer shell electron, ejecting it from its orbit. An electron can be considered free when its binding energy is a great deal less than the incident photon. This reaction ionizes the atom, producing an ion pair—a positive atom and a negative electron—called a **Compton electron** or **recoil electron**. This interaction was first described by A.H. Compton in 1923 (Fig. 2-13). The incident (or primary) x-ray photon is scattered in all directions (including backward) and retains most of its original energy. Both the scattered x-ray photon and the Compton electron may have sufficient energy to undergo many more ionizing interactions before losing all their energy. The original Compton electron will drop into an atomic shell vacant hole created previously by another ionization event and come to rest. Two factors determine the amount of energy the x-ray photon retains: (1) its energy and (2) its angle of deflection off the Compton electron. At narrow angles of deflection, scattered photons retain almost all their original energy. This creates a serious problem in diagnostic radiology, because photons that are scattered at narrow angles have an excellent chance of reaching an x-ray film and producing fog. These scattered photons are difficult to remove from the beam by filters because they are so energetic. Because we cannot remove these photons from the beam, they will also cause film fog. At the higher diagnostic energies (60 to 100 keV), Compton scattering is the most common interaction between x-rays and body tissues and is responsible for al-



**Figure 2.11 Interaction of X-Rays With Matter.** (A) X-rays absorbed completely by photoelectric effect. (B) X-rays transmitted to film without interaction. (C) X-rays scattered by Compton interaction.





**Figure 2.13 Compton Scattering.** Compton scattering results in ionization of the atom and change in direction and reduction in energy of the incident x-ray photon.

most all the scatter radiation. In dental radiology, approximately 62% of the x-ray photons undergo Compton scattering. This can be minimized by using rectangular collimation and shorter exposure times afforded by higher mAs, higher kVps, and faster film speed.

### X-RAY BEAM ABSORPTION

X-rays are absorbed in materials and tissues by **photoelectric absorption**. This occurs when an incident x-ray photon, with a little more energy than the binding energy of a K shell electron of the material or tissue, encounters the electron and ejects it from the orbit. The x-ray photon disappears completely, giving up all its energy to the electron. The ejected electron, called the **photoelectron**, flies into space and is absorbed by another atom (Fig. 2-14).

The extent that x-rays are absorbed by photoelectron absorption depends on four factors:

1. The wavelength or photon energy of the x-rays (kVp).
2. Thickness of the material.
3. Density (mass/unit volume) of the material.
4. Atomic number of the material.

The wavelength or photon x-ray energy of the x-radiation is indirectly determined by the kilovoltage applied to the x-ray tube. The higher kilovoltages produce more shorter-wavelength x-rays and they penetrate material more readily. The relation of x-ray absorption to thickness is simple, because obviously a thicker piece of any material absorbs more x-radiation than a thinner piece of the same material. Density (wt/vol) of a material can be defined as the compactness of a material and is numerically equal to its specific gravity. The effect is similar to that seen for thickness. For instance, an inch of water ( $H_2O$ ) will absorb more x-rays than an inch of ice ( $H_2O$ ). The atomic number (number of protons in nucleus) of an object usually has far more effect on x-ray absorption than thickness or density. The higher the atomic number

of the material, the greater the absorption factor of the material. For example, a sheet of aluminum ( $Z = 13$ ), being of lower atomic number than copper ( $Z = 29$ ) or lead ( $Z = 82$ ), absorbs a lesser amount of x-rays than does a sheet of copper or lead of the same area and weight.

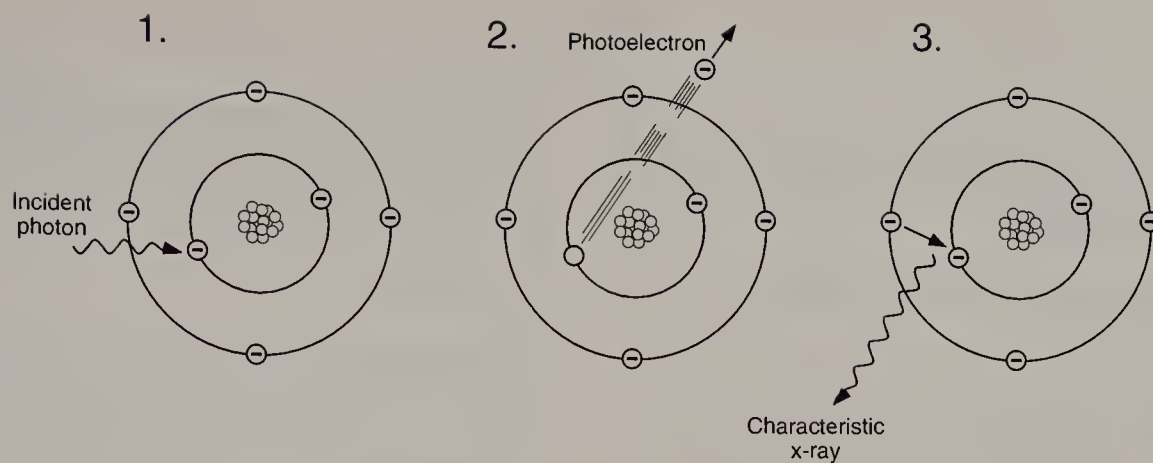
### X-RAYS PASSING THROUGH A BODY TISSUE WITHOUT INTERACTING WITH TISSUE ATOMS

In dental bitewing x-ray examination (see Chapter 5), approximately 9% of the primary photons will pass through the tissues of the jaw without interacting with tissue atoms. The remnant radiation collected on the film emulsion from these photons will produce radiolucent, or darker density areas, on radiographs after the films have been chemically processed.

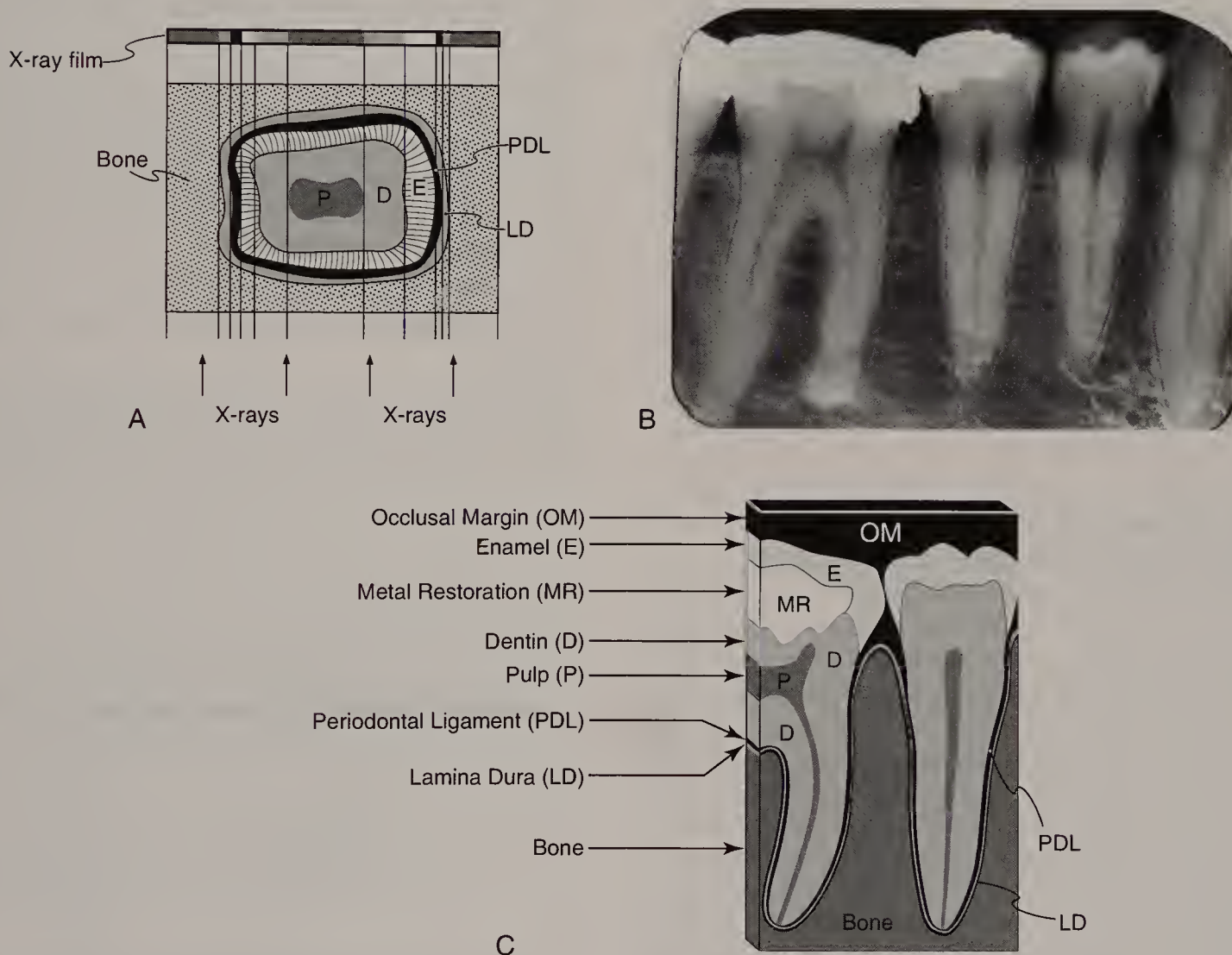
### ATTENUATION OF X-RAY BEAM IN DENTISTRY

**Attenuation** is the reduction in the intensity of an x-ray beam as it transverses dental tissues by either the absorption (photoelectric) or deflection (Compton scattering) of the photons from the x-ray beam. To further simplify our discussion, we can disregard the attenuation of scatter radiation resulting from Compton interactions. Once a photon is deflected from its original course, it will be considered completely attenuated<sup>1</sup> or absorbed; that is, completely removed from the beam, because these scatter reactions add nothing to the diagnostic information of the radiographic image. X-rays that undergo photoelectric absorption produce diagnostic information in a negative sense. Because these x-rays do not reach the film, they represent structures that have high absorption characteristics and result in clear, white areas on the film. These white or bright areas—which usually represent cortical bone, enamel, or metallic restorations—are called **radiopaque** structures or materials. There are other x-rays that penetrate the jaws and are transmitted with no interaction





**Figure 2.14 Photoelectric Absorption and Characteristic Radiation.** (1) When an incoming x-ray photon with the right amount of energy collides with an inner K shell electron of an atom of tissue (e.g., a calcium atom in bone), the K shell electron is ejected from its orbit. (2) The incoming x-ray photon disappears completely, giving up all its energy to the ejected electron, called a photoelectron. The photoelectron flies into space and is absorbed by another calcium atom. The process of absorbing x-ray photons by matter is called photoelectric absorption. The original calcium atom is now in an excited state. (3) An electron from the outer L shell jumps into the K shell vacancy, giving off K-characteristic radiation of calcium. (The atom of calcium is now a positive ion because it lacks an electron and will become stable again when it attracts another electron).



**Figure 2.15 Differential Absorption.** (A) Cross-section of tooth. The enamel and lamina dura completely absorb radiation, and dentin partially absorbs radiation. Pulp and periodontal ligament transmit most of the radiation because those tissues absorb very little radiation. D, dentin; E, enamel; LD, lamina dura; P, pulp; PDL, periodontal ligament space. (B) Radiograph of mandibular premolar region. Pulp and periodontal ligament spaces are black (radiolucent); lamina dura and enamel are white (radiopaque). Dentin is gray. (C) A diagrammatic representation of the density differences in the molar and premolar teeth, as seen in radiograph.

whatsoever. They result in dark areas on the radiograph. These areas are called **radiolucent** because structures such as soft tissue, pulp, and periodontal ligament are easily penetrated by the x-radiation.

### Differential Absorption of the X-Ray Beam in Dentistry

In considering the use of x-rays in dentistry, one must understand that the human jaws are complex structures made up of tissues, not only differing in thicknesses and density, but of tissues and materials with different atomic numbers. These structures absorb x-rays to different degrees (**differential absorption**). Metallic restorations, such as silver alloy (amalgam) and gold, absorb more x-rays than enamel; enamel absorbs more than dentin; dentin more than cementum; cementum more than cortical bone; cortical bone more than cancellous bone; and cancellous bone more than soft tissue, such as the periodontal ligament, the pulp, gingiva, and oral soft tissues. Teeth and bone contain large amounts of calcium and **phosphorus**, with atomic numbers of 20 and 15, respectively; the atomic number of muscle is approximately 7.4. Diseased structures often absorb x-rays differently from normal structures. Even the age of the patient may have a bearing on absorption. For example, in the elderly, the bones of the jaws in most instances have less calcium content and hence there is less x-ray absorption.

In review, the variations in absorption (differential absorption) of the jaws depend for the most part on the thickness, atomic number, and densities of the tissues of the jaws and, of course, the quality (kVp) of the x-ray beam used (Fig. 2-15).

## RECORDING THE LATENT IMAGE AND MAKING IT VISIBLE

After interaction of the x-ray beam with the anatomical structures of the patient, the exit beam or beam of **remnant** x-rays consists of attenuated x-ray photons corresponding to the pattern of thicknesses, atomic numbers, and densities of the tissues and materials through which the beam has passed. We cannot make direct use of this information (an aerial image) unless we transfer it to a recording medium suitable to viewing by the eye. The most important method used to decode this information carried by the attenuated beam is by means of photographic film that can be exposed in one of two ways. First, the film may be exposed by the direct action of the remnant x-rays, as is done in intraoral radiography. Second, the energy of the x-ray beam may be converted into light by intensifying screens, and this emitted light, in turn, is used to expose the film. This latter method is used in extraoral radiography (panoramic and cephalometric films). The image formed by the exit or remnant radiation ex-

posing the film by either method is called the **latent image**. Chemically processing the exposed film makes the latent image visible and permanent.

### X-RAY FILM

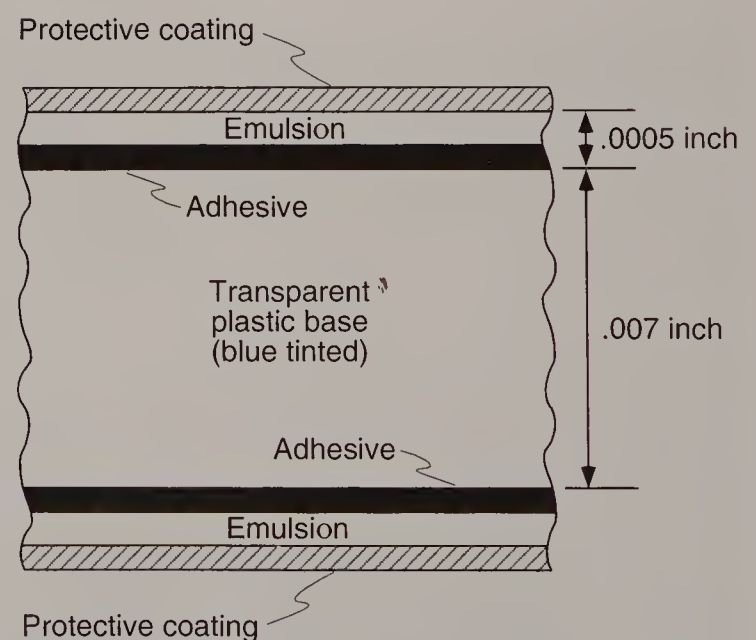
Radiographic film is composed of a radiation-sensitive or photographically active emulsion, usually coated on both sides of a transparent sheet of plastic called the base. The layers of the emulsion are attached to the base by a thin layer of adhesive. The delicate emulsions are covered by a supercoating of gelatin, which protects the emulsion from rough handling before exposure, scratching, pressure, and contamination during processing. The emulsion is applied to both sides of the base (called double-emulsion films) to provide increased speed to the film (Fig. 2-16). This increased speed also means less radiation for the patient because of the shorter exposure times (less radiation) and fewer retakes due to movement during the exposure.

#### Base

The base is composed of a thin clear plastic, usually either of triacetate or polyester. A blue tint is added, providing a film that is easier to view and prevents eyestrain. Polyester is more resistant to warping with age and stronger than triacetate. Therefore, polyester bases can be made thinner than triacetate bases but are just as strong. Polyester is the current film base of choice used by almost all manufacturers of radiographic film.

#### Emulsion

The emulsion consists of a homogeneous mixture of gelatin and silver halide crystals. The gelatin is similar to that used in food preparation but is of much higher qual-



**Figure 2.16 Radiographic Film.** Cross-section of x-ray film showing its components.



ity. It is made from cattle bone. The gelatin is clear so that it will transmit light, and is sufficiently porous to allow the processing chemicals (**developer** and **fixer**) to penetrate it and gain access to the silver halide crystals rapidly without destroying its strength or performance.

### Silver Halide

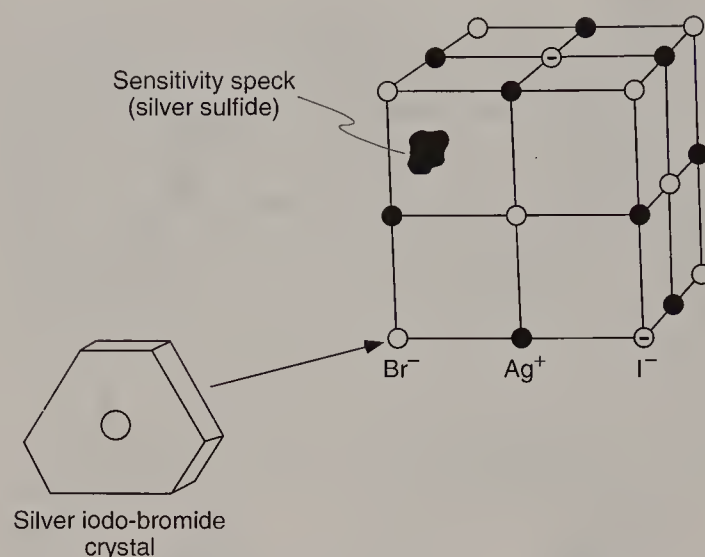
The active ingredient of the radiographic emulsion is the **silver halide** or silver iodo-bromide crystal. In the typical emulsion, 90 to 99% of the silver halide is silver bromide (AgBr) and approximately 1 to 10% is silver iodide (AgI). The presence of AgI gives the emulsion a higher sensitivity than a pure AgBr emulsion. These atoms have relatively high atomic numbers (I = 53, Br = 35, Ag = 47) compared with the gelatin emulsion and polyester base (atomic numbers of both are about 7). The interaction of the x-ray photons or light photons with these atoms results in the formation of a latent image that cannot be detected by the naked eye. The student will have noted that x-ray film can be exposed by both x-rays and light. When the exposed film is processed in a solution called the developer, a chemical reaction takes place whereby the exposed silver iodo-bromide crystals are reduced to tiny masses of black metallic silver, leaving the unexposed crystals essentially unaffected. The metallic silver, suspended in the gelatin, produces the visible image on the radiograph.

### FORMATION OF THE LATENT IMAGE

The **latent image** is defined as the invisible image that is produced in the film emulsion by light or x-rays and is converted into a visible image on development (processing). The silver iodo-bromide grain or crystal is flat and triangular, and the arrangement of the atoms in the crystal is cubical. The network or lattice of an individual silver iodo-bromide crystal contains silver, bromine, and iodine ions held together by **electrovalence forces** (ionic bond) (Fig. 2-17). When an x-ray photon interacts with the Ag, Br, and I atoms of the silver iodo-bromide crystal of the emulsion, free photoelectrons are released. These free photoelectrons, while traversing the crystal, will have sufficient energy to dislodge additional electrons from other atoms of the crystal lattice. Therefore, as a result of one x-ray photon interaction, a great number of electrons are released and drift about inside the crystal.

### SENSITIVITY SPECK OR TRAP

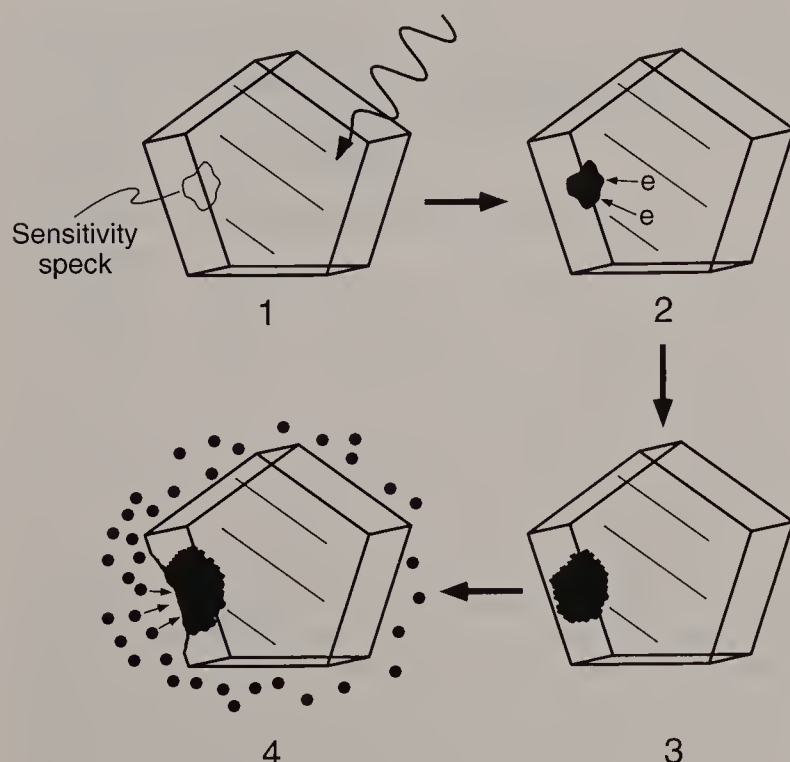
Eventually, these released electrons are caught by a **sensitivity speck or trap** in the crystal. Such traps can be imperfections in the crystal structure or chemicals (silver sulfide) in or on the grain (crystal) that may have been introduced during the emulsion-making process by the



**Figure 2.17 Silver Iodo-Bromide (AgIBr) Crystal (Grain) and Lattice (Network).** The AgIBr crystal is triangular, but lattice arrangement of atoms in the crystal is cubical. Lattice diagram of AgIBr crystal is shown on the right. The straight lines joining the circles represent the electrovalence forces holding the ions together in the crystal. **Sensitivity Speck (Silver Sulfide) or Trap:** The sensitivity speck (silver sulfide) is an imperfection that is usually a result of a sulfur-containing compound added to the emulsion by the manufacturer. This makes the crystal very sensitive to x-ray and light photons.

manufacturer (Fig. 2-17). In any case, the effect (sensitivity trap) is to hold the negatively charged electrons at least temporarily in one place. Silver ions ( $\text{Ag}^+$ ), which exist naturally in the crystals, can be thought of as positive ions because they are missing an electron. Positively charged silver ions tend to migrate toward the negatively charged trapped photoelectrons at the sensitivity speck, and the positively charged silver ion in turn attracts another negatively charged photoelectron. This process results in the formation of an atom of metallic silver at the trap sight. Because of its effect on the crystal structure, this new silver atom makes the trap still more effective in trapping additional electrons. In turn, these additional electrons attract more ions, forming more silver atoms. When this cluster becomes sufficiently large, it becomes a “development center” on the crystal that is not observable, even microscopically. This unobservable image on the exposed film composed of radiation- or light-activated **silver halide** crystals and nonactivated silver halide crystals is called the latent image. The development of the exposed film by the developer solution starts at the development center (sensitivity speck) of the radiation or light-activated silver halide crystal. The silver there acts as a catalyst, spreading out from it until the whole grain becomes an irregular mass of black silver producing gray to black areas on the film. Under normal development, the grains that have not absorbed sufficient light or x-ray photons to form development centers will develop into clear, transparent areas on the film (Fig. 2-18).





**Figure 2.18 Production of Latent Image.** (1) An x-ray or light photon interacts with a silver iodo-bromide ( $\text{AgI/Br}$ ) crystal to allow an electron to escape from a  $\text{Br}^-$  or  $\text{I}^-$  ion. The  $\text{Br}^-$  or  $\text{I}^-$  ion, which becomes neutral by loss of an electron, migrates from the crystal and is taken up by the gelatin of the emulsion. (This leaves a remaining  $\text{Ag}^+$  ion.) (2) The free electron is captured and temporarily held at the sensitivity speck in the crystal. (3) The trapped electron attracts the remaining  $\text{Ag}^+$  ion to the sensitivity speck, forming a neutral  $\text{Ag}$  atom. (4) The first  $\text{Ag}$  atom acts as an electron trap for a second  $\text{Ag}^+$  ion. The repeated attraction and the neutralizing of silver ions builds up a clump of silver atoms, called the latent image center in the crystal, which must be present before the developing process can cause visual amounts of metallic  $\text{Ag}$  to be deposited.

## TYPES OF X-RAY FILM

X-ray films used in dentistry can be of the direct exposure or the indirect exposure type. Extraoral film is of the screen or indirect exposure type film. Dental x-ray film (intraoral type) is a direct exposure film because the film is more sensitive to exposure by x-ray photons than by light photons. The only current use of direct exposure film is for intraoral use where only small areas are exposed and a high definition radiographic image is desired.

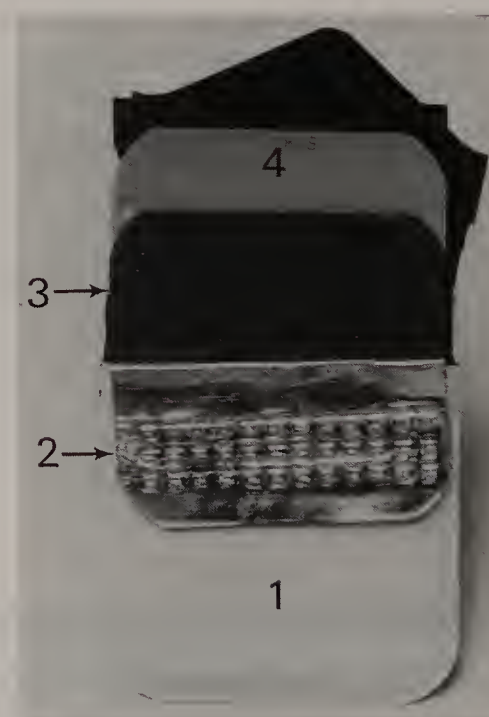
### EXTRAORAL FILM

In the indirect exposure type film (screen film), the energy of the x-ray beam is converted into light by intensifying screens (the film is sandwiched between two screens), and this light is used to expose photographic type film. Extraoral (screen) indirect exposure film is used in dentistry for panoramic, cephalometric, skull, and tomographic x-

ray techniques. Extraoral or screen films (indirect exposure) are used with intensifying screens because they decrease the x-ray dose to the patient and still result in a properly exposed x-ray film. Screen-film combinations are discussed in Chapter 11.

### DENTAL INTRAORAL X-RAY FILM (DIRECT EXPOSURE FILM)

Dental x-ray film is individually wrapped in packets of white, pebbled, moisture-resistant paper or polyvinyl wrap. Within this, the film is further protected by being wrapped in thin black paper and backed by a thin sheet of lead foil. The lead foil placed in back of the film first protects it from radiation that may be back-scattered by the tissues of the oral cavity during exposure. Second, it absorbs some of the radiation remaining after the x-ray beam exposes and passes through the film. Third, the lead foil contributes to the rigidity of the packet. The film manufacturer places various geometric patterns in the lead foil backing that will appear in the radiographic image if the back of the film packet is mistakenly placed toward the x-ray tube during exposure (Fig. 2-19). All dental films currently manufactured are double-emulsion coated films. When the emulsion is coated on both sides of the base it is called a double-emulsion film and this increases the speed of the film. This increased speed means less radiation for both the patient and the operator. To identify the "tube side" of the



**Figure 2.19 Dental X-Ray Film Packet.** (1) White, moisture-resistant outer covering, (2) sheet of lead foil to protect the film from radiation backscatter, (3) black interleaving paper, and (4) double-emulsion film.

film, a raised dot is placed in the corner of the film. The raised portion of the dot is always toward the x-ray tube, and the depressed side of the dot is toward the tongue. An embossed circle on the printed label of the film packet locates the position of the raised dot on the x-ray film. This raised dot is necessary to distinguish films taken on the right and left sides of the patient.

### Types of Intraoral Film (Fig. 2-20)

There are three types of intraoral film: periapical film, bitewing film, and occlusal film.

**Periapical Film.** As the name suggests, the objective of using periapical film is to show the apex of the tooth and surrounding bone, but it should also show the entire crown. There are three sizes of periapical film: the No. 0 child film, the No. 1 (narrow) adult anterior film, and the No. 2 (standard) adult film for posterior periapicals and bitewings.

**Bitewing Film.** The bitewing film shows the crowns of teeth of both arches and their interproximal alveolar bone crests on one film. The bitewing packet has a wing, or tab, attached or placed on the side of the film that the patient bites. A bite-tab attached to the No. 2 periapical film converts it to a bitewing film. Alternately, an instrument such as the XCP bitewing film-holder can be used. In 9- to 12-

year-old children, one No. 2 standard film on each side of the arch is sufficient; in adolescents and adults, two No. 2 periapical films on each side of the arch are usually necessary. A bitewing film can be made for 5- to 9-year-old children by placing a tab on a No. 1 narrow film; one for children younger than 5 years of age can be made by placing a tab on a No. 0 periapical film packet.

**Occlusal Film.** The occlusal film is considerably larger than the periapical film and is so named because the patient bites on the entire film between the occlusal surfaces of the upper and lower teeth. The objective of the occlusal film is to show large segments of the maxillary and mandibular arches, parts of the maxilla, and the floor of the mouth.

### Size and Speed of Intraoral Film

**Size of Film.** Dental intraoral film sizes and speed have been standardized by the American Dental Association. The standard sizes of intraoral film are shown in Table 2-1.

The comparative sizes of the intraoral films used in dentistry are shown in Figure 2-20 and Table 2-1.

**Speed of Film.** The efficiency with which a film responds to x-ray exposure is known as **film sensitivity** or, more commonly, **speed**. X-ray films that require very little exposure to x-radiation to produce a radiograph are said to be very sensitive, to be very fast, or to possess high speed. Thus, exposure time and film speed vary inversely.



**Figure 2.20 Sizes of Intraoral Film.** Size No. 0, children's film; Size No. 1, narrow anterior periapical film; Size No. 2, adult regular film used for posterior periapicals and for posterior bitewings; size 4, occlusal film. Size No. 3 is no longer in common use.

**TABLE 2-1. Sizes of Intraoral Film**

| Type-Size Number <sup>a</sup> | Dimensions |                |
|-------------------------------|------------|----------------|
|                               | mm         | in             |
| Periapical                    |            |                |
| 1.00                          | 21 × 32    | 4/5 × 1 1/4    |
| 1.0                           | 22 × 35    | 7/8 × 1 3/8    |
| 1.1                           | 24 × 40    | 15/16 × 1 9/16 |
| 1.2                           | 31 × 41    | 1 1/4 × 1 5/8  |
| Bitewing (interproximal)      |            |                |
| 2.00                          | 21 × 32    | 4/5 × 1 1/4    |
| 2.0                           | 22 × 35    | 7/8 × 1 3/8    |
| 2.1                           | 24 × 40    | 15/16 × 1 9/16 |
| 2.2                           | 31 × 41    | 1 1/4 × 1 5/8  |
| 2.3                           | 27 × 54    | 1 1/16 × 2     |
| Occlusal                      |            |                |
| 3.4                           | 57 × 76    | 2 1/4 × 3      |

<sup>a</sup>The digit at the left of the decimal point represents the use of the film (periapical, bitewing, or occlusal). The digits on the right indicate the size of the film (00, 0, 1, 2, 3, or 4).



TABLE 2-2. Speed Classification of Intraoral Film

|   |         | Speed Range in<br>Reciprocal Roentgens <sup>b</sup> |
|---|---------|-----------------------------------------------------|
| A | Slowest | 1.5–3.0                                             |
| B |         | 3.0–6.0                                             |
| C |         | 6.0–12.0                                            |
| D |         | 12.0–24.0                                           |
| E |         | 24.0–48.0                                           |
| F | Fastest | 48.0–96.0                                           |

<sup>b</sup>A roentgen is a measure of radiation exposure or quantity. A reciprocal roentgen is 1/R or 1 over the amount of exposure in roentgens to achieve a certain density (blackness) on a film.

tually measured by determining the amount of x-radiation necessary to produce a certain density (or “blackness”) in the emulsion that has been processed in a rigidly controlled manner. For example, if film E speed requires approximately half as much x-radiation as film D speed to produce the same blackness in the emulsion, film E speed is said to be twice as fast as film D speed (Table 2-3).

T-Grain Film and Film Speed

In 1994, Eastman Kodak Company (Rochester, NY) introduced an E+ speed (EKTASPEED Plus) film, and in 2000 introduced an even faster F speed (INSIGHT) film (Fig. 2-22). Both of these films utilize a patented T-grain emulsion, which uses a flat or tabular-shaped grain in the emulsion. This provides a greater surface area due to the tabular shape, compared with the earlier rounded emulsion grains.

The Kodak Company markets three speeds of film: Ko-

Film lets dentists reduce radiation dosage to the lowest possible exposure of any intraoral film on the market today.

By switching to INSIGHT film, dentists currently using D speed film, such as Kodak Ultra-speed Intraoral Dental Film, can lower their radiation exposure settings by as much as 60%. Dentists using an E speed film, such as Kodak EKTASPEED Plus Intraoral Dental Film, can lower their radiation exposures by as much as 20% (Fig. 2-23 and Table 2-3).

In other words, the faster the film, the less radiation exposure needed. Intraoral film speeds have been standardized on an alphabetical basis according to a speed range recorded in “reciprocal roentgens” and are shown in Table 2-2.

Currently, manufacturers of dental film indicate the film speed on the outside of the film box in an alphabetical classification with the expiration date (Fig. 2-21). Also, the back side of the film packet is color coded to indicate film speed. The three film speeds currently available are D, E, and F speed films. X-ray films are compared by determining their relative sensitivity. This is ac-

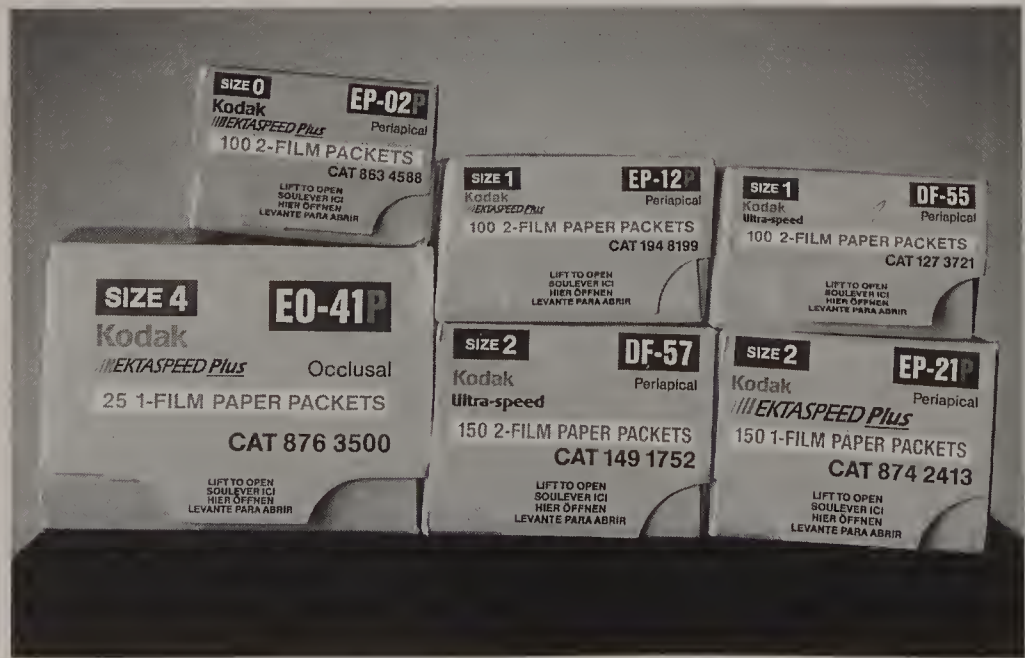


Figure 2.21 Film Box Labels. Kodak EKTASPEED and Ultra-speed Dental Films. Speed and size of film are located on film box.



**TABLE 2-3. Exposure Guidelines for Kodak Intraoral Dental Film**

| Regions    | INSIGHT<br>(sec) <sup>a,b</sup> | Ultra-speed<br>(sec) <sup>a,b</sup> | EKTASPEED<br>Plus (sec) <sup>a,b</sup> |
|------------|---------------------------------|-------------------------------------|----------------------------------------|
| Maxillary  |                                 |                                     |                                        |
| Anterior   | 0.16                            | 0.40                                | 0.20                                   |
| Premolar   | 0.16                            | 0.40                                | 0.20                                   |
| Molar      | 0.20                            | 0.50                                | 0.25                                   |
| Mandibular |                                 |                                     |                                        |
| Anterior   | 0.12                            | 0.32                                | 0.16                                   |
| Premolar   | 0.16                            | 0.40                                | 0.20                                   |
| Molar      | 0.16                            | 0.40                                | 0.20                                   |
| Bitewing   | 0.16                            | 0.40                                | 0.20                                   |

**Adjusting Exposure Times**

To adjust exposure times for kVp settings other than 70, multiply the current exposure time by the appropriate exposure factor multiplier (see below). This will give you the correct exposure time at the new kVp. See the following for examples.

|                            |      |      |     |      |      |      |      |
|----------------------------|------|------|-----|------|------|------|------|
| New kVp                    | 60   | 65   | 70  | 75   | 80   | 85   | 90   |
| Old kVp                    | 70   | 70   | 70  | 70   | 70   | 70   | 70   |
| Old time (sec)             | 0.3  | 0.3  | 0.3 | 0.3  | 0.3  | 0.3  | 0.3  |
| Exposure factor multiplier | 1.47 | 1.2  | 1.0 | 0.84 | 0.72 | 0.62 | 0.53 |
| New time (sec)             | 0.44 | 0.36 | 0.3 | 0.25 | 0.22 | 0.19 | 0.16 |

**Adjusting kVp Settings**

X-ray intensity varies as the square of the kVp. To maintain mean density while changing kVp, the following rules of thumb can be used:

To reduce contrast, reduce exposure time by a factor of 2 for every 15-kV increase.

To increase contrast, increase exposure by a factor of 2 for every 15-kV reduction.

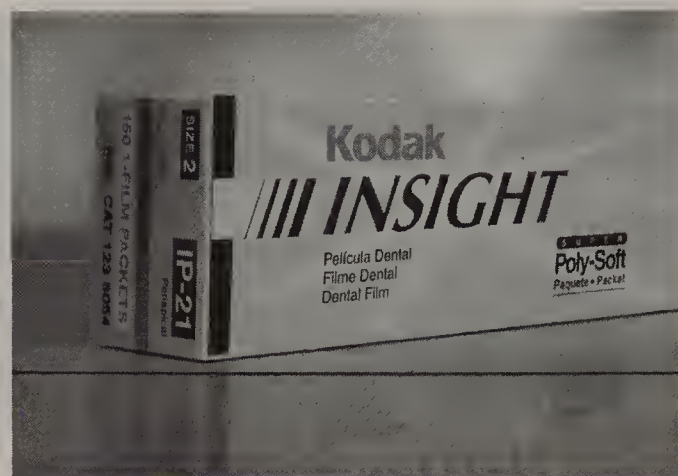
The above guidelines were developed following recommended time-temperature processing with Kodak Automated Processing Chemicals.

<sup>a</sup>Exposure factors: kVp = 70, mA = 8, FSFD = 16 inches.

<sup>b</sup>For large patients, increase time by approximately 25%. For children and small and/or edentulous patients, decrease time by approximately 30%.

**Film Emulsion Sensitivity**

The film emulsion is sensitive to a number of conditions. Some of these conditions are heat, light, x-rays, fumes, bending, and pressure. The high-speed emulsions are even more sensitive to these conditions. This means that more care and precision are needed when handling, exposing, unwrapping, and processing these films.



Available in most common sizes.

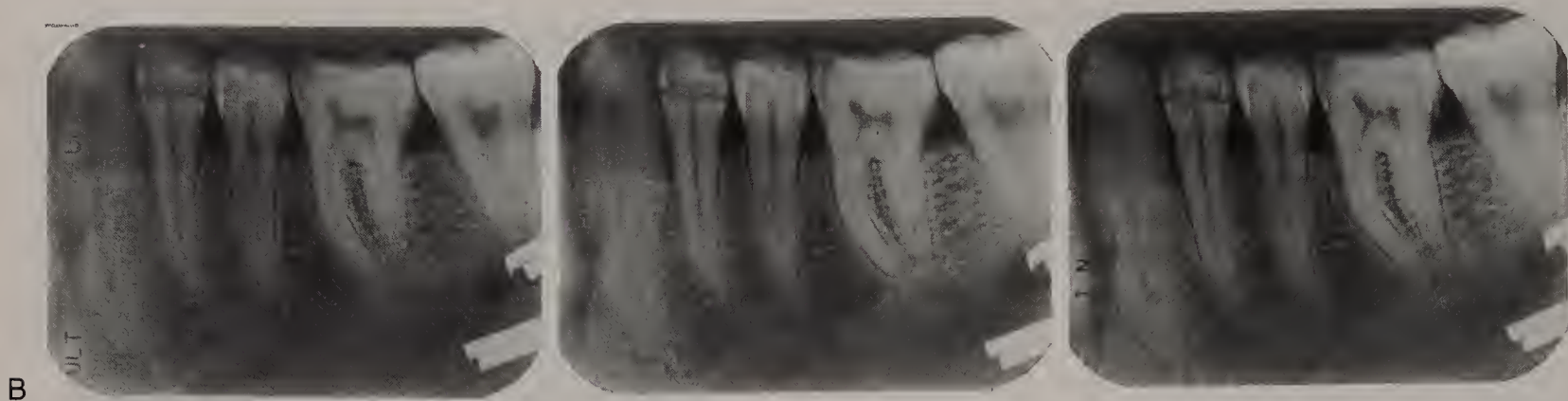
**Film Storage**

All unopened film should be stored in a cool place, such as a refrigerator. It should not be stored beyond the expiration date; thus, ordering should be based on use. Open intraoral film should be stored outside the x-ray room away from any radiation or in the x-ray room in special lead-lined containers that protect the film. Opened boxes of screen film should be stored in a light-tight area in the vicinity of where cassettes are loaded and unloaded.



A

**Figure 2.23 Embossed Film Markings.** (A) KS: older "D" or Ultra-speed film; ULT: newer "D" or Ultra-speed film; PLS: E+ or EKTASPEED Plus film; IN: "F" or INSIGHT film. (continued)



**Figure 2.23 Embossed Film Markings. (Continued)** (B) From left to right note the ULT, PLS and IN speed indicators on left edges of images. Image quality is similar in each instance.

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 2.1. DIFFERENTIAL ABSORPTION AND RECORDING OF IMAGES

#### Materials and Equipment Needed

1. Wood pencil with attached eraser.
2. Five No. 2 intraoral films.
3. X-ray machine(s).
4. X-ray processing facility.
5. Ball-point pen.
6. X-ray mount and special pencil.

#### Instructions

**Step 1:** Turn on the x-ray machine.

**Step 2:** Set the exposure time at about 1/4 second (15 impulses) if you have a short (8-inch) BID or about 1 second (60 impulses) if you have a long BID.

Determine BID length by measuring from the focal spot mark (dot or symbol) on the tube-head to the tip of the BID. Do not just measure the length at the BID itself.

**Step 3:** If the machine has a mA setting, set this at about 7 or 10. If the machine has a kVp setting, set this at about 65 or 70.

**Step 4:** (Note: Exposure times, mA, and kVp settings may require some further adjustment. Check with the instructor.) Obtain the No. 2 intraoral films and a wooden pencil with a fixed eraser on one end.

**Step 5:** With a ball-point pen, label the front of one film as No. 1 and write your first name on it. Place this film front side up on the counter top and position the BID tip directly over the film so that the BID tip touches the counter top as it covers the film.

Expose this film and put it in your pocket.

**Step 6:** Place a second film front side up on the counter top. Place the eraser end of the pencil on top of the film.

Expose this film and put it in your pocket.

**Step 7:** Place a third film back or tab side up on the counter top. Place the eraser end of the pencil on top of the film.

Expose this film and put it in your pocket.

**Step 8:** Take a fourth film and unwrap and remove the film; hold the film between your fingers for a few seconds and place this in your pocket. While unwrapping, observe and identify the different parts of the film packet including the outer plastic wrapping, the inner paper wrap, the film itself, and the lead foil.

Place the fifth film, which has had nothing done to it, in your pocket.

**Step 9:** Now enter the darkroom and place the unwrapped film in the processor. Unwrap and process the other four films. If manual processing only is available, the instructor will demonstrate this.

**Step 10:** Obtain an x-ray mount with at least five No. 2 film slots or a single sheet of clear acetate or plastic.

Label five areas as follows:

- a. Exposed to x-rays and name.
- b. Pencil tip image front side up.
- c. Pencil tip image back side up.
- d. Exposed to light.
- e. Unexposed.

**Step 11:** After the films are processed properly, match the five films with their correct spot on the mount.



## CASE-BASED QUESTIONS FOR LABORATORY EXERCISE

Answer the following questions by inserting the correct letter choice(s) (a, b, c, d, or e from Step 10). Each letter may be used more than once and there may be more than one correct answer.

1. Which film(s) demonstrate(s) the differential absorption of x-rays by matter?
2. Which film(s) demonstrate(s) imaging of radiolucent material(s)?
3. Which film(s) demonstrate(s) imaging of radiopaque material(s)?
4. Which film(s) demonstrate(s) exposure of all the silver halide crystals?
5. Which film(s) demonstrate(s) exposure of no silver halide crystals?

## CASE-BASED PROBLEM-SOLVING

You have just taken a set of four bitewing films. Only one image (A) turns out perfect. The others appeared as follows: no image, film looks like a clear piece of plastic (image B); an image darker than A with an apparent extra set of teeth (image C); and an image lighter than A with the teeth partially obscured by a visible geometric pattern (image D). What went wrong in the taking of images B, C, and D?

## REVIEW QUESTIONS

1. The film layer that contains the silver halide crystals is known as the:
  - A. Base.
  - B. Protective layer.
  - C. Top coat.
  - D. Emulsion.
2. Films that are all black and white with very few grays are said to be:
  - A. Very dense.
  - B. High contrast.
  - C. Fogged.
  - D. Low contrast.
3. A latent image is:
  - A. An image that is very late in its formation.
  - B. A very light radiographic image.
  - C. Produced after exposure but before developing.
  - D. A very dark radiographic image.
4. A piece of lead foil is placed in intraoral film pack-

ets. Which of the following is true concerning the lead foil?

- A. It filters out back-scattered radiation, as it is in front of the film.
  - B. It contributes to the rigidity of the packet.
  - C. It may produce a pattern on properly exposed and properly processed film.
  - D. It is contained in all sizes of intraoral film packets with the exception of occlusal film.
5. The film used with intensifying screens is said to be:
    - A. More sensitive to radiation.
    - B. Better when not sandwiched between two intensifying screens.
    - C. More sensitive to light.
    - D. Faster because it uses only single emulsions with two screens.
  6. The transformer used to heat the filament of the x-ray tube is:
    - A. The autotransformer.
    - B. The step-up transformer.
    - C. The step-down transformer.
    - D. The high-tension transformer.
  7. The step-up transformer is used to:
    - A. Step up the current to heat the filament.
    - B. Allow the operator to vary the kVp.
    - C. Change low-input voltage to high-output voltage with low milliamperage.
    - D. None of the above.
  8. The substance that is the most radiopaque is:
    - A. Lead glass.
    - B. Plastic.
    - C. Wood.
    - D. Rubber.
  9. A dentist decides to change his or her intraoral exposure technique from 10 mA and 1.5-second exposure to 15 mA. The new exposure time is how many second(s)?
    - A. 0.35.
    - B. 1.
    - C. 2.
    - D. 6.
  10. A 0.5-second exposure would produce how many impulses of x-radiation?
    - A. 5.
    - B. 15.
    - C. 30.
    - D. 60.



11. Some components of the x-ray tube include:
  - A. An anode.
  - B. An aluminum filament.
  - C. Helium.
  - D. Cooling oil.
  - E. A lead collimator.
12. The kilovoltage in an x-ray generating system regulates:
  - A. The number of electrons produced.
  - B. Thermionic emission.
  - C. The velocity of electrons traveling from the filament to the target.
  - D. The velocity of x-ray photons produced.
13. The interaction in which the entire photon of x-radiation is removed from the beam by atomic interaction is called:
  - A. The Thomson effect.
  - B. The photoelectric effect.
  - C. The Compton effect.
  - D. Excitation.
14. Which of the following are characteristics of photoelectric absorption?
  - A. It depends on atomic number.
  - B. It differentiates between hard and soft tissues.
  - C. It is more likely to occur in inner orbits.
  - D. It occurs in dental radiography.
  - E. All of the above.
15. Sensitization specks:
  - A. Are defects in calcium tungstate crystals.
  - B. Are defects in silver bromide crystals.
  - C. Act as electron traps.
  - D. A and C.
  - E. B and C

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# Diagnostic Quality of Dental Radiographs

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Define umbra and penumbra.
2. Define radiopaque and radiolucent.
3. Discuss geometric factors that can be controlled to reduce the amount of magnification and distortion of a radiographic image.
4. Define density and contrast.
5. Discuss the factors that primarily control density.
6. Discuss the factors that primarily control contrast.
7. List the four conditions on which the diagnostic quality of a dental radiograph is dependent.
8. Discuss the characteristic curve.
9. Discuss the five rules for accurate image formation.
10. Understand the concept of coverage.
11. Observe accurate image projection through the Workshop/Laboratory Exercises.
12. Observe penumbra, magnification, and distortion through the Workshop/Laboratory Exercises.
13. Explain accurate image projection by shadow casting using the Case-Based Problem-Solving format.
14. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

|                      |               |                     |                      |
|----------------------|---------------|---------------------|----------------------|
| anatomical accuracy  | detail        | inverse square law  | radiographic quality |
| characteristic curve | distortion    | latitude            | radiolucencies       |
| contrast             | exposure time | long-scale contrast | rule of isometry     |
| coverage             | fog           | magnification       | scatter radiation    |
| definition           | fidelity      | milliampere seconds | short-scale contrast |
| densitometer         | film contrast | penumbra            | unsharpness          |
| density              | film speed    |                     |                      |

## INTRODUCTION

Diagnosis is the art of distinguishing one disease from another. The professional education and training of the dentist affords him or her the responsibility of diagnosis and

prescription of treatment. To make the most use of the dental radiograph as an aid in the diagnosis of dental disease, it is important that the dentist have a radiograph that provides the maximum possible information concerning a particular anatomical region. In other words,

the dentist must have a radiograph that has the highest possible quality. **Radiographic quality** refers to the fidelity (exactness in detail) with which an anatomical structure is represented on the radiograph and denotes the visibility and definition of the images of structural details. **Definition** (sharpness) refers to the distinctness and sharp demarcation of all elements in the dental film. **Detail** is the point-by-point delineation of the minute structural elements of the object in the images formed on the dental film.

The diagnostic quality of a dental radiograph is dependent on four conditions

1. Proper Visual Characteristics
  - a. Density.
  - b. Contrast.
2. Minimal Geometric Characteristics
  - a. Radiographic image unsharpness.
    - (1) Geometric unsharpness.
    - (2) Motion unsharpness.
    - (3) Screen unsharpness.
  - b. Magnification.
  - c. Distortion.
3. Anatomical Accuracy
4. Adequate Coverage of Anatomical Region of Interest

A clear understanding of the effects and significance of each factor will aid the operator in the routine production of diagnostic quality radiographs.

## VISUAL CHARACTERISTICS

The diagnostic quality of the radiograph is directly influenced by two visual characteristics of the radiographic image called density and contrast.

### RADIOGRAPHIC DENSITY

Radiographic density refers to the degree or gradation of "blackness" on a radiographic film. It depends on the amount of radiation reaching a particular area on the film and the resulting mass of metallic silver per unit area. As the reader will recall, the silver halides of the emulsion that have been sensitized by radiation are changed by the developing agents into particles of metallic silver, which appear black because of their finely divided state. The greater the amount of x-ray energy that reaches the film, the greater the degree of blackening on that area of the film. Areas where relatively few or no x-ray photons reach the film will appear gray or translucent on the processed radiograph. After the exposed film is processed, the film is viewed by placing it in front of an illuminator or view-box. It is the variation in the amount of light passing through the film that identifies the image seen. The heav-

ier the deposit of black silver masses, the greater the quantity of light absorbed (and not transmitted) through the emulsion, and the darker the area appears. The darker areas on the film are regions of the anatomical part of the body that freely let the x-rays pass through to expose the film and are called **radiolucencies**. A high degree of radiographic density produces a **dark film**; a **light film** has a thin or low degree of radiographic density.

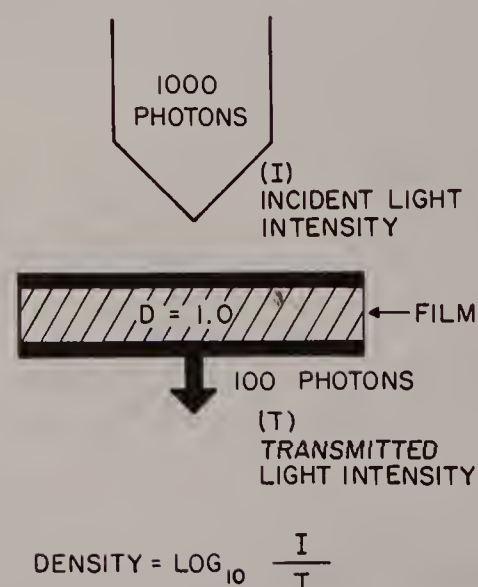
### Measuring Density

Radiographic density is measured by an instrument called a **densitometer**. This instrument indicates the relationship between the intensity of the light beam of an illuminator as it strikes one side of a given area of a radiograph (called incident light intensity) compared with the light transmitted through the radiograph (transmitted light intensity) (Fig. 3-1).

Density is expressed mathematically as a logarithm using the common base 10. It is defined by the following equation:

$$\text{density} = \log(10) \frac{\text{incident light intensity (I)}}{\text{transmitted light intensity (T)}}$$

**Example:** When the silver allows 1/10 of the illuminator or incident light through the radiograph, the ratio is 10:1, which is equal to 10. The common logarithm of 10 is 1; therefore, the density of the film is equal to 1. Again, if the silver allows only 1/100 of the light to pass through the radiograph, the ratio is equal to 100:1 or 100. The common logarithm of 100 is 2, and the density of the film is equal to 2. Actually, one does not have to know logarithms to use a densitometer because it is calibrated to



**Figure 3.1 Radiographic Density.** The reduction in intensity or the ability of the film to stop light, in this instance, is 1000/100 or 10, or one tenth of the light is transmitted through the film. The log of 10 is 1. Thus, the density of this radiograph is 1.0.



directly read density. In routine radiography, the useful range of film densities is approximately 0.3 (very light) to 2 (very dark). Beyond these extremes, the image is usually too light or too dark to be diagnostically useful.

### Importance of Density

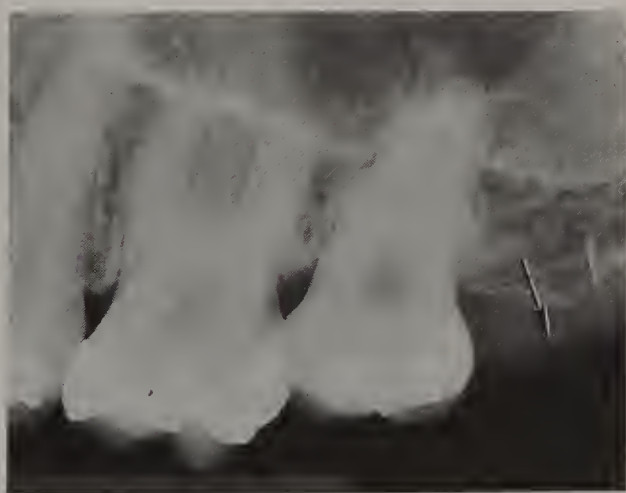
Density is extremely important in the diagnostic quality of a radiograph because it carries information. Visible detail of the radiographic image is not possible without density. However, there must be a correct amount of density to a radiograph because too much density (dark) will conceal information, and not enough density (light) will destroy detail in the lighter areas.

The desirable degree of radiographic density cannot be fixed as permanent, because one dentist may prefer a certain degree of density while another may prefer a greater or lesser density for the same region. The degree of radiographic density may be considered to be largely a matter of individual preference. Of course, one does not want a film that is too dark or too light—the right amount of density is needed to visualize the anatomical structures accurately. In dental radiographs of correct density, the dentist should be able to see a faint outline of the soft tissues in edentulous spaces or distal to the molar teeth when the radiographs are examined in the manner habitually used (Fig. 3-2).

### Primary Factors Controlling Density

Listed below are the three important exposure factors that control the density of a radiograph. In dental radiography, the first factor mentioned (mAs) is generally the factor that is most often altered.

**Milliamperage Seconds.** The density or blackness of the radiograph varies directly and proportionately to the milliamperage (tube current) and the exposure time. Therefore, exposure time and milliamperage are inter-



**Figure 3.2 Most Desirable Radiographic Density.** Radiograph of maxillary molar region. Note the thin shadow of soft tissue over bone in the tuberosity area distal to the maxillary second molar.

changeable and considered as a single factor (mAs). For instance, the density of a radiographic image produced by a direct exposure of 1.5 seconds at 10 mA is identical to the density of the image produced by an exposure time of 1 second at 15 mA. The product of mA and exposure time is equal to 15 mAs in each instance. The higher the mAs, the more x-rays that will strike the film and the greater the quantity of metallic silver deposited in the film emulsion. The quantity (or mAs) of the x-ray beam is usually measured by the use of a pocket dosimeter or another type of dosimeter (ionization chamber) (see Chapter 8).

**Kilovoltage.** Kilovoltage is referred to as the “penetrating power” of the x-ray beam and influences density. As the kilovoltage becomes greater and the effective wavelengths of the x-ray beam become shorter, the penetration of the x-ray beam becomes greater. Therefore, a greater amount of x-radiation will strike the film emulsion, which in turn will cause more metallic silver to be deposited in the emulsion. This will result in a higher radiographic density if all other factors remain constant.

**Source-Film Distance.** Because the intensity of an x-ray beam varies inversely to the square of the source-film distance (inverse square law), the time of exposure necessary to maintain a constant density in a radiograph varies directly to the square of the focal-film distance. The shorter the distance between the focal spot and the film, the more x-rays that strike the film, and therefore the higher the density.

**Example:** Doubling the distance gives one-fourth the density; halving the distance gives four times the density.

### Secondary Factors Controlling Density

**Development Conditions.** The radiograph may be darker or lighter depending on whether the films are underdeveloped or overdeveloped. However, it is difficult to overdevelop a film that has been properly exposed, even when manual processing is used. Underdevelopment frequently occurs and produces a low-density image. This usually occurs as a result of developer solution that is depleted or too cold.

**Type of Film.** High-speed films, such as ANSI types E and F, require less mAs to cause a density change compared with slower-speed films, such as ANSI type D.

**Intensifying Screens (Extraoral Radiographs).** High-speed screens require less mAs to cause a density change in the radiograph. Intensifying screens are devices used to convert x-ray energy to light energy and are used in panoramic and cephalometric radiography.

**Grids.** The use of grids requires more mAs to keep a constant density. Grids are devices used primarily in extraoral radiography (such as cephalometrics) to prevent scattered radiation from reaching the film. It consists of a series of narrow lead strips separated by spaces of low-density material.

## RADIOGRAPHIC CONTRAST

The contrast on a film is the difference in the densities seen on it.

Mathematically, contrast can be expressed as  $D_1 - D_2$ , where  $D_1$  is the density of an extreme black area of the film and  $D_2$  is the density of an extreme white area.

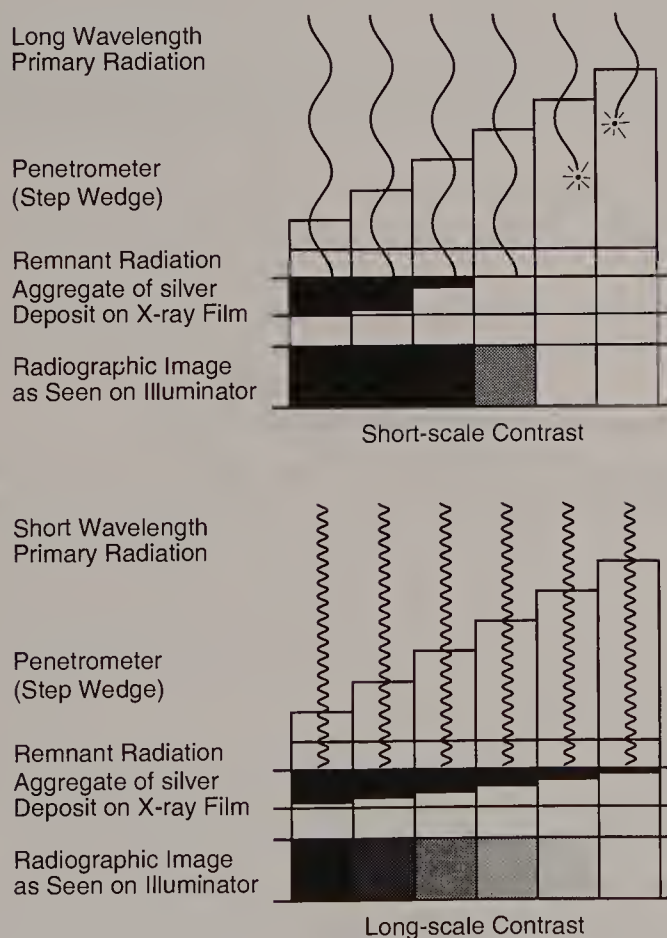
Contrast is affected primarily by the kilovoltage; however, it can be affected by the type of film used, the characteristics of processing solutions, and the type of tissue irradiated (its thickness, density [mass/volume], and atomic number).

### Long-Scale and Short-Scale Contrast

The lower the kilovoltage, the greater the short-scale contrast; as the kilovoltage is increased, the long-scale contrast increases. At higher kilovoltages (80 to 90 kV), pen-

etration of the tissues is greater; therefore, the density differences of adjacent areas on the radiograph will be small, and the radiograph is said to have long-scale contrast. If the kilovoltages are low (60 to 65 kV), penetration of the tissue is less, and the density differences between adjacent areas will be great. In this case, the film is said to have short-scale contrast.

Long-scale and short-scale contrast can be illustrated by means of a penetrometer or a step-wedge. A penetrometer is a radiographic testing device made of aluminum and built up in steps of varying thicknesses. Figure 3-3 shows an aluminum penetrometer (step-wedge) being irradiated by x-rays; the exposed x-ray film cross-section is shown beneath each step-wedge or penetrometer. The resulting radiographic image as it appears when viewed on the illuminator is depicted below the film cross-section in both illustrations. The penetrometer demonstrates how long-scale contrast compares with short-scale contrast in Figure 3-4. In general, a compromise between the long-scale and the short-scale contrast is desired. Periapical radiographs should usually manifest long-scale contrast, whereas bitewing radiographs should have short-scale



**Figure 3.3 Scale of Contrast.** *Short-Scale (low) Contrast:* If the kilovoltage is low (65 kVp), a greater percentage of the wavelengths of the beam will be longer and the amount of penetration will be less. The density differences between adjacent areas will be great, and the film will have short-scale contrast. There will be fewer shades of gray between the lighter and darker areas of the radiographic image. *Long-Scale (high) Contrast:* If the kilovoltage is high (90 kVp), a greater percentage of the wavelengths of beam will be shorter, the penetration of the x-rays through the penetrometer will be greater, the density difference of adjacent areas are small, and the film will have what is called long-scale contrast.



**Figure 3.4 Contrast by Penetrometer.** Comparison of long-scale and short-scale contrast using penetrometer.



contrast. A short-scale contrast radiograph is thought to be best for the visualization of dental caries, and the long-scale contrast film is best for visualization of osseous changes such as periodontal and periapical disease in the jaws. However, this concept is debatable; if a dentist uses a darkened room and masks the full-mouth survey of mounted radiographs on a high-illumination viewing box, the long-scale radiographs may be better than short-scale radiographs for interpreting interproximal caries. It should be remembered that kilovoltage is also a controlling factor in density and contrast. Thus, if the kilovoltage is increased, the mAs must be decreased to maintain the previous radiographic density.

### Relationship Among Contrast, Density, and Exposure

When the contrast is changed, the radiographic density of the film will be altered. However, when radiographic density is altered by itself, there will be no obvious change in the contrast. Why is this true? A change in kilovoltage will produce a change in contrast. The higher the kilovoltage, the lower will be the contrast. However, because kilovoltage is also a controlling factor in radiographic density, an increase in kilovoltage will also increase the radiographic density.

If you are confused. . . remember, when the kilovoltage is increased, the milliamperage seconds (a controlling factor in radiographic density) must be decreased to maintain the previous radiographic density. Remember that cathode electrons hit the target faster at higher kVps, thus producing more x-ray photons that, in turn, increase the density on the radiograph.

Changing the exposure time is used in most cases when the mA is fixed. To illustrate this concept, the exposure chart below demonstrates the use E speed film and a 16-inch target-film distance for the maxillary molar region. The mAs is 2.5 using the 90-10 technique compared with 7.5 mAs for the 65-10 technique.

| Density | Contrast            | kVp | mA | Seconds | mAs |
|---------|---------------------|-----|----|---------|-----|
| Same    | Low or long-scale   | 90  | 10 | 0.25    | 2.5 |
| Same    | High or short-scale | 70  | 10 | 0.75    | 7.5 |

Contrast cannot be varied by a change in milliamperage unless a variation in voltage is made to compensate for the milliamperage variation. If the mA is increased (10 to 15 mA), the kVp must be lowered to maintain the same density; by decreasing the kVp, the contrast will increase (short-scale contrast). Density can be altered without

changing the contrast. How is this accomplished? **Milliamperage seconds** is the prime factor in controlling radiographic density but it is not a controlling factor in contrast. Therefore, a change in mAs or exposure time will produce a change in radiographic density but not a noticeable change in contrast.

**Example:** Two radiographs of the same region can be made—one of greater density (higher mAs), and one of lesser density (lower mAs)—with the kVp remaining constant in both radiographs. These two films will have differences in overall blackness (density), but the extreme blackness and whites (contrast) of both films will remain the same.

If you are confused. . . in general, it may be said that each increase of 15 kVp will decrease the contrast and increase the density; therefore, the mAs must be decreased by 50% to maintain the same density. With each decrease of 15 kVp, the contrast will increase and the density will decrease; therefore, the mAs must be increased 50% to maintain the same density.

### Fog and Scatter

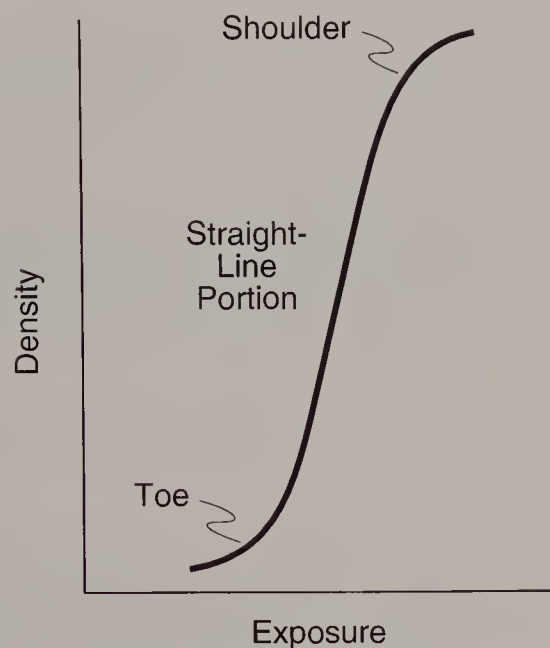
Radiographic contrast will be reduced by the addition of undesirable density from fog and scatter radiation. Fog is a darkening (increased density) of the radiograph by sources of energy other than radiation from the primary beam. Film fog can be reduced by proper film storage and film processing. Scatter radiation results from Compton interactions with body structures. When the scatter radiation hits the film emulsion, it results in an overall darkening (greater density) of the radiograph, which causes a loss in image contrast.

### Characteristic Curve

The characteristic curve was first used in photography by Hunter and Driffield of England in 1890; sometimes the curve is called the H & D curve. Film manufacturers use such curves to monitor film quality and consistency. Characteristic curves are constructed by taking a series of exposures of a certain film type, developing the film, reading the density by use of a densitometer, and plotting the density readings against a known exposure. A typical H & D characteristic curve is shown in Figure 3-5. There are great variations in exposure at the high and low levels of exposure, which result in very small changes in density. These low and high levels of the curve are called the toe (low density) and the shoulder (high density), respectively. In the intermediate straight slope portion of the curve, small changes in exposure result in large changes in density. This is called the straight-line portion of the curve and is the area of proper exposure.

The characteristic curve will give useful information concerning speed (sensitivity), contrast, and latitude of the film (Fig. 3-6).





**Figure 3.5 Characteristic Curve.** Typical characteristic curve of a radiographic film that shows the relationship between exposure and density.

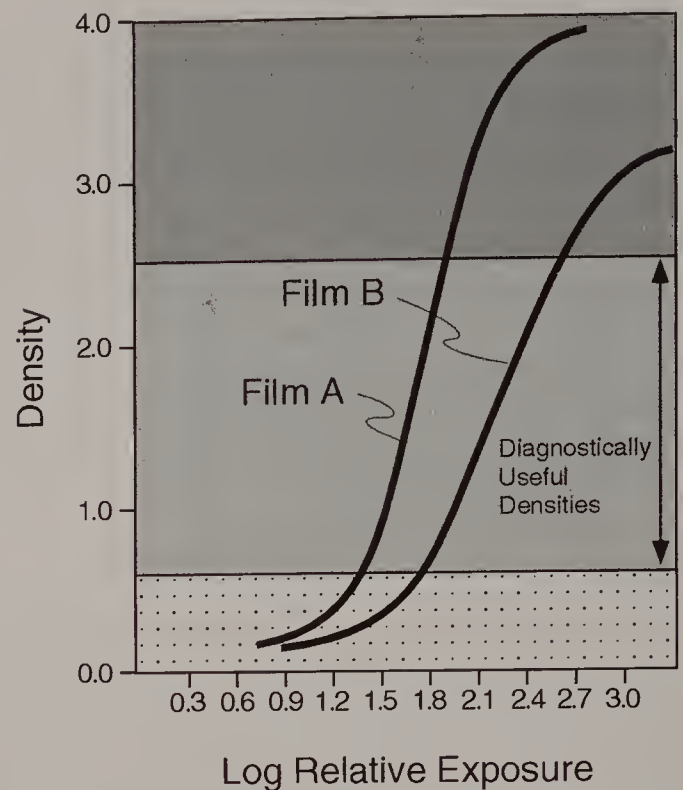
**Film Speed and the Characteristic Curve.** The characteristic curve of a faster film will be to the left of a characteristic curve of a slower film. This is because less exposure time is required to produce the same level of density even though the films may have similar contrast.

**Film Contrast and the Characteristic Curve.** Film contrast is inherent in the type of film being used. By analysis of the characteristic curve, one can readily determine the degree of contrast for a particular film. The slope of the characteristic curve of a film in the useful diagnostic range is a measure of its contrast (Fig. 3-6).

There is no simple method to define film contrast. The most commonly used method is the average gradient or slope of the useful straight line portion of the characteristic curve. The greater the slope of the curve in this region, the greater the film contrast. In Figure 3-6, film A has a higher contrast than film B. When dental direct-exposure films are considered, the slope of the curve continually increases with increasing exposure. As a result, properly exposed films have more contrast than underexposed (light) films. Film contrast will be maximal when optimum film processing conditions are used. Incomplete or excessive development of films results in decreased film contrast.

**Latitude and the Characteristic Curve.** There are two types of latitude: film latitude and exposure latitude.

**Film Latitude.** Film latitude refers to the range of exposures (mAs) to which an x-ray film will respond with densities within the accepted range for diagnostic radiology (usually considered to be a density range from 0.5 to 2.5). Figure 3-6 shows two films with different latitudes. Film B has a greater latitude (less steepness of the curve) but



**Figure 3.6 Characteristic Curve—Relationships Among Contrast, Speed, and Latitude.** Film A has a higher contrast than film B because the slope of the straight portion of the characteristic curve is steeper. Also, the speed of film A is faster than film B because film A requires less exposure to produce any density. Film A has faster speed, higher contrast, and lower latitude than film B. Note that film B has greater latitude (less steepness of the curve) but less film contrast than film A. Generally, the greater the film latitude, the lower the film contrast (long-scale contrast).

less film contrast (long-scale) than film A. Generally, film latitude varies with the reciprocal (opposite) of film contrast. In other words, the greater the film latitude, the lower the film contrast. Conversely, a film with short-scale (high) contrast (greater slope of curve) will have narrow latitude.

**Exposure Latitude.** Exposure latitude is the range of exposures of an x-ray film permissible for a good diagnostic result. The greater the exposure “error” that can be tolerated, the greater the latitude of the radiographic exposure technique. Exposure latitude improves when the kVp is increased, and the film contrast decreases. In practice, a high kVp technique has more room for error in choice of exposure time (fixed mA) because the exposure latitude is greater. At lower kilovoltage, the latitude is less, and the mAs must be selected carefully.

## SUMMARY OF VISUAL CHARACTERISTICS

The mAs (mA and exposure in seconds or impulses) and kVp control film density (blackening on film). The mAs is the most important factor. When the kVp and mA are

fixed, the exposure time is the most important factor in controlling density. The kVp controls image contrast (density differences on the film). When the kVp is fixed, contrast can only be controlled by the operator's choice of film, screens, and processing solutions. High-contrast (short-scale contrast) radiographs seem to be better for the interpretation of caries. Therefore, a low kVp technique (65 kVp) is usually used for bitewing exposure techniques. Long-scale contrast (low contrast) seems to be the best technique for interpretation of periodontal disease and bony lesions. If long-scale contrast radiographs are used under ideal viewing conditions (darkened room, bright illumination, and masking of films), it is the opinion of many that the long-scale contrast radiograph is even better than a short-scale contrast radiograph for caries interpretation.

If you are confused. . . think of density as the overall darkness of a film (controlled by the amount of radiation) and contrast as a range of colors; except in a black and white film, it will be shades of gray. If the density is adequate, the image on the radiograph will be neither too dark nor too light. If contrast on the radiograph is the best that can be achieved diagnostically, one can definitely see the enamel, dentin, pulp, alveolar bone, and gingival soft tissue on the radiograph.

## GEOMETRIC CHARACTERISTICS

The formation of an accurate radiographic image is dependent on minimizing certain geometric characteristics that are present to a certain degree in every radiograph.

### THREE GEOMETRIC CHARACTERISTICS

**Image or geometric unsharpness** refers to diffusion of detail. **Penumbra** (from the Latin words *pene* for "almost" and *umbra* for "shadow") is a fuzzy, unsharp margin surrounding the radiographic image. Penumbra is often called the **edge gradient**, which is defined as the region of partial illumination that surrounds the **umbra** or complete shadow.

**Image magnification** is equal enlargement of the radiographic image. It is a form of distortion in which the shape of the object is not substantially altered. However, magnification is rarely uniform because the objects (**buccal cusps**) farther away from the film will always magnify more than objects closer to the film (**lingual cusps**) when the same technique factors are used.

**Image shape distortion** of the radiographic image is the unequal enlargement or magnification of different parts of the same object.

## CAUSES OF IMAGE OR GEOMETRIC UNSHARPNESS, MAGNIFICATION, AND SHAPE DISTORTION

There will always be a certain amount of geometric unsharpness, magnification, and shape distortion of the radiographic image for three reasons:

1. **X-rays originate from a definite area rather than a point source.** It is impossible to have a point source of x-rays because of the limited heating capacity of x-ray tubes. The source of radiation in modern dental x-ray machines varies from 0.5 to 1.2 mm<sup>2</sup>, depending on the mA and kVp capabilities of the machine. The focal spot of the anode acts as if it were composed of many point sources of x-rays, with each point source forming its own image of an object. The edges of each of these images will not be in exactly the same point on the film.
2. **X-rays travel in diverging straight lines as they radiate from their source of origin.** This divergent quality of ionizing radiation is an important source of magnification.
3. **Human structures have depth as well as length and width.** Therefore, in dental radiography, a three-dimensional object is recorded on the two-dimensional surface of a film. This results in **unequal magnification** of different parts of an object because of varying distances of these parts from the film.

## DEMONSTRATING GEOMETRIC CHARACTERISTICS BY SHADOW CASTING

To understand geometric characteristics of x-rays, we can compare the taking a photograph to the making a radiograph. Proper exposure time and intensity are required for both. After all, x-rays are no more than very short, invisible light waves. Images are recorded in both, because the x-rays and the visible light photons travel in straight lines. In that regard, an x-ray image may be considered analogous to a shadow image. The sharpness of the shadow image from a light source as it is projected on a wall is a function of a number of geometric factors.

To demonstrate shadow formation by light, one needs to obtain a small, clear penlight source (7-W bulb) or small flashlight. The light source should be set up approximately 3 feet from a white wall, turned on, and a hand should be placed an inch or two from the wall. The shadow produced will be nearly the same size as the experimenter's hand, with its edges clear and well-defined. If the hand is moved toward the light source, the shadow will be enlarged or **magnified** and its edges will become fuzzy and indistinct. Next, a large frosted bulb or large flashlight should be substituted for the light source. This time, the hand shadow will have fuzzy edges even with the hand close to the wall. Again, the hand should be moved toward the larger light source; the shadow should enlarge



and the fuzziness (blur) increase. The fuzzy portion, or blur, of the shadow around the umbra (shadow) is called the penumbra or the area of **unsharpness**. To minimize the unsharpness of the light shadow, the penumbra must be reduced. The hand image can also be distorted by placing the light source in such a manner that the light waves strike the hand in an oblique direction, rather than perpendicularly. The angle of the hand can also be changed with respect to the wall. This is called **shape distortion**. Nevertheless, the same laws that apply to the fuzziness (blur) at the edge of the object (penumbra) apply to the

To avoid confusion in comparing light waves and x-rays, it should be remembered that light waves produce shadows by reflecting light from an opaque object. X-rays will penetrate this same object and will not produce a true shadow, because details of the object will be visible in the processed film. Therefore, x-rays produce x-ray images rather than shadows.

## FIVE RULES FOR ACCURATE IMAGE FORMATION

The following five rules for accurate shadow casting by light waves are also applicable to x-rays in the formation of an accurate radiographic image.

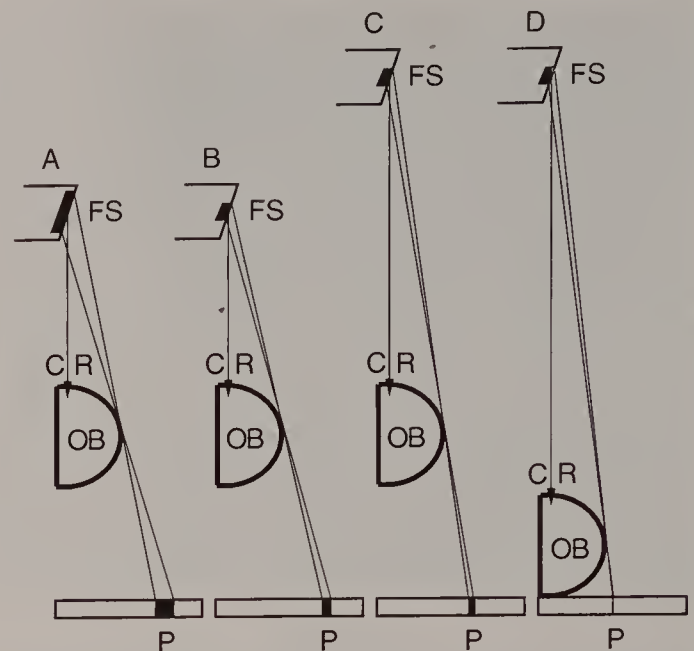
1. The x-rays should originate from as small a focal spot as possible. This is determined by the manufacturer. Efforts should be made to minimize voluntary and involuntary motion unsharpness of film or x-ray tube. This will increase the size of the focal spot.
2. The distance between the focal spot (source) and the object to be examined should always be as long as is practical.
3. The film should be as close as possible to the object being radiographed.
4. As far as is practical, the long axis of the object should be parallel to the film.
5. The central ray should be as nearly perpendicular to the film as possible to record the adjacent structures in their true spatial relationships.

By following the above five rules, measures can be taken to minimize the inherent geometric characteristics found in every radiograph.

## FACTORS INFLUENCING GEOMETRIC CHARACTERISTICS

### Image or Geometric Unsharpness

Radiographic image unsharpness is the fuzzy area or penumbra surrounding the contour lines of the teeth and osseous tissues of the radiograph. Considering the relatively small size of the dental structures and tissues, it is very im-



**Figure 3.7 Five Rules of Accurate Image Formation.** Diagrams illustrating how the accuracy of the radiographic image can be improved by decreasing the size of the penumbra (P). The penumbra affects image unsharpness and magnification. Note the changes in size of the penumbra: from A to B by decreasing the size of a focal spot (FS) of the anode; from B to C by increasing the distance between the focal spot and the film; and from C to D by decreasing the distance between the object (OB) and the film.

portant to minimize these areas of fuzziness or unsharpness in the dental radiograph. The smaller the size of the focal spot, the smaller the penumbra and consequently the sharper the definition of the radiographic image (Fig. 3-7).

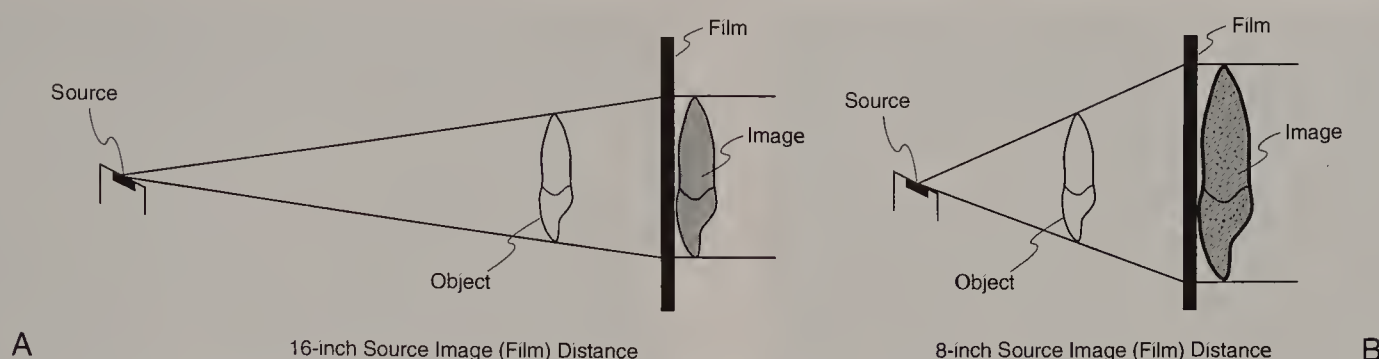
When the focal spot is relatively small (0.5 to 1.2 mm), as in dental x-ray tubes, the radiographic image is influenced very little by magnification. The focal spot size cannot be adjusted in dental x-ray machines. It is an important feature to consider when purchasing the x-ray machine. In all situations, sharpness is improved when the source-object distance is increased and the object-film distance is decreased (Fig. 3-7). It should be remembered that the longer the object-film distance, the greater the unsharpness. In the dental radiograph, the dental structure farthest from the film will have the greatest unsharpness. Note that the lingual cusp and the lingual root of a tooth will have more sharpness on the radiograph than the buccal cusp and the buccal root or roots on a tooth. The lingual structures are sharper because they are closer to the film.

If you are confused... remember, radiographic image unsharpness can be minimized by reducing the size of the focal spot, increasing the source-object distance, and reducing the object-film distance.

### Magnification

Magnification is the equal enlargement of the actual size of the object as it is projected onto the radiograph. The





**Figure 3.8 Magnification and Distance Factors.** Note that the magnification of the tooth is less with **(A)** long source-film distance compared with **(B)** short source-film distance.

factors that influence magnification are the same factors that influence radiographic image or geometric unsharpness; however, the distance factors (source-film distance and object-film distance) have more influence than the focal-spot size. It is possible to minimize magnification (equal enlargement) of dental structures by increasing the source-film distance (long BID) and reducing the object-film distances as much as is practical. The relationships among the x-ray beam, the object being radiographed, and the image of the object being projected on the film can be illustrated in a simple drawing (Fig. 3-8).

#### Calculating Magnification

By using the following formula, the true size of the actual tooth can be calculated. This is helpful in endodontics and orthodontics.

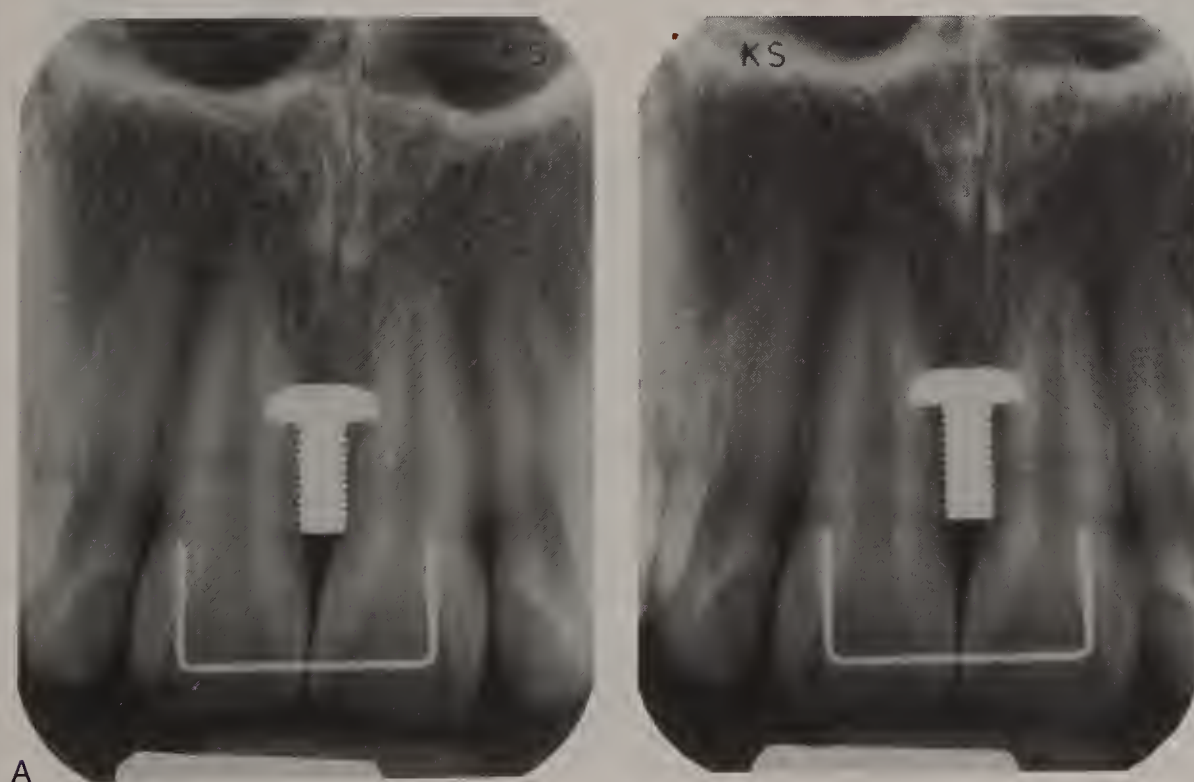
$$\begin{aligned} \text{(O) Object size} \\ = \frac{d \text{ (source-object distance)} \times I \text{ (image length)}}{D \text{ (source-film distance)}} \end{aligned}$$

**Example:** What is the true size of a tooth when the source-film distance is 16 inches, the source-object distance is 15 inches, and the tooth-image length on the radiograph measures 28 mm?

**Solution:**

$$\text{(O) Object size} = \frac{15 \times 28}{16} = 26.25 \text{ mm}$$

In summary, magnification and penumbra size (unsharpness) depend primarily on two factors: **source-film distance** and **object-film distance**. Magnification can be kept at a minimum by keeping the film as close as possible to the object and the source-film distance as long as possible or practical. In Figure 3-9A, the radiograph was taken with a long source-film distance (long BID) and reveals teeth that are less magnified than the teeth in the radiograph in Figure 3-9B, which was taken with a shorter source-film distance (short BID). The width of the staple in Figure 3-9B measured 2 mm longer than the staple in Figure 3-9A.



**Figure 3.9 Geometric Unsharpness and Distance Factors.** Radiographs taken with **(A)** long source-film distance and **(B)** short source-film distance. In both cases, only the source-film distances were different; the object-film distances were the same. Note the sharpness (less penumbra) of outline of the screw in A compared with B. Also, the staple in B is 2 mm longer than in A.

In a properly exposed radiograph, sharpness and detail are adequate when the lamina dura, periodontal membrane space, and individual bone trabeculae can be seen.

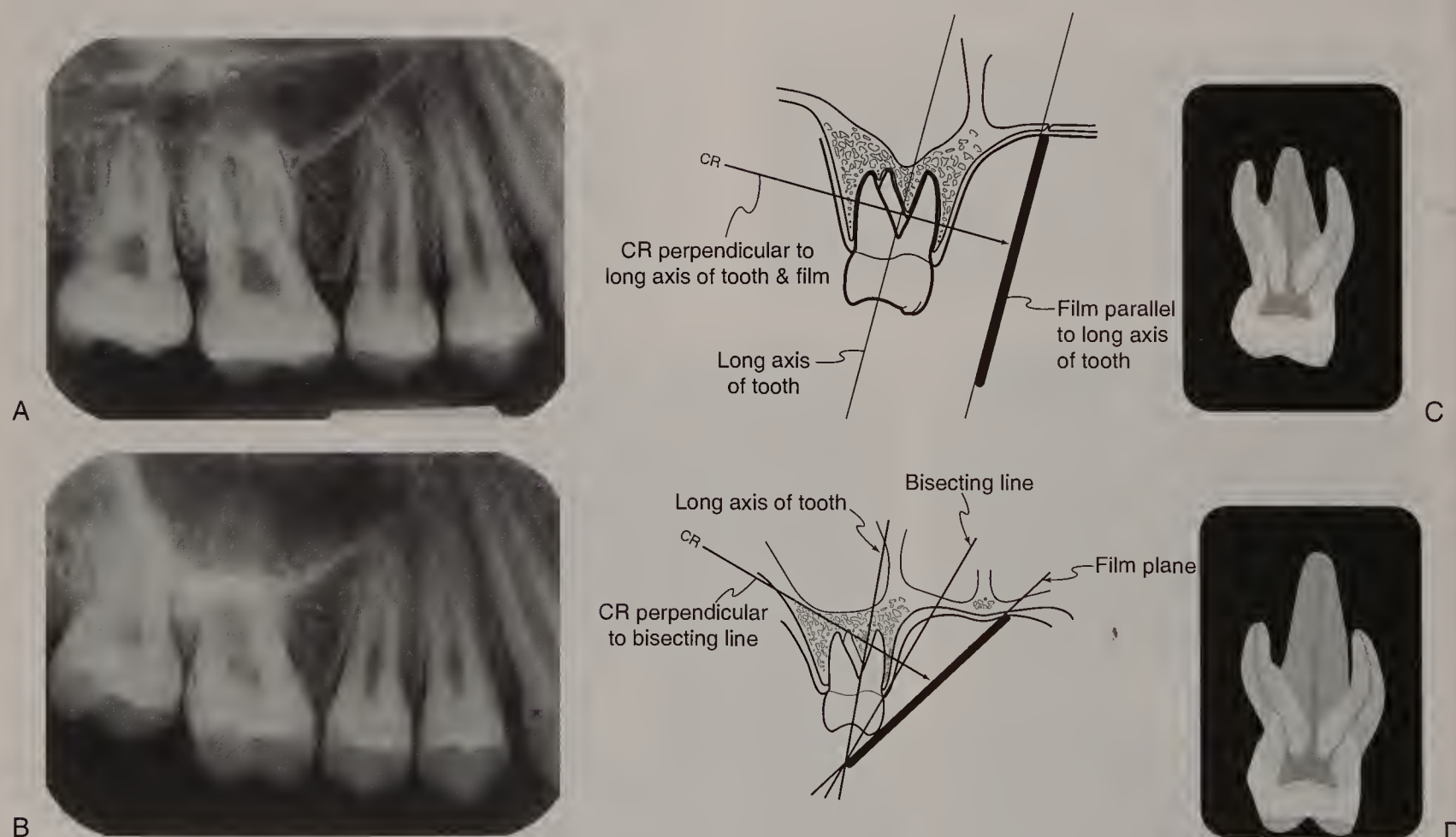
### Shape or Dimensional Distortion

Distortion is unequal magnification of different parts of the object. Shape distortion can be minimized by using the radiographic intraoral **paralleling technique**, whereby the film is placed parallel to the long axes of the teeth and the beam of radiation is directed at right angles to the teeth and film. In the **bisecting technique**, the beam of radiation is directed perpendicular to the line bisecting the angle formed by the long axes of the teeth and the film. Inherent shape-distortion problems arise when the bisecting technique is used that are **not** found when the paralleling technique is used (Fig. 3-10). The bisecting rule of isometry applies admirably to plane surfaces that have length and width dimensions, but it has certain shortcomings when objects have depth as well as length and width. If the bisecting principle is even slightly neglected, the resultant image will be foreshortened or elongated. The maxillary molar buccal roots will always be foreshortened in comparison to the lin-

gual root when using the bisecting technique, because the depth dimension is greater in these teeth.

If you are confused . . . think of the **penumbra** as causing the objects in a photograph to appear out of focus, and magnification as an enlargement of the objects in a photograph that occurs with a magnifying glass. To minimize **penumbra** and **magnification** on a photograph or a radiograph, it is the distances that count in radiography: (1) use a long BID or long target-film distance, and (2) get the film as close to the tooth as possible (object-film distance) and still be able to achieve parallelism of film with the teeth.

Think of distortion as an altered shape of objects in a photograph that occurs with the use of trick mirrors. To minimize distortion, remember that it is the angles that count. The film and the tooth should be parallel to each other, and the flat end of the BID should be parallel to the tooth and the film. Another way to consider the "angles" is to think of the central ray of the x-ray beam to be perpendicular to the tooth and the film, which are parallel to one another.



**Figure 3.10 Dimensional Distortion and Anatomic Accuracy.** Radiograph **A** was taken with a paralleling technique, as shown in **C**. Radiograph **B** was taken with the bisecting technique shown in **D**. Note the amount of foreshortening of the buccal roots of the maxillary molar radiograph shown in **D**, when compared with the buccal roots of maxillary molar radiograph shown in **C** (taken with the paralleling technique). Compare **A** with **B** for anatomic accuracy. Both **A** and **B** were taken of the right maxillary first molar region of the same patient.



If you take into account all the factors to minimize **penumbra**, **magnification**, and **distortion**, the periodontal ligament space, lamina dura, and individual trabeculae will be easily seen and sharply defined in the x-ray image.

## ANATOMICAL ACCURACY

**Anatomical accuracy** occurs when the anatomical structures are reproduced on the film in the true spatial relationship as they normally appear. Anatomical accuracy is obtained when the film is placed parallel to the long axis of the teeth and the radiation beam directed perpendicular to both.

A properly exposed radiograph is said to have anatomical accuracy when:

1. The labial and lingual cementoenamel junctions of the anterior teeth are superimposed.
2. The buccal and lingual cusps of the posterior teeth (especially the molars) are superimposed.
3. The contacts of the teeth are opened in at least one of the projections of a given area.
4. The buccal portion of the alveolar bone crest is superimposed over the lingual portion of the alveolar bone crest (posterior teeth).
5. There is no superimposition of the zygomatic process of maxilla over the roots of the maxillary molar teeth.

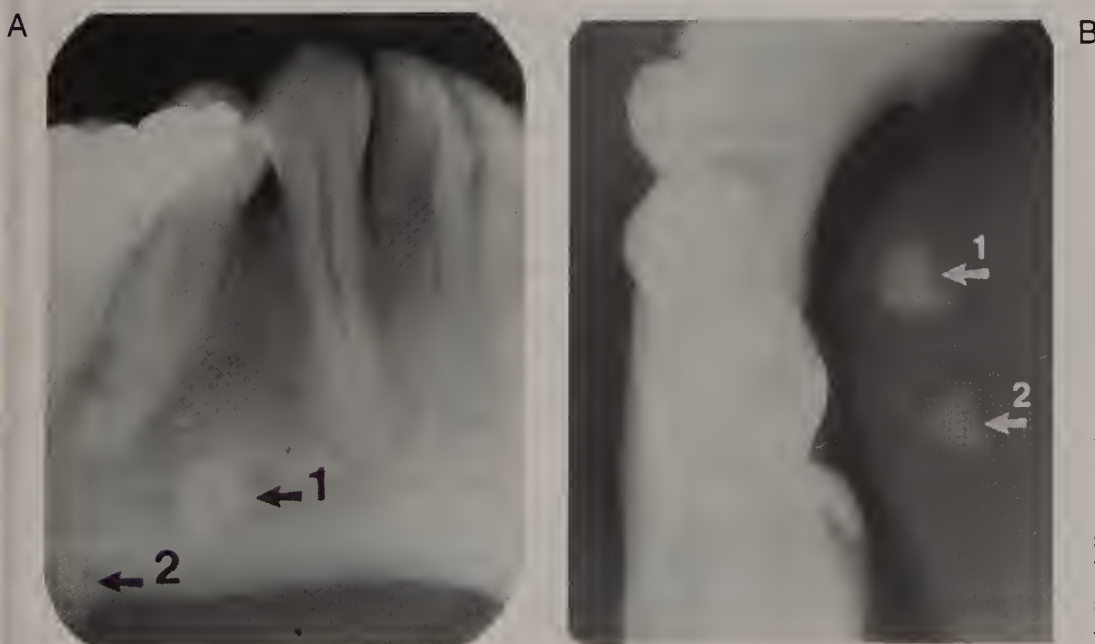
The reader should compare radiograph A (taken with the long BID paralleling technique) and radiograph B (taken with the short BID bisecting technique) in Figure 3-10.

The long-BID paralleling technique radiograph has greater anatomical accuracy than the short-BID bisecting technique radiograph, because the paralleling long-BID technique radiograph reveals the following:

1. Better superimposition of buccal and lingual cusps (better caries detection).
2. Better superimposition of buccal portion of alveolar bone crest over the lingual portion of alveolar bone crest (better interpretation of crestal alveolar bone height).
3. Minimal superimposition of zygomatic bone over roots of maxillary molars (better for interpreting periapical pathology).
4. Better definition and less magnification (better film for overall interpretation).
5. Minimal foreshortening of buccal roots of molars (better for endodontic preoperative and postoperative radiographs).

If you are confused . . . think of anatomical accuracy in terms of building a house on a hill; you still want the floors to be horizontal and the walls perpendicular. Here the angles count, so make certain the film is parallel to the tooth and the BID is perpendicular to the film and tooth. The buccal and lingual cusps should be superimposed in the x-ray image.

**Explanatory note on BID length:** Currently, a long BID is defined as 16 inches. The BID length is measured from the dot or focal spot mark on the tubehead to the flat end of the BID. An 8-inch BID is referred to as a short BID; the 12-inch BID is a compromise between the 8- and 16-inch BID lengths. All these lengths are measured as previously described. An 8-inch BID should not be used with the paralleling technique, because the distances between the teeth and film will be quite long, thus breaking one of the five



**Figure 3.11 Localization of Area of Interest.** (A) Periapical radiograph shows two small radiopaque areas, of which No. 2 extends beyond the inferior cortex of the mandible. See Figure 5.47 for extended periapical coverage. (B) The occlusal radiograph shows the opacities are outside of the mandible and are consistent with stones in Wharton's duct of the submandibular salivary gland. These are the reason the patient experiences swelling and pain in the area at mealtimes.

rules for accurate shadow casting or x-ray projection. The long 16-inch BID compensates for this; however, the use of the short 8-inch BID (short target-film distance) breaks a second rule of good x-ray projection (shadow casting) and exacerbates the problem. On the other hand, the bisecting technique calls for the film to be placed as close as possible to the tooth. Therefore, an 8-inch BID can be used, but even then, the longer BID with the bisecting technique is better.

## RADIOGRAPHIC COVERAGE

It is important that the area of interest is well covered in the radiograph. In the periapical radiograph, an adequate amount of bone (at least 2 to 4 mm) surrounding the apices of the teeth should be revealed. Supplemental films, such as occlusal films, may sometimes be mandatory to view the area of suspected abnormality completely (see Chapter 5). Additional films may have to be taken at right angles to each other to localize the area of interest (Fig. 3-11).

Adequate coverage of the area of interest depends on several factors:

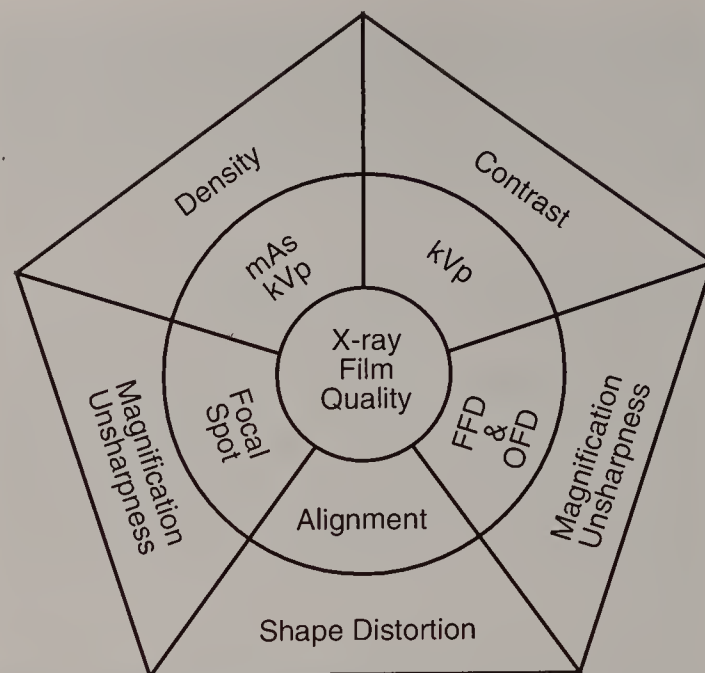
1. Proper alignment of film and the radiation beam to area of interest.
2. Proper selection of film types.
3. Proper selection of film-projection techniques.

## SUMMARY OF DIAGNOSTIC QUALITY

The diagnostic quality of the radiographic film is dependent on the proper combination of several factors. The functions of these factors are given below:

1. Milliampere seconds (mAs) regulate density (blackness) of the radiograph.
2. Kilovoltage
  - a. regulates degree of x-ray penetration of tissues;
  - b. influences scatter radiation fog;
  - c. regulates contrast scale; and
  - d. influences density of the radiograph.
3. Focal-spot size influences unsharpness and magnification of the radiographic image.
4. Source-film and object-film distances influence unsharpness and magnification of the radiographic image.
5. Alignment of film and beam of radiation influence distortion, anatomical accuracy, and coverage.

Therefore, if all other exposure factors remain constant, the factors listed in Figure 3-12 will influence the x-ray image characteristics of density, contrast, geometric unsharpness, magnification, and shape distortion in various ways.



**Figure 3.12 Diagnostic Quality Summary.** Summary of controlling factors of density, contrast, magnification, and shape distortion (geometric unsharpness).

## SUMMARY OF DIAGNOSTIC FEATURES AS VIEWED ON FILM

1. The image will not be too light or too dark overall (density).
2. The five basic tissues can be seen: enamel, dentin, pulp, alveolar bone, and soft tissue (contrast).
3. The apical periodontal membrane space, lamina dura, and individual trabeculae can be seen (detail, sharpness).
4. The buccal and lingual cusp tips are superimposed (distortion, anatomical accuracy).
5. All the needed structures for an accurate diagnosis can be seen (coverage).

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 3.1. RULES FOR ACCURATE IMAGE PROJECTION

#### Materials and Equipment Needed

1. Six No. 2 intraoral films, Kodak E+ speed.
2. Two small metal paper clips.
3. A small piece of cardboard.
4. X-ray machine and processing facility.

#### Instructions

- Step 1:** Turn on the x-ray machine. Set the kVp at about 65 and the mA at 7 or 10, depending on the machine. Twist off the BID. (The instructor will help you.)



**Step 2:** Obtain intraoral films and two smaller-sized metal paper clips. Separate the two rounded tines of one of the paper clips so that they are about 1/4 inch apart.

**Step 3:** For each of the following exposures, place the two paper clips side by side on the plain or front side of the film. With a ball-point pen, label each film number.

**Step 4:** Exposure No. 1: place film No. 1 on the counter top with the two paper clips side by side along its length. From the focal spot mark on the tube-head, place a distance of 4 inches between it and the film. Direct the x-ray beam perpendicular to the film ( $90^\circ$ ). Set the exposure time at 1/32 second (2 impulses) and expose this film. (Exposure values may need adjustment.)

**Step 5:** For films No. 2 and 3 do exactly as for No. 1, except for film No. 2 use a distance of 8 inches and 1/8 second (7 impulses) exposure time. Expose this film. For film No. 3 use a distance of 16 inches and 1/2 second (30 impulses) exposure time. Expose this film.

**Step 6:** For film No. 4 place the BID flat end on an angle of  $20^\circ$  off perpendicular ( $70^\circ$  or  $110^\circ$ ), use a distance of 16 inches, and a 1-second exposure time. Direct the central ray at the center of the film and expose it.

**Step 7:** Move a little U-shaped spacer or platform made from a piece of cardboard so that the top of the U is the same size as the No. 2 film and the top stands 1 inch from the counter top. Place film No. 5 on the counter top, the U-shaped spacer on top of the film, and the two paper clips on top of the spacer. Set the focal spot 8 inches from the film. Direct central ray perpendicular to the film and set the exposure time at 1/8 second (7 impulses). Expose this film.

Expose film No. 6 in exactly the same way, except use a focal spot to film distance of 16 inches and an exposure time of 1/2 second (30 impulses). Expose this film.

**Step 8:** Process films No. 1 through 6; label and mount the processed films.

#### CASE-BASED QUESTIONS FOR LABORATORY EXERCISE

1. Explain why the density does not vary among films No. 1, 2, and 3, although the exposure times do.
2. Which films demonstrate the effect of varying BID length?

3. What happens to the images of the paper clips as BID length gets longer?
4. With the distance set at 16 inches, what happens when you vary the perpendicularity of the central ray to the object and film (compare films No. 3 and 4)?
5. What happens when the object-film distance is lengthened when BID length is kept constant (compare films No. 3 and 5)?
6. What happens when the object-film distance is lengthened and then the BID length is changed from 16 inches to 8 inches (compare films No. 5 and 6)?
7. Among the six films, which has the greatest magnification? Why?
8. Among the six films, which has the greatest penumbra? Why?
9. Among the six films, which is the most unsharp? Why?
10. Among the six films, which is the sharpest? Why?
11. Among the six films, which has the greatest distortion? Why?

#### CASE-BASED PROBLEM-SOLVING

Using a flashlight and a plain wall surface or large piece of white cardboard, show how you could demonstrate the five principles of accurate image formation. Use the wall as the recording surface (film), the flashlight bulb as the focal spot, the beam of light as the beam of x-rays, and your hand and fingers as the object. Do not forget to demonstrate the geometric factors.

#### REVIEW QUESTIONS

1. Why is extending the source-film distance to 16 inches or using the so-called "long BID" a necessary adjunct to the paralleling or right-angle radiographic technique?
  - A. To avoid unsharpness of the image.
  - B. To avoid shape distortion of the image.
  - C. To reduce secondary radiation.
  - D. To facilitate correct vertical angulation of the BID.
  - E. To avoid superimposition of anatomical structures.
2. How do you change from long-scale contrast film to a short-scale contrast film and still maintain density?
  - A. Decrease the kVp and increase the mAs.
  - B. Decrease the kVp and decrease the mAs.
  - C. Increase the kVp and decrease the mAs.
  - D. Increase the kVp and increase the mAs.

3. Which of the following would minimize the size of the penumbra?
  - A. Large focal spot.
  - B. Long source-film distance.
  - C. Short source-film distance.
  - D. Long object-film distance.
4. If by mistake you used the exposure time for the short-BID technique (8-inch source-film distance) while using the long-BID technique (16-inch source-film distance), what would be the density of the film?
  - A. Too light.
  - B. No visible change in density.
  - C. Too dark.
  - D. Altered from long-scale to short-scale.
5. What is the primary factor in controlling density?
  - A. kVp.
  - B. Source-film distance.
  - C. mAs.
  - D. Collimation.
  - E. Film development.
6. What is the primary factor in controlling contrast?
  - A. Film speed.
  - B. Source-film distance.
  - C. kVp.
  - D. Exposure time.
  - E. mA.
7. Which of the following properties of x-rays is the basis for the rules of geometric projection?
  - A. X-rays travel at the speed of light.
  - B. X-rays travel in diverging straight lines from a point source.
  - C. The course of an x-ray photon can be diverted with an electromagnetic source.
  - D. X-rays can form a latent image on photographic film.
8. Regardless of the target-film distance, incorrect horizontal angulation will cause:
  - A. Elongation of the x-ray image.
  - B. Foreshortening of the x-ray image.
  - C. No significant change in the x-ray image.
  - D. Overlapping of teeth in the x-ray image.
9. The size of the x-ray tube focal spot influences radiographic:
  - A. Density.
  - B. Contrast.
  - C. Definition.
  - D. Distortion.
10. Which of the following does **not** control magnification of the radiographed object?
  - A. Focal spot-film distance.
  - B. Alignment of film, objects, and radiation BID.
  - C. Object-film distance.
  - D. Cathode size.
11. Which of the following does not constitute an advantage of the smallest possible focal spot?
  - A. Decreased geometric unsharpness.
  - B. Increased magnification.
  - C. Increased definition.
  - D. Decreased penumbra.
12. The density of an intraoral film indicates the:
  - A. Degree of darkness.
  - B. Difference between densities.
  - C. Speed of the screens.
  - D. Kilovoltage used.
  - E. None of the above.
13. Fog affects the contrast of an intraoral film because it:
  - A. Decreases film density.
  - B. Increases film density.
  - C. Produces white specks on the film.
  - D. Produces phosphorus crystals on the film.
14. Adequate coverage of the area of interest on the radiograph depends on which of these factors?
  - A. Proper alignment of film and the radiation beam to the area of interest.
  - B. Proper selection of film types.
  - C. Proper selection of film-projection techniques.
  - D. All of the above.
15. Which of the following factors minimize penumbra formation and magnification on a radiograph?
  1. Long BID.
  2. Short target-film distance.
  3. Film as close as possible to the teeth.
  4. Large focal spot.
  5. Short BID.
  - A. 2 and 5.
  - B. 5 only.
  - C. 1 and 3.
  - D. 3 and 4.
  - E. 1 and 4.

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# Radiographic Techniques and Procedures

- CHAPTER 4      Radiographic Infection Control Procedures
- CHAPTER 5      Intraoral Radiographic Techniques
- CHAPTER 6      Processing and Film Mounting Procedures
- CHAPTER 7      Analysis of Errors and Artifacts
- CHAPTER 8      Quality Assurance and Legal Aspects





# Radiographic Infection Control Procedures

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Discuss his or her general knowledge of the roles of various regulatory agencies in infection control.
2. Identify personal protective equipment.
3. List Spaulding's classification of inanimate objects.
4. List the specific infection control procedures needed in the x-ray room before and during the exposure of an intraoral film.
5. Describe how contaminated films are transported to the processing facility.
6. Describe how to prevent cross-infection when using a daylight loader or a darkroom to process films.
7. List the clean-up procedures required in the darkroom, daylight loader, and x-ray room.
8. Perform all necessary infection control procedures for the taking of a single intraoral radiograph using the Workshop/Laboratory Exercises format.
9. Suggest another radiologic technique other than the intraoral complete survey technique, which is simpler and has fewer infection control procedures than the recommended infection control procedures for intraoral radiography, using the Case-Based Problem-Solving format.
10. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

|                                |                         |                     |                      |
|--------------------------------|-------------------------|---------------------|----------------------|
| alcohol-phenol spray           | cytomegalovirus         | iodophors           | semicritical         |
| bacteria                       | daylight loader         | panoramic infection | sterilization        |
| barrier envelopes (pouches)    | disinfection            | control             | surface barriers     |
| Bloodborne Pathogen Rule (BBP) | exposure incident       | phenolics           | surface disinfectant |
| contamination                  | foot exposure switch    | phenols (complex)   | chemicals            |
| cross-contamination            | high-level disinfection | regulatory agencies | unit dosing          |
|                                | infectious organisms    | sanitization        | viruses              |

## INTRODUCTION

Dental patients and dental health-care workers (DHCWs) are constantly exposed to many infectious and potentially **infectious organisms**, whether airborne, salivaborne, waterborne, or bloodborne. Some of these include the common **viruses** such as the common cold and flu viruses; cy-

tomegalovirus; herpes simplex viruses 1 and 2; hepatitis B, C, D, E and G viruses; Epstein-Barr virus (infectious mononucleosis); and human immunodeficiency virus (HIV). Apart from viruses, **bacteria** such as staphylococci, diplococci, pneumococci, mycobacterium, chlamydia, spirochetes, and pseudomonas may also infect exposed DHCWs or patients. Many apparently healthy ambula-

tory patients suffer from infectious diseases, including sexually transmitted diseases, involving the oral cavity. Thus, it is necessary to use universal precautions and strict infection control protocols and procedures to protect both DHCWs and patients.

It is postulated that diseases can be spread in three ways:

1. From a patient to a DHCW.
2. From a DHCW to a patient.
3. From a patient to another patient.

Transmission may occur via a common vehicle such as blood, saliva, or airborne particles and through either direct or indirect contact via contaminated instruments or surfaces.

## AGENCIES THAT DEVELOP GUIDELINES AND REGULATIONS

In 1991, the federal government, through the Occupational Safety and Health Administration (OSHA), published the **Bloodborne Pathogen (BBP) Rule**, designed to protect the employee who works with bloodborne pathogens; however, the rule does not apply to the employer or patients. DHCWs who take x-rays do not commonly come into contact with blood, although they do come into contact with saliva. OSHA (Bloodborne Pathogen Rule, 1991) defines saliva as an “other potentially infectious material” (OPIM) in the transmission of bloodborne pathogens. Therefore, stringent procedures should be followed in dental radiography to prevent the spread of infectious diseases. This is especially true for intraoral radiography. In panoramic and extraoral radiography, there is little or no potential for contamination.

Another agency that is important in setting regulations is the Environmental Protection Agency (EPA). Because the EPA is more interested in the environment than people, it regulates surface disinfectant chemicals and the environmental aspects of infectious and other regulated waste disposal. Chemicals used to disinfect and sterilize objects in the radiography area must have an EPA registration number and be approved by the EPA.

Regulatory agencies responsible for producing infection control guidelines are the American Dental Association (ADA), American Academy of Oral and Maxillofacial Radiology (AAOMR), Centers for Disease Control (CDC), and the Office of Sterilization and Asepsis Procedures (OSAP). The ADA plays an important role in coordinating the regulations and recommendations set forth by the various agencies and published their most recent infection control guidelines in April 1996. The CDC played a major role in developing overall guidelines for all forms of medical practice including dentistry. The term

**universal precautions** refers to a set of precautions designed to prevent transmission of HIV, hepatitis B, and other salivaborne and bloodborne pathogens in the health-care setting. Universal precautions means that the same infection control measures must be used for all patients for any dental procedure where there is contact with saliva or blood. It also assumes that if there has been an **exposure incident**, then transmission of disease has occurred until otherwise “ruled out” by specific medical diagnostic testing procedures and protocols.

Although in most states the CDC and ADA guidelines are adopted by practitioners on a voluntary basis, the BBP Rule (Bloodborne Pathogen Rule, 1991) is enforced by either federal or state OSHA inspectors in a police role. The OSHA inspectors also look for chemical and safety hazards not necessarily covered by the BBP rule but published in other federal regulations. OSHA inspectors may levy fines as low as \$25 or \$50 for minor infractions and up to \$50,000 to \$70,000 for repeated or multiple serious violations and/or failure to abate. In most states the State Board of Dental Examiners (BDE) adopts many of the CDC and/or ADA infection control guidelines as regulations. These are actively policed and enforced by inspectors or representatives of the BDE. The difference between state board inspectors and OSHA inspectors is that state board inspectors look for infractions of infection control regulations that may affect the spread of disease to and from patients, owner DHCWs, and employee DHCWs. The employer DHCW is exempted from the OSHA regulations; however, it is the employer who must ensure employee compliance, and it is the employer who will pay all fines due to infractions by any employee. DHCWs not exposed to bloodborne pathogens or chemical and safety hazards are not subject to the OSHA rule.

## PERSONAL PROTECTIVE EQUIPMENT

Because saliva is considered to be a potentially infectious material in the transmission of bloodborne pathogens, there is a potential for contamination by saliva. During any radiographic procedure, universal precautions must be observed by exposed DHCWs, including the use of adequate personal protective equipment (PPE) such as gloves, the proper handling of contaminated materials, and the **decontamination** of surfaces and/or instruments exposed to saliva. It is not usually necessary to wear PPE such as impervious gowns, long sleeves, masks, and protective eyewear during routine dental radiology procedures when no aerosols, droplets, or spatter are generated (Fig. 4-1). It is advisable to use gowns, masks, and pro-





**Figure 4.1 X-Ray Room and Infection Control.** Personal protective equipment (PPE) such as the mask, protective eyewear, and gowns are not needed. The BID, yoke, and tubehead will need to be covered, the operator will need gloves.

protective eyewear when treating patients with gagging problems or respiratory infections such as the common cold, if such patients are accepted for treatment.

## CONTAMINATION OF DENTAL PROCESSING SOLUTIONS

It is possible to contaminate the processing solutions during the processing of intraoral radiographs. Katz et al. (1988) have shown that bacteria, when inoculated in very high concentrations, can survive in the dental radiographic developer and fixer for 2 weeks. Bachman et al. (1990) reported that bacteria inoculated on radiographic film in high doses survive the processing cycles in an automatic processor and contaminate and persist in the processing solutions. Stanczyk et al. (1993) investigated microbiologic contamination of an automatic dental processor and daylight loader during 1 week of simulated clinical use. The results from this study show that microbial contamination on radiographic film can survive the processing cycle. In addition, the films frequently became cross-contaminated within the processor. **Cross-contamination** within the processor emphasizes the need for strict attention to aseptic film handling before processing. Because there is no contamination of the hands or film cassette during the taking of panoramic or other extraoral films, such as cephalometric radiographs, no particular infection control procedures are needed on a routine basis. The only source of cross-infection is the biteblock used in panoramic radiology. This is usually covered with

a plastic barrier or decontaminated between procedures. In either case, the patient is asked to remove the contaminated barrier and throw it in the regular trash or to remove the biteblock and place it in a nearby container for further decontamination and processing. On a routine basis, various parts of the extraoral and panoramic x-ray machines should be disinfected, especially those “high-touch” parts used by patients and DHCWs. A schedule for these disinfection procedures must be available for the OSHA inspector.

## SURFACE DISINFECTION AND SURFACE BARRIERS

Based on Spaulding’s classification of inanimate objects (1968), surfaces that come into contact with intact mucous membranes but do not enter normally sterile areas of

Most items that become contaminated in dental radiology are semicritical. Semicritical items require **high-level disinfection** (kills tuberculosis [TB]), but whenever possible it is best to sterilize (kills all microbes) these. Table 4-1 enumerates the types of decontamination required for items in Spaulding’s categories and provides some examples.

In conjunction with the classification of surfaces and other items, DHCWs should adhere to routines whereby **high-touch** areas/surfaces are delineated. High touch areas/surfaces require **sanitization and disinfection** using a spray-wipe-spray technique once in the morning, once at the **end of the work shift**, and when **visibly contaminated**. The objective of the first step in this technique is sanitization, that is, removing potentially infectious material. This is followed by disinfection—spraying the decontaminating solution onto the surface and leaving it for 5 to 10 minutes or as recommended by the manufacturer. The product selected must have an EPA registration number on the label. The ADA and EPA have recommended that all products, such as **complex phenols, alcohol-phenol sprays, iodophors, and chlorine solutions**, must be labeled. Alternately during the day, surface covers or barriers may be used and changed between patients. All products should be EPA-registered, intermediate-level disinfectants that will kill **hydrophilic and lipophilic** viruses. When disinfectants are used in a secondary container, this container should be labeled to conform to the secondary labeling requirements in the hazard communications part of the Bloodborne Pathogen Rule. The secondary label should contain the product name, manufacturer, chemical identity, and appropriate hazardous warnings. In addition, hazard-related PPE such as protective eyewear, mask, gloves, and long sleeves should be worn when diluting concentrates of many of these solutions.



TABLE 4-1. Spaulding's Classification of Surfaces in Dental Radiology

| Spaulding's Categories | Contaminated Items                                                                                                                                                                                                                                                                                                                                                                                                                                                | Level of Decontamination                                               |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Critical               | Items that penetrate tissue and/or contact blood <ul style="list-style-type: none"><li>• None in day-to-day OMR.</li></ul>                                                                                                                                                                                                                                                                                                                                        | Sterilization required<br>OR<br>Disposable instruments                 |
| Semicritical           | No tissue penetration but contacts mucous membrane <ul style="list-style-type: none"><li>• Most intraoral devices and materials used in OMR.<br/><i>Examples:</i> Intraoral films, film holders, position-indicating devices, panoramic bite guides, digital image receptors.</li></ul>                                                                                                                                                                           | Sterilization, high-level disinfection<br>OR<br>Use of barriers        |
| Noncritical            | No tissue penetration, no contact with mucous membrane or saliva by equipment/devices, touches intact skin only <ul style="list-style-type: none"><li>• Most extraoral and panoramic OMR devices, especially parts thereof contaminated by the operator.<br/><i>Examples:</i> Leaded aprons, thyroid collars, panoramic side and front guides, cones, handles and knobs, yokes, tubeheads, control units, chair seats, handles, and head and arm rests.</li></ul> | Sanitization, intermediate-level disinfection<br>OR<br>Use of barriers |
| Environmental surfaces | No direct patient contact <ul style="list-style-type: none"><li>• Environmental surfaces that do not normally touch the patient but may be contaminated by the care provider.<br/><i>Examples:</i> High-touch surfaces on which exposed films/instruments are placed, table tops and working surfaces in the operatory, as well as the darkroom and daylight loader.</li></ul>                                                                                    | Sanitization, intermediate-level disinfection<br>OR<br>Use of barriers |

OMR, oral and maxillofacial radiology.

INFECTION CONTROL PROCEDURES RECOMMENDED IN INTRAORAL RADIOGRAPHY

The infection control procedures for intraoral radiography are more complex than those used in panoramic or extraoral radiography (Fig. 4-2).

There are three standard infection control procedures or methods used in intraoral radiography: (1) the Recom-

mended Three-Glove Method, (2) the Alternate Over-glove Method, and (3) the use of Commercial Protective Barriers (Pouches).

The Three-Glove Method is the recommended method of choice. This method involves first removing the contaminated gloves used in the intraoral film exposure technique. This is done in the x-ray machine room. Next, the contaminated exposed films, which were previously placed in a cup, are transported to the darkroom or daylight loader with



Figure 4.2 Infection Control Materials. (A) Numerous infection control materials are needed for intraoral radiography, and the infection control procedures involve many steps. (B) Only one biteblock cover or a disposable biteblock is needed for infection control in panoramic radiography, and the infection control procedures are very simple.



clean, bare hands (see Fig. 4-10B). A second pair of gloves is then donned over clean, washed hands to unwrap the contaminated film packets in the darkroom or inside the daylight loader. Powder-free gloves are recommended, because glove powders may affect the emulsion and result in artifacts in the radiographic image or may cause allergies. A third pair of gloves is used for cleaning the darkroom, daylight loader, and x-ray room operatory.

The **Overglove Method** is an alternative method, which involves placing plastic overgloves over the contaminated gloves in an aseptic manner before transporting the exposed, contaminated films to the darkroom or the daylight loader (see Fig. 4-10A). It is there the plastic overgloves are discarded and contaminated films are removed from the film packet without touching the films with the previously contaminated gloves. The contaminated gloves are then removed and the films are fed into the automatic processor with clean, bare hands.

A second pair of gloves is used to remove the waste film from the darkroom, daylight loader, and the x-ray operatory. The alternate, overglove method is not recommended, because it is not a proficient method and has the risk of contaminating the films during infection control processing procedure.

## USE OF COMMERCIAL PROTECTIVE BARRIER ENVELOPES (POUCHES)

Eastman Kodak (Rochester, NY) has introduced intraoral D, E+, and F speed films of all sizes previously sealed in plastic barrier envelopes (pouches) (Kodak dental film with ClinASept barrier) (Fig. 4-3). This plastic barrier envelope protects the film from contact with saliva while taking radiographs. Empty plastic barrier envelopes (ClinASept



**Figure 4.3 Barrier Envelopes.** (Right) Plastic barrier envelopes. (Left) Eastman Kodak has introduced prepackaged intraoral D, E+, and F speed films sealed in plastic envelopes. Empty polyester envelopes (ClinASept) may be purchased separately and used to seal and protect conventional film.



**Figure 4.4 Plastic Barrier Envelopes Used With No. 1 Film.** No. 1 film may be placed into these empty barrier envelopes, and the excess plastic folded over the film. Note V-shaped notch.

barriers) may be purchased separately and used to seal and protect conventionally wrapped film (Fig. 4-3). Although empty commercial barrier plastic envelopes are large enough to accommodate No. 2 regular film, they do not sell a No. 1 film size empty plastic barrier. However, a No. 1 film (narrow, anterior film) can be placed in the No. 2 film size plastic empty envelope and the excess plastic folded over the No. 1 film (Fig. 4-4). The plastic barrier-protected film fits into the Dentsply/Rinn XCP film-holding biteblocks well (Fig. 4-5). If these commercial plastic



**Figure 4.5 Film With Plastic Barrier Envelopes Will Fit Into Film-Holding Instruments.** Dentsply/Rinn XCP instrument holding a barrier envelope protecting the film from saliva. The Masel Precision film-holding instrument will also accommodate a film with a plastic barrier envelope.





**Figure 4.6 Opening the Plastic Barrier Envelope.** The clean film is removed from the plastic envelope and dropped into a container. There is a small "V" cut into the edge of the envelope to facilitate opening.

barrier envelopes are used on a film, they can be carefully opened and the film packet dropped out into a cup or a clean paper towel (Fig. 4-6). The film packet can then be opened in the conventional manner in the darkroom. The plastic barrier envelope has a small V-shaped notch at the edge (Fig. 4-4) that facilitates opening the envelope. Therefore, film packets with protective barrier envelopes (pouches) can be conveniently opened in a lighted area, and the film packet dropped onto a clean paper towel or into a paper cup (Fig. 4-6). The film packet can then be transported to the daylight loader or darkroom for processing with clean, bare hands. Use of these plastic barrier



A



B



C

**Figure 4.7 Preparation of X-Ray Room.** (A) All surfaces of chair arms and headrest that may be touched should be covered with plastic wrap. (B) The yoke, tubehead, and beam indicating device (BID) should be covered. (C) The counter top work surface and control panel should be covered. Sterile x-ray instruments, x-ray film, paper cup, cotton rolls, and powder-free latex or vinyl gloves should be placed on the counter top.



envelopes provides the only uncomplicated method of using a daylight loader and maintaining the integrity of an infection control procedure. They are recommended for use with both paper- or plastic-covered film packets. If barrier envelopes are not used, the recommended three-glove method should be used.

## PREPARATION OF THE X-RAY ROOM FOR INFECTION CONTROL

Plastic wrap should be used to cover all surfaces that may be touched, including chair arms, headrest, yoke, tubehead, beam indicating device (BID), and x-ray control panel and switch (Fig. 4-7). These surfaces will then not need to be cleaned and disinfected after dismissal of the patient. Areas that were not covered but were touched and therefore contaminated will require cleaning and disinfection after patient dismissal. The counter top work surface should also be covered with plastic wrap. To avoid unnecessary contamination of patient records, the chart should remain in only clean areas of the office.

## EXPOSURE TECHNIQUE (RECOMMENDED THREE-GLOVE METHOD OR PLASTIC BARRIER ENVELOPE METHOD)

After the patient is seated and the chair adjusted, the disinfected leaded apron and thyroid collar are placed on the patient. Before donning powder-free latex or vinyl gloves, the operator's hands should be washed with an appropriate antimicrobial soap, such as 4% chlorhexidine gluconate or 3% parachlorometaxylenol (PCMX),<sup>\*</sup> or alternately with ordinary liquid hand soap. The patient should be asked to remove partial dentures, dentures, and eyeglasses and store these to avoid cross-contamination. The use of a preprocedural antimicrobial mouth rinse by the patient is a useful and recommended step before inserting any item into the oral cavity. An antimicrobial mouth rinse containing 0.12% chlorhexidine gluconate, a phenolics solution, or a sanguinarine (herb)-based active ingredient will reduce intraoral microorganism counts significantly. Before intraoral radiography, the operator should don the first pair of powder-free latex or vinyl gloves (Fig. 4-8) and perform a cursory oral examination for complicating factors such as tori, high muscle attachments, ankyloglossia (tongue-tied), shallow maxillary palate, malposed teeth, deviations in direction or inclination of interproximal spaces, and the patient's propensity to gag. The operator should then set the x-ray machine control panel for proper mA, kVp, and exposure time settings.

The operator should then open the sterile pack containing the film-holding devices, place the film in the bite-



**Figure 4.8 Powder-Free Latex or Vinyl Glove Container.** Convenient container for three sizes of powder-free latex or vinyl gloves.

block, and position the film and biteblock in the patient's mouth for each exposure. The tubehead and BID should be positioned by touching only areas covered with plastic barrier covers. To avoid contamination, a foot exposure switch can be used to trigger the x-ray unit (Fig. 4-9).

If the x-ray machine does not have a foot exposure switch, the hand-held exposure button must be covered by a plastic or latex barrier. After exposing the radiograph, excess saliva is wiped from the film packet with a paper towel and then dropped into a clean paper cup without touching the outer surface of the cup. The paper cup should be kept away from the remaining unexposed films.

After the film packets with plastic barrier envelopes have been exposed, the operator should remove the plas-



**Figure 4.9 Foot Exposure Switch.** An x-ray exposure switch is controlled by a foot pedal to maintain infection control.



tic barrier envelope from each film packet (Fig. 4-6) and shake out the film packet into an empty paper cup. (As an added prevention against contamination, the plastic barrier envelopes can first be disinfected by a spray-wipe-spray procedure; and then after 10 minutes, the plastic barrier envelope can be removed from the film packet as described in Figure 4-6.)

### **TRANSPORTATION OF CONTAMINATED FILM PACKETS TO DARKROOM OR DAYLIGHT LOADER (THREE-GLOVE METHOD OR PLASTIC BARRIER ENVELOPE METHOD)**

When plastic barrier envelopes are not used, the contaminated film packets require special handling during transportation to the darkroom and daylight loader.

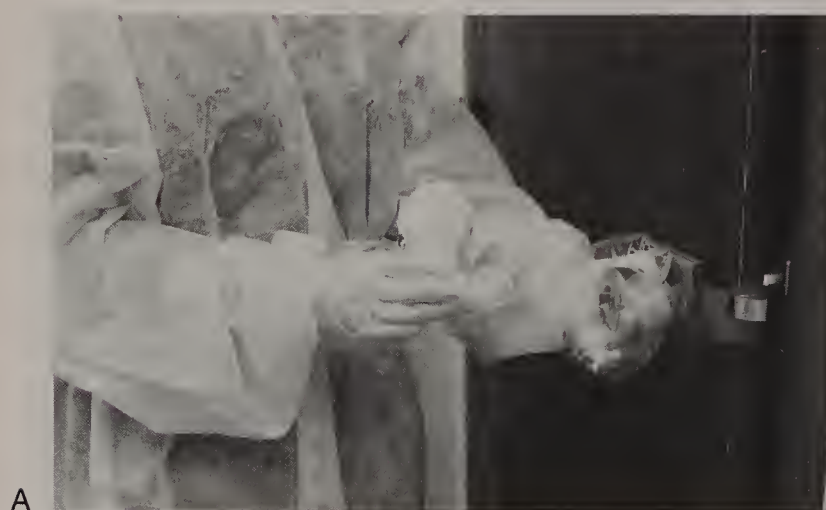
The three-glove method of infection control processing involves first the removal of the first pair of contaminated gloves in the area of the x-ray machine, and transportation of the paper cup filled with contaminated, exposed film packets to the darkroom or daylight loader with clean, bare hands (Fig. 4-10B).

### **DARKROOM PROCESSING OF CONTAMINATED FILM PACKETS (RECOMMENDED THREE-GLOVE METHOD)**

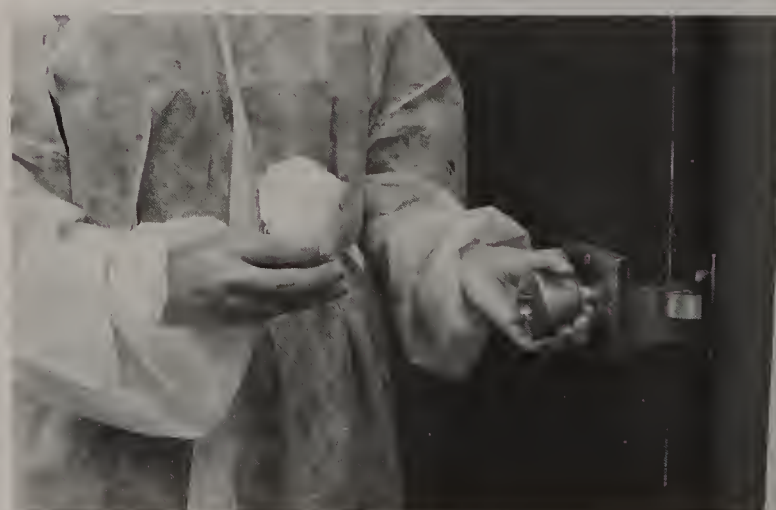
After placing two paper towels on the work surface near the processor, the operator pours the exposed films from the paper cup onto the first (left) paper towel. A second

pair of gloves must then be donned over clean, washed hands to unwrap the contaminated film packets in the darkroom or inside the daylight loader. Powder-free latex or vinyl gloves are recommended, because glove powders may affect the emulsion and result in artifacts in the processed x-ray film image or may cause allergies.

The film is removed from the packet without touching (contaminating) the film (Fig. 4-11). The operator should hold the film packet by the color-coded end and grasp the black tab and pull it away from the lead foil and packet (Fig. 4-12). This will pull the black-paper-covered film from the packet. The black-paper-covered film should then be carefully held over the second (right) paper towel and gently shaken until the film drops from the black-paper onto the second (right) paper towel (Fig. 4-12). After all film wrappers have been removed and placed on the first (left) paper towel, the operator should discard these and the contaminated cup into a regular waste bin while still wearing the contaminated gloves. The contaminated gloves can then be removed carefully and discarded in the regular trash bin. The operator should wash his or her hands in the darkroom with an antimicrobial or regular hand soap. According to OSHA, hands must always be washed immediately after degloving. With clean, ungloved hands, the exposed films can be held by their edges and fed into the automatic processor slot or be attached to the processing racks used in manual processing. After placing the films into the processor or processing solutions, the authors recommend that hands be washed again. The films should be removed from the automatic processor and dried, if manual processing is used. The processed films can now be brought out of the darkroom in a clean paper cup, ready to be mounted.



A



B

**Figure 4.10 Transportation Phase.** (A) Overglove plastic-type method of transporting contaminated film to processing area. (B) Two-glove method—contaminated gloves are removed for transportation, and new gloves are donned in processing area.





**Figure 4.11 Components of Film Packet.** From left to right: moisture and light-proof film packet, sheet of lead foil, black light-proof paper, and radiograph film.



**Figure 4.12 Method for Removing Films From Packet Without Touching Them With Contaminated Gloves.** From top to bottom: packet tabs are grasped; packet tab is opened; black interleaf paper and film are slid from outer wrapping; and film is dropped onto clean paper towel. Contaminated film packet should be dropped onto a separate paper towel.

## DAYLIGHT LOADER TECHNIQUE WITH CONTAMINATED FILM PACKETS (RECOMMENDED THREE-GLOVE METHOD)

In the three-glove method, the operator places the cup with the films in the bottom of the daylight loader chamber with bare, clean hands. Hands are then washed, and new second powder-free gloves are donned. After inserting the gloved hands through the sleeves, the film unwrapping procedure is as follows.

The film packets are carefully opened with the contaminated gloves by pulling gently on the outer tab. The exposed film should never be touched by the contaminated gloves (Fig. 4-13). The black-paper tab is carefully pulled back; when the black-paper-covered film is out of the white outer packet, the black-paper is gently shaken until the films drop into the clean paper cup on the right. As the operator opens each film packet, he or she discards the black-paper, lead foil, and plastic white film packet on the left side of the chamber. Once all film wrappings have been removed and the uncontaminated exposed films have been dropped into the clean paper cup on the right, the second pair of powder-free gloves are removed aseptically and discarded on the left side of the daylight loader chamber floor. With clean, ungloved hands, the operator picks up the films by the edges and feeds them into the processor (Fig. 4-14). When the last film has been fed into the processor slot, the ungloved hands are pulled through the sleeves. Waste from the daylight loader and the x-ray operator is removed and placed into a regular waste bin using a third pair of gloves worn over clean, bare hands. Hands must be washed again before processed films are removed from the processor and placed into the film mounts.

## POSTPROCEDURAL DUTIES (RECOMMENDED THREE-GLOVE METHOD)

According to OSHA, any contaminated film-holders should be placed in a holding solution before further decontamination and sterilization. In the previously used room containing the x-ray machine, operators should wear a **third** pair of latex or vinyl examination gloves to remove contaminated waste materials and plastic surface covers from radiographic equipment, chair, and control unit. These are discarded into a regular waste bin. Also, any contaminated surfaces or equipment should be disinfected using the three-step spray-wipe-spray method. The apron and/or thyroid collar should be cleaned and disinfected (Fig. 4-15). Soiled disposable items, such as latex or vinyl gloves, paper towels, and x-ray film packets, are not considered as infectious (regulated) medical waste.

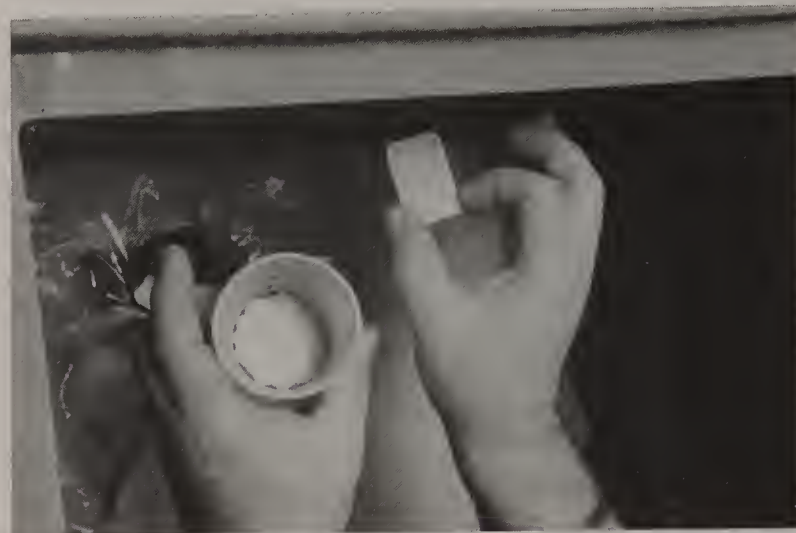


**Figure 4.13 Removing Film From Packets Into Daylight Loader.** With the three-glove method, powder-free latex or vinyl gloves are placed onto clean, washed hands outside the daylight loader, and the newly gloved hands are inserted through the sleeves. With powder-free latex- or vinyl-gloved hands inside the daylight loader, the polysoft cover of the film should be removed without touching the film. The film is dropped into the paper cup without being touched.

“Regulated” waste must be “capable of releasing fluids when compressed.” Examples include blood or saliva-soaked gauze or cotton rolls.

## ATLAS OF INFECTION CONTROL PROCEDURES IN INTRAORAL RADIOGRAPHY

The recommended infection control procedures in intraoral radiography are listed next in outline form to serve as a convenient guide for the x-ray operator.



**Figure 4.14 Feeding Film Into Daylight Loader Slots.** After removing film from packets, gloves are discarded. With ungloved, clean hands, the film should be picked up by the edges and fed into processor slots.



**Figure 4.15 Spray-Wipe-Spray.** Disinfection by the spray-wipe-spray method of nonwrapped, contaminated equipment is necessary on completion of the procedure if contaminated and at the end of the day.

### Activities During the Exposure Phase (Recommended Three-Glove Method or Method Using Commercial Protective Envelopes [Pouches])

1. Administer a preprocedural mouth rinse such as 0.12% chlorhexidine gluconate.
2. Disinfect surfaces at the beginning and end of each day (between patients only if visibly contaminated).
3. Avoid spraying electrical switches; wipe with disinfectant-moistened paper towel.
4. Apply surface covers to the yoke, tubehead, BID, control unit, head rest, arm rest, and any hand-held switches.
5. Place a paper towel/surface cover on a work area to hold film packets, sterilized film-holding devices, bite-blocks, paper cups, and a pair of latex or vinyl powder-free examination gloves.
6. Put on first pair of latex or vinyl powder-free gloves.



7. Place the sanitized leaded apron and collar on the patient after seating the patient.
8. Set the required mA, kVp, and exposure time on the control unit and reset as required during the exposure procedure.
9. Open the sterile pack containing the film-holding devices; affix the film and position in the patient's mouth.
10. Position the tubehead and BID during exposure technique procedures by touching only areas with surface cover barriers.
11. Use a foot switch or a wrapped hand-held switch to trigger the unit.
12. Drop exposed films into a paper cup without touching the outer surface of the cup.
13. If exposed film packets have plastic barrier envelopes, disinfect the envelopes and remove the noncontaminated film packets. After removal of the gloves in an aseptic manner, the hands are washed and then the noncontaminated film packets are carried in a clean cup to the processing room with clean, bare hands. The films can now be processed without further infection control considerations.

#### **Activities During the Transportation Phase (Recommended Three-Glove Method)**

1. Remove first pair of gloves.
2. Pick up the cup with exposed films and the extra empty cup.
3. With clean, bare hands carry the two paper cups to the processing area.

#### **Activities During the Darkroom Film Processing Phase (Recommended Three-Glove Method)**

1. Place two paper towels on a work surface near processing area.
2. Pour the cup of exposed film onto first (left) paper towel.
3. Wash hands and don new second pair of latex or vinyl powder-free gloves.
4. Open each film packet by pulling gently on the outer tab, which will reveal an inner black-paper tab.
5. Carefully hold paper tab and tease it out of the packaging, shaking it gently until the film drops onto the clean second (right) towel. Keep the contaminated film packet wrapping separate from the film on the first (left) towel.
6. Once all wrappers have been removed and the films dropped onto the second (right) paper towel, discard the film wrappings on the first (left) paper towel, and the second pair of powder-free latex or vinyl gloves in the regular waste bin.
7. With clean, bare hands pick up films by the edges and feed them into the automatic processor or attach films to a processing hanger, if using manual processing.
8. Wear new **third** pair of gloves to remove waste and surface covers from radiographic equipment, chair, and the control unit in x-ray operatory; discard them into a regular waste bin.

#### **Activities During the Daylight Loader Film Processing Phase (Recommended Three-Glove Method)**

##### **Film Processing: Daylight Loader**

1. Open lid of the processor with clean, bare hands in the recommended three-glove method.
2. Place two paper towels on the floor of the loader's open chamber.
3. Place the clean, empty cup on the right side (for right-handed DHCWs) and the cup with the contaminated films on the left side of the chamber floor.
4. Close the lid of the chamber. Wash hands and don second pair of powder-free latex or vinyl gloves.
5. Insert newly gloved hands through the sleeves of the daylight loader.
6. Open each film packet by pulling gently on outer tab, revealing the inner black-paper tab.
7. Hold paper tab carefully and tease it out of packaging, shaking it gently until the film drops into clean paper cup (Fig. 4.13).
8. Discard paper, lead foil, and plastic outer wrap on the left side.
9. Once all wrappings have been removed and films dropped into cup, discard powder-free latex or vinyl gloves on the left side.
10. With clean, bare hands pick up films by the edges and feed them into the processor (Fig. 4-14).
11. Remove ungloved hands through sleeves.
12. Place new third pair of gloves on hands to remove waste from loader chamber, surface covers from radiographic equipment, chair, and control unit in x-ray operatory, and discard them into a regular waste bin.
13. Wash hands with a liquid soap and water.
14. Remove films from processor and mount them.

#### **Unit Dosing of Materials for Intraoral Radiography (Recommended Three-Glove Method or Method Using Barrier Envelopes Called Pouches)**

Unit dosing of the materials is needed before the start of any radiographic procedure and is essential to control cross-contamination. The following is a list of materials that have been unit dosed for infection control procedures used in intraoral radiography.

##### **Materials During Film Exposure**

1. One dose of preprocedural and antibacterial mouth rinse.
2. Paper towel.
3. Disinfectant.
4. Barriers (commercial preformed or a roll of plastic wrap).
5. Powder-free gloves (latex or vinyl).
6. Radiographic films (polysoft type).
7. Sterile film-holders.
8. Two paper cups.
9. Leaded thyroid collar and apron.

*Masks, eyewear, and protective gowns are needed when a patient has a known gag reflex or respiratory infections.*

**Materials During Transportation (Recommended Three-Glove Method—Without Barrier Envelopes Called Pouches)**

1. Empty paper cup.
2. Cup with exposed films.
3. Two paper towels or plastic wrap.
4. Clean, bare hands.

**With Barrier Envelopes (Pouches)**

1. Cup with noncontaminated exposed film packets.
2. Clean, bare hands.

## INFECTION CONTROL PROCEDURES RECOMMENDED FOR PANORAMIC RADIOGRAPHY

When taking panoramic radiographs, the operator should come to the panoramic x-ray machine with washed hands and no gloves (Fig. 4-16A). There is no need to wrap anything for this procedure, except to cover the bite guide with a “baggie” or “finger cot” or to use a premanufactured, disposable bite guide. The patient should be asked

to rinse with a preprocedural mouthwash. A sanitized (clean) poncho-style leaded apron is placed on the patient. To prevent contamination of the operator’s hands, the patient places and removes the disposable biteblock or cover and discards them in a regular waste bin after the exposure (Fig. 4-16B). The patient chin rest, head positioning guides, and “hand grips” of the panoramic x-ray unit should be sanitized after making the exposure. No further infection control procedures are necessary for processing (Fig. 4-16C).

### WORKSHOP/LABORATORY EXERCISES

#### EXERCISE 4.1. PREPARATION OF THE X-RAY ROOM

**Materials and Equipment Needed**

1. One intraoral film.
2. Two paper cups.
3. Food wrap or other barrier material.
4. EPA-registered disinfecting solution.
5. Latex or vinyl examination gloves (powder-free).



A



B



C

**Figure 4.16 Panoramic Radiology.** (A) No personal protective equipment is required for the operator. (B) Patient places and removes plastic or latex biteblock protective sleeve. (C) Processing panoramic film requires no infection control procedures; this device labels the panoramic film electronically before processing.



6. Dentsply/Rinn (or other) biteblocks and film-positioning device.

#### Instructions

For this exercise, the student must demonstrate the proper infection control preparations of the x-ray unit control and machine parts, chair, and adjacent counter top work areas before taking one periapical radiograph using the paralleling technique. When all preparations have been made, the instructor will check the room before continuing on to Exercise 4.2.

### EXERCISE 4.2. FOOD DYE DEMONSTRATION

#### Materials and Equipment Needed

1. Latex or vinyl examination gloves used in Exercise 4.1.
2. Cup containing “contaminated” film packet, which has been “whetted” with water or better still, glycerine (available in food and drug stores) solution. The water or glycerine solution should be colored with food dye.

#### Instructions

Using the three-glove method, demonstrate either:

**Step 1:** Transportation, placement into the daylight loader, unwrapping of the contaminated film packet, and isolation of the clean film therein. Do not process the film. Demonstrate how the contaminated materials are discarded.

Or . . .

Transportation, entry into the darkroom, preparation of the counter top, unwrapping of the contaminated film packet, and isolation of the clean film. Do not process the film. Demonstrate to the instructor how the contaminated materials are discarded.

**Step 2:** Examine your hands; note if any food dye is on them. Explain the significance of this. Explain the significance of any food dye remaining on the counter top or processing equipment.

### EXERCISE 4.3. POSTPROCEDURAL DUTIES

#### Materials and Equipment Needed

1. Gloves (clean).
2. Waste container(s).
3. Waste materials used in Exercise 4.1.
4. Decontaminating solutions.
5. Paper towels or other “wipe” material.

#### Instructions

Return to the room where the x-ray machine is located. Demonstrate to the instructor all procedures necessary before preparing the room for the next x-ray patient.

Explain why you chose to place all or some discarded materials in either or both the “unregulated” waste container versus the “regulated” waste container.

### CASE-BASED PROBLEM-SOLVING

Intraoral radiography is such a hassle, especially when it comes to infection control! For this exercise, and in many other clinical circumstances, we accept that one or several intraoral radiographs will always be needed. However, assuming the information in a full-mouth survey is needed, can you suggest another method whereby all, most, or even information about anatomical structures adjacent to the patient’s teeth and jaws can be obtained, but without most of the infection control hassles of the full-mouth survey? Make an infection control comparison chart comparing the full-mouth survey and your proposed alternate method.

**Hint:** Carefully read “Atlas of Infection Control Procedures in Intraoral Radiography” and “Infection Control Procedures Recommended for Panoramic Radiography” in this chapter. The answers are mentioned in several areas within the chapter.

### REVIEW QUESTIONS

1. In which of the following can diseases be spread as a result of taking an intraoral radiograph?
  - A. From patient to DHCW.
  - B. From DHCW to patient.
  - C. From one patient to another patient.
  - D. All of the above.
  - E. None of the above.
2. The components of an infection control protocol in dental radiography include:
  - A. Operatory.
  - B. Darkroom.
  - C. Operator.
  - D. A and C only.
  - E. All of the above.
3. Bacterial spores are a problem in sterilizing x-ray instruments and equipment because:
  - A. They are resistant to antibiotics.
  - B. They are easy to kill but are usually protected by organic matter.
  - C. They are very resistant to physical and chemical agents.
  - D. Most pathogenic bacteria are spore formers.
4. In general, personal protective equipment includes:
  - A. Gloves.
  - B. Masks.

- C. Gowns.
  - D. Resuscitation bags, pocket masks, other ventilation devices.
  - E. All of the above.
5. You are about to perform a full-mouth survey on a patient who has no medical conditions as indicated by the medical history and interview. For this appointment the dental professional should wear:
    - A. Gloves only.
    - B. Glasses and a face mask.
    - C. Glasses and gloves.
    - D. Glasses, gloves, and a face mask.
  6. Which of the following statements is/are correct?
    - A. Taking sterilized x-ray instruments out of a package and placing them in clean drawers is recommended.
    - B. Hands should be washed thoroughly before and after taking intraoral radiographs.
    - C. The risk of contracting acquired immune deficiency syndrome (AIDS) during x-ray procedures is greater than the occupational risk for hepatitis B.
    - D. Both A and C are correct.
    - E. Both A and B are correct.
  7. The most commonly used glove type for x-ray procedures is what kind of gloves?
    - A. Medical grade vinyl.
    - B. Sterile vinyl.
    - C. Unsterile latex.
    - D. Sterile latex.
    - E. Medical grade latex.
  8. The class of chemical that is least effective as a surface disinfecting agent is:
    - A. Hypochlorite.
    - B. Iodophor.
    - C. Complex phenol.
    - D. Synthetic phenol.
    - E. 70% isopropyl alcohol.
  9. With respect to x-ray instruments, which of the following statements is most appropriate?
    - A. Sterilize everything.
    - B. Be certain to sterilize hands before x-ray procedures.
    - C. Dark drawer sterilization can work under certain conditions.
    - D. Do not worry about sterilization for most x-ray instruments.
    - E. Do not disinfect when you can sterilize.
  10. Which of the following is not a virus?
    - A. Epstein-Barr.
    - B. Pneumococci.
    - C. Herpes simplex.
    - D. Hepatitis B.
  11. Glove powder can affect some film emulsions; thus, powder-free gloves are recommended. Glove powder may also be responsible for:
    - A. Allergic reactions.
    - B. Dirty uniforms.
    - C. Nonallergic skin reactions.
    - D. All of the above.
  12. The OSHA Bloodborne Pathogen Rule is enforced by:
    - A. Federal inspections.
    - B. State inspections.
    - C. Employees.
    - D. All of the above.
  13. Using the recommended infection control method for processing films, as stated by the authors in this chapter, how many pairs of gloves are actually used from the beginning to the end of the procedure?
    - A. One glove and an overglove.
    - B. Two latex or vinyl gloves.
    - C. Three latex or vinyl gloves.
    - D. Two latex gloves only.
  14. Is it true that bacteria from dirty films can survive in the processing solutions?
    - A. Yes.
    - B. No.
  15. Is it true that microbial contamination of an x-ray film can survive the processing cycle?
    - A. Yes.
    - B. No.

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# Intraoral Radiographic Techniques

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *State the three types of intraoral projections.*
2. *Explain the four basic principles of periapical techniques.*
3. *Identify the two types of intraoral periapical techniques.*
4. *Discuss the six rules to follow in using the paralleling technique.*
5. *Demonstrate the Dentsply/Rinn long BID paralleling technique.*
6. *Describe the bisecting angle technique.*
7. *Demonstrate the bitewing technique.*
8. *Describe the three types of occlusal projections.*
9. *Discuss the proper positioning of a patient in the event an aiming device is not used during the exposure.*
10. *Describe how to manage patients with special problems.*
11. *Perform a full-mouth or half-mouth survey on a skull or manikin using the Workshop/ Laboratory Exercises format.*
12. *Explain how to handle a common problem with the paralleling technique in the maxilla using the Case-Based Questions format.*
13. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                           |                            |                            |                         |
|---------------------------|----------------------------|----------------------------|-------------------------|
| afferent/efferent         | cone-cutting/partial image | mandibular cross-sectional | psychic stimuli         |
| aiming/locator ring       | cross-sectional occlusal   | projection                 | rectangular BID         |
| ala-tragus line           | radiograph                 | mandibular symphysis       | rectangular collimation |
| beam indicating device    | digital method             | projection                 | retromolar mylohyoid    |
| (BID)                     | edentulous                 | maxillary orientation line | space                   |
| bisecting angle technique | elongation                 | maxillary topographic      | rule of isometry        |
| biteblock                 | exostosis                  | projection                 | sagittal plane          |
| bitewing radiograph       | film-holders               | mean tangent               | tactile stimuli         |
| bitewing tab              | film placement             | medulla oblongata          | thoracicoabdominal      |
| central ray               | foreshortening             | oropharyngeal muscles      | muscles                 |
| commissure-tragus line    | gag reflex                 | paralleling technique      | vertical angulation     |
| complete-mouth x-ray      | glossopharyngeal nerve     | periapical radiograph      | vertical bitewings      |
| survey (CMX) or full-     | horizontal angulation      | posterior bitewing         |                         |
| mouth survey (FMX)        | indicator rod              | instrument                 |                         |

## INTRODUCTION

Intraoral radiographs are made by placing the film packet inside the oral cavity and projecting the x-ray beam at various angles from a position outside the mouth through the anatomical region of interest toward the film. There are three types of intraoral projections: (1) periapical, (2) bitewing, and (3) occlusal.

### PERIAPICAL RADIOGRAPHS

Periapical radiographs (*peri* meaning “around,” and *apical* meaning “apex” or “end” of tooth root) record images of the outlines, position, and mesiodistal extent of the teeth and surrounding tissues. In a periapical radiograph, it is essential to obtain the full length of the tooth and at least 2 mm of the periapical bone (Fig. 5-1). The most universal film size is the No. 2 film size, which can be used for the older pediatric patient and for almost all adults.

### BITEWING RADIOGRAPHS

Bitewing radiographs record, on a single film, images of the outlines, position, and extent of the crowns and the coronal one-third of the interalveolar bone and a portion of roots of the maxillary and mandibular teeth. Much less frequently, vertical bitewings are used to extend the vertical coverage of the interalveolar bone and roots; however, the horizontal coverage is diminished, so more radiographs must be taken. A bitewing tab or special bitewing film-holding device is needed to hold the film in place. Bitewing film can be purchased pretabbed in various sizes. Also, bitewings can be made by purchasing bitewing tabs that can be centered horizontally or vertically on the film packet. They are valuable for detecting inter-

proximal caries, overhangs on restorations, periodontal conditions, calculus deposits, chronic resorption of the interalveolar bone, the pulp chamber shape and size, pulp stones, and the occlusal relationship of the teeth. Bitewings are particularly valuable for the detection of small interproximal carious lesions that are difficult or impossible to find by other clinical methods, including periapical radiographs. This is because the film is very close to and parallel to the teeth, and the x-ray beam is perpendicular to the teeth and film.

### OCCUSAL RADIOGRAPHS

Occlusal radiographs record images of the incisal edges and the occlusal surfaces of the teeth and a cross-section (a plane at right angles to the long axes of the teeth) of the dental arches. The maxillary occlusal radiograph depicts images of the hard palate, upper lip, and base of the nose; the mandibular occlusal radiograph records the images of the tongue, floor of the mouth, and lower lip. Occlusal radiographs are used to detect the presence and relative positions of impacted or embedded teeth, foreign bodies, fractures, calcified stones in the salivary ducts, and other gross abnormal conditions or lesions of the jaws.

### COMPLETE-MOUTH SURVEY/FULL-MOUTH SURVEY

A complete-mouth x-ray survey (CMX) or full-mouth survey (FMX) is composed of a series of individual periapical and bitewing radiographs. The CMX or FMX should completely cover all the teeth and tooth-bearing alveolar bone of both arches. A complete intraoral radiographic survey may consist of as many as 22 films, whereas another survey may have fewer total films. The number of radiographs needed for a complete radiographic examination of a patient will depend on the technique used, number of teeth present, condition of the teeth, age of the patient, individual anatomical variations, film size used, and diagnostic needs of the dentist. We recommend that an adult dentulous CMX or FMX consist of 14 to 16 periapicals and 4 bitewings (Fig. 5-2A). For patients who are partially or totally edentulous (without teeth), the CMX or FMX can be streamlined to as many as 10 to 14 periapicals (Fig. 5-2 B).

### BASIC PRINCIPLES OF PERIAPICAL RADIOGRAPHY

There are certain basic principles that must be considered in the learning and perfecting of periapical intraoral radiographic techniques. They include (1) the anatomy of the teeth and jaws, (2) patient head position, (3) x-ray beam angulation, and (4) point of entry of x-ray beam.



Figure 5.1 Periapical Radiograph. Left mandibular molar view.





**Figure 5.2 Full-Mouth X-Ray Surveys.** (A) Full-mouth dentulous survey of 8 No. 2 periapical films, 8 No. 1 periapical films, and 4 No. 2 posterior bitewings. (B) Full-mouth survey of edentulous mouth using 14 No. 2 films.

## ANATOMICAL CONSIDERATIONS

There are two anatomical considerations the operator must take into consideration before the placement of the film into the patient's mouth. They are the (1) location of the long axes of the teeth and (2) location of the apices of the teeth.

### Location of the Long Axes of the Teeth

Excellence in intraoral radiographic technique depends on the operator's knowledge of the approximate positions of the long axes of the teeth in the jaws. Practically all the teeth in the upper jaw are tilted outward (buccally or facially) (Fig. 5-3). The flatter the palatal vault of the maxilla, the greater the tendency for the teeth to tilt outward. In the mandible, the six anterior teeth are usually tilted outward; on occasion, they are positioned vertically or tilted backward (lingually). The mandibular premolars, on the other hand, are usually positioned more nearly vertical, and the lower molars tilt slightly lingual (Fig. 5-4). Also, the operator should be aware that the crown or apparent axis of the tooth is different from the root or true axis of the tooth (Fig. 5-5). A line drawn through the ver-

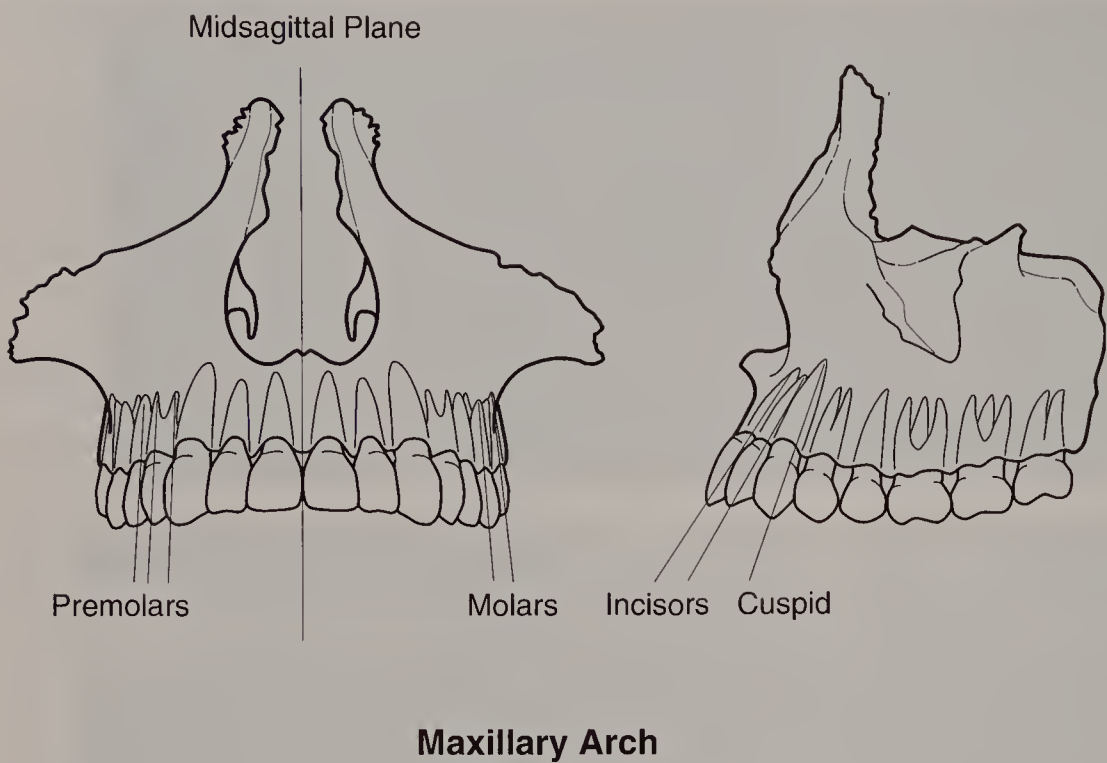
tical axis of the crown of the tooth and one drawn through the root forms an angle (crown-root angle) that generally varies from 5 to 20°. Furthermore, the greater the tilt of the tooth, the greater the crown-root angle.

### Location of the Apices of the Teeth

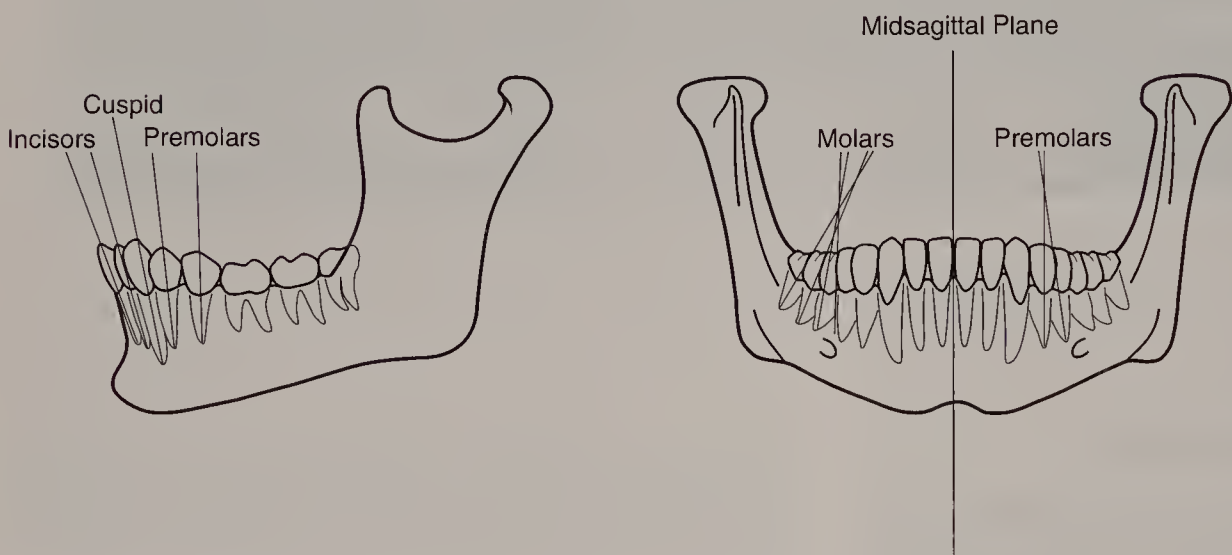
The apical region of the maxillary teeth is located on an imaginary line drawn from the tragus (bump in front of the ear opening) of the ear to the ala (wing) of the nose. To localize each maxillary tooth's apical region, a line is dropped from various landmarks on the face to the **ala-tragus line** (Fig. 5-6). The apices of the mandibular teeth are 0.5 cm above the lower border of the mandible. The same landmarks used for localizing the maxillary teeth may be used in the mandible, except the vertical lines must be extended further down past the ala-tragus line to the point 0.5 cm above the inferior border of the mandible.

## HEAD POSITION

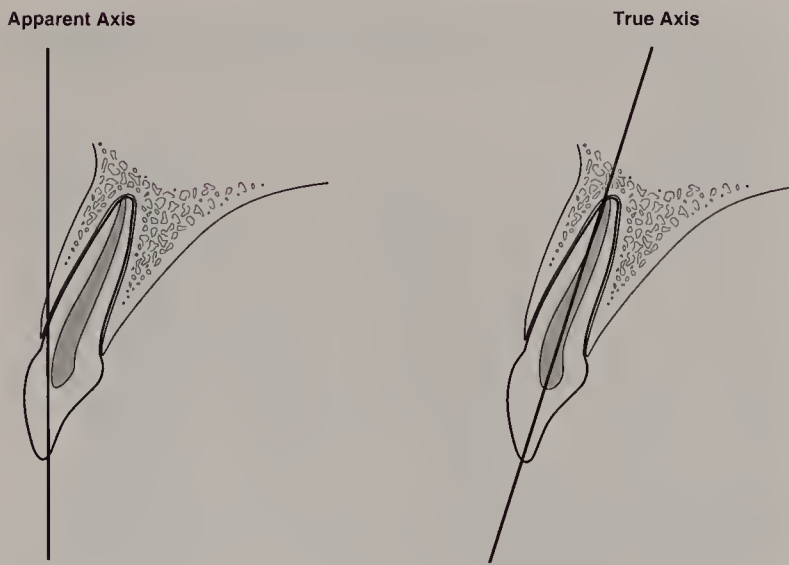
In almost all the intraoral periapical techniques, it is recommended that the patient be placed in an upright posi-



**Figure 5.3 Maxillary Teeth Angulations.** Drawing of long axes of teeth in the maxillary arch. Note that all teeth are inclined outward.

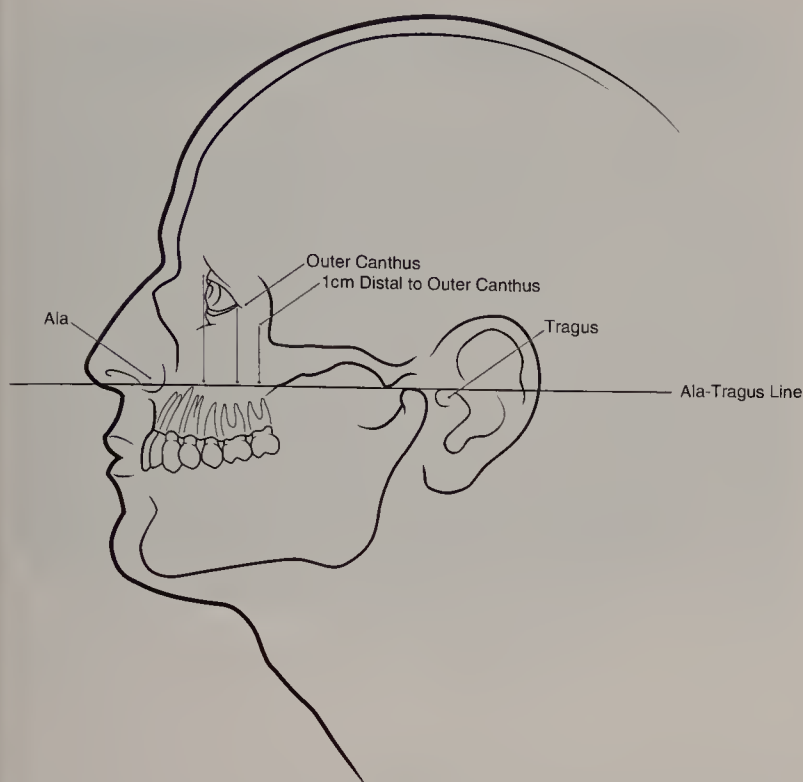


**Figure 5.4 Mandibular Teeth Angulations.** Drawing of long axes of teeth in mandibular arch. Anterior six teeth are usually tilted outward; the mandibular premolars are usually positioned more nearly vertical. Lower molars tilt slightly inward.



**Figure 5.5 True Vertical Axis of Tooth.** The true vertical axis of the tooth generally varies with the vertical axis of the crown by 5 to 20°.





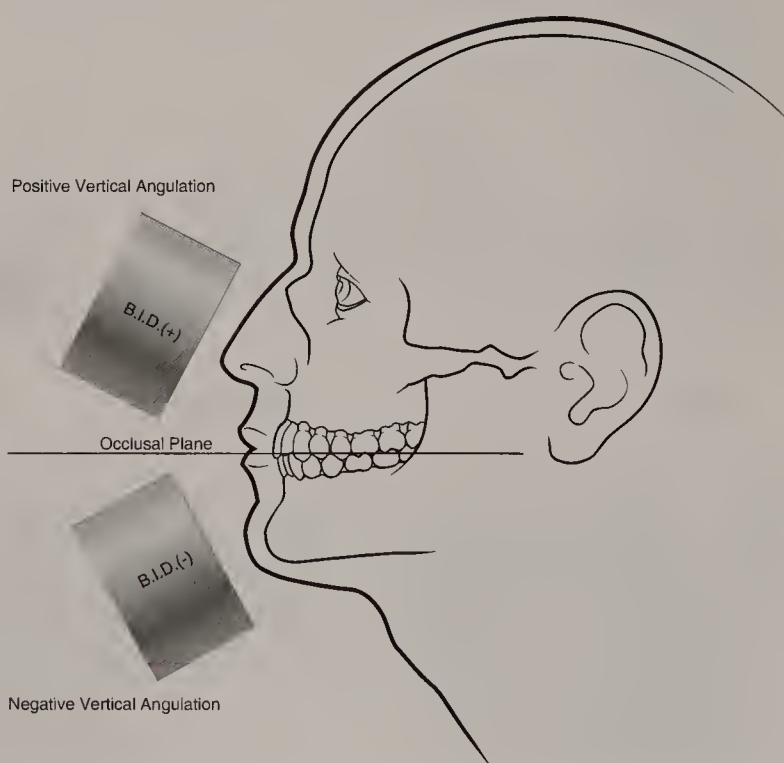
**Figure 5.6 Locating Apices of Teeth.** Drawing of apices of maxillary teeth. To localize each maxillary tooth apical region, use the imaginary line from various landmarks on the face to the ala-tragus line. The landmarks for the maxillary second molar, first molar, second premolar, canine, and incisors are shown on the drawing. In the mandible, the root apices can be established by estimating the points of entry from the lower border of the mandible. This is usually the width of the thumb (0.25 inches).

tion with the occlusal plane of the teeth to be radiographed parallel to the floor, and the sagittal plane of the head perpendicular to the floor. The sagittal plane of the skull divides the skull vertically in the midline into right and left halves. The **maxillary orientation line** is an imaginary line drawn from the tragus of the ear to the ala of the nose and is often referred to as the ala-tragus line. This line should be parallel to the floor when radiographing the maxillary teeth. The mandibular occlusal plane changes when the mouth is opened. It is on a line from the corner of the mouth to the tragus of the ear. Therefore, the patient's head should be tilted slightly backward so the occlusal plane of the mandible will be parallel to the floor when the mouth is opened. The operator should make sure that the patient does not open too wide, as this will contract the muscles of the floor of the mouth and make it difficult to place mandibular periapical films down far enough. If the patient tenses the muscles of the floor of the mouth, the film will not go down far enough, and the patient will experience pain when closing down on the biteblock. These muscles can be relaxed by swallowing. The sagittal plane of the skull (midline of the face) should be perpendicular to the floor before placing films into the mouth. The correct head position makes for a good starting point no matter what intraoral radiographic

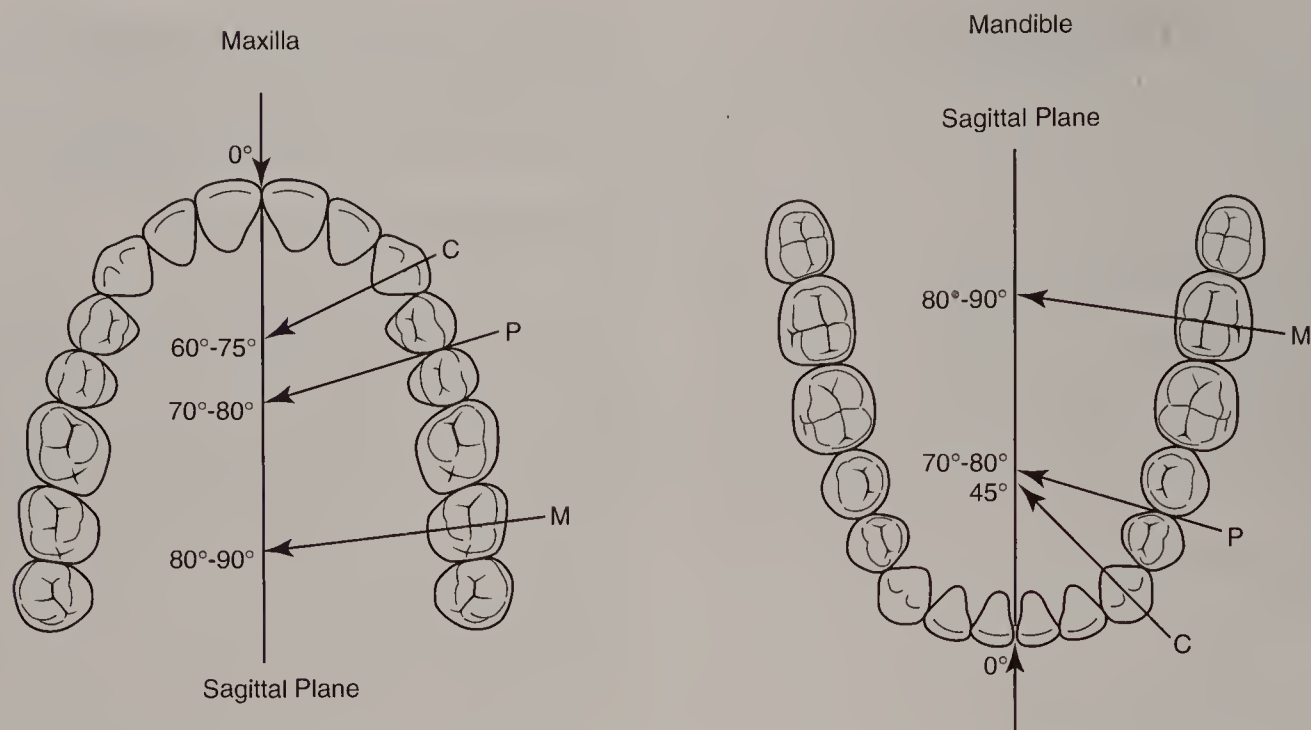
technique is used. Also, for the operator's comfort and to avoid back strain, the chair should be raised or lowered so the patient's mouth is about level with the operator's elbow when he or she stands beside the patient.

## X-RAY BEAM ANGULATION

The x-ray tubehead has two directional projections: vertical angulation and horizontal angulation. **Vertical angulation** is the movement of the tubehead up and down in relation to the occlusal plane, which is parallel to the floor (Fig. 5-7). The changes in vertical angulation are measured in degrees and recorded on a dial located on the side of the x-ray tubehead. A downward angulation of the BID is a positive, or plus (+), angulation; an upward angulation of the BID is a negative, or minus (-), angulation. **Horizontal angulation** is the movement of the x-ray tubehead around the patient's head in relation to the sagittal plane when the patient is in an upright position (Fig. 5-8). Horizontal angulation is the same direction as the horizon. The horizontal angles rotate around the patient's head, or 360°, as if the head were a center of a circle. The horizontal angulation of the x-ray beam should be directed through the contacts of the teeth and perpendicular to the horizontal plane of the film, if possible (Fig. 5-9). There are countless ways that teeth may be rotated or malposed from the normal occlusal pattern. To open the contact areas of teeth on a radiograph, the operator must observe how the teeth contact one another and then project the



**Figure 5.7 Vertical Angulation.** Above occlusal plane: BID-positive vertical angulation. Below occlusal plane: BID-negative vertical angulation.

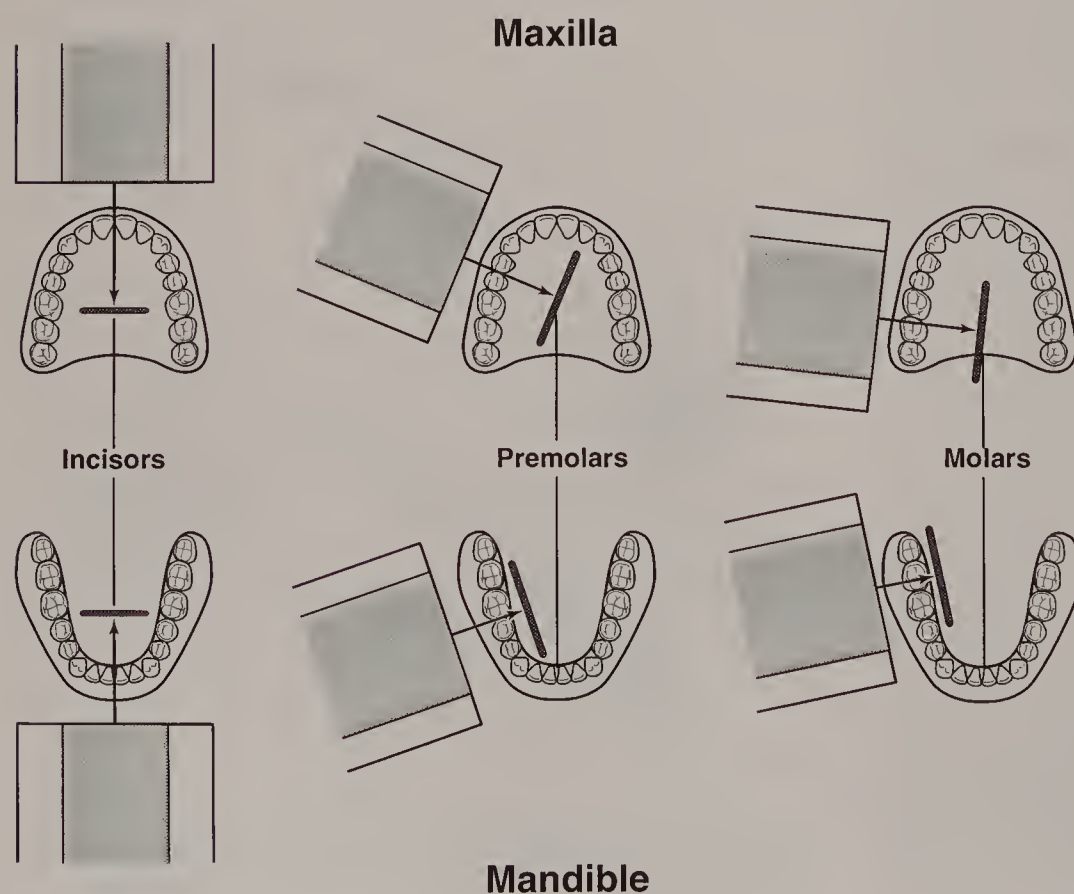


**Figure 5.8 Horizontal Angulation.** Horizontal angulation for various regions of the mouth.

x-rays through the contact areas of the teeth at a 90° angle to the film. Improper horizontal angulation will cause overlapping of the tooth images, which may obscure diagnostic information such as the presence of caries, recurrent caries, calculus, or an open contact (Fig. 5-10).

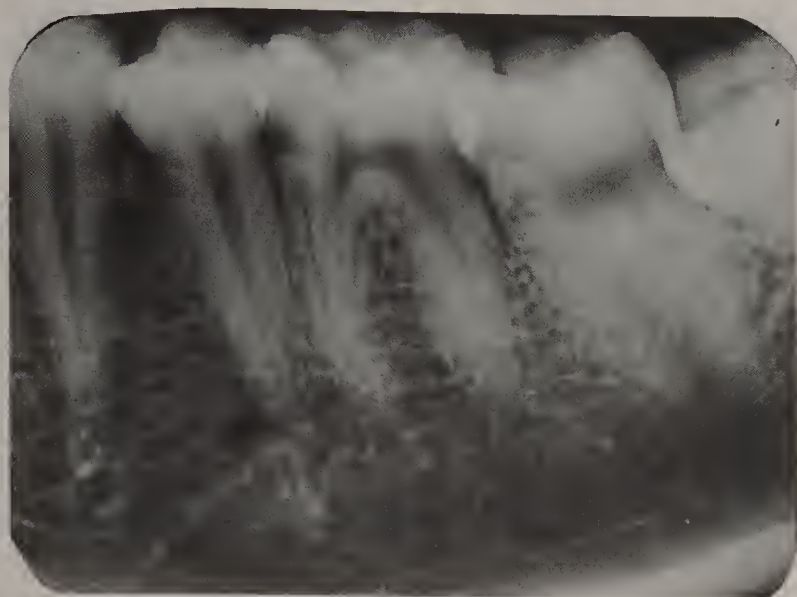
### POINT OF ENTRY

The point of entry of the x-ray beam should be directed through the center of the region being radiographed. The objective is to completely cover the film with the beam of



**Figure 5.9 Horizontal Angulation (Path of Central Ray Perpendicular to Horizontal Plane of Film).** Summary of proper horizontal angulations of BID and film coverage with x-ray beam for each region of the jaw. Note the size of the smaller rectangular BID and the size of the larger circular BID.





**Figure 5.10 Overlapping.** Overlapping of mandibular premolars and molars from improper film placement or BID placement.

radiation. If this is *not* done, a “cone-cut” or “partial image” will be seen in the resultant radiograph (Fig. 5-11). This area on the film will be clear, as it was not exposed to the x-ray beam.

## PERIAPICAL RADIOGRAPHY TECHNIQUES

There are two intraoral periapical techniques that are used in dental radiography to minimize shape distortion of the radiographic image: the **paralleling technique** and the **bisecting angle technique**. The paralleling technique is preferred because it produces a more accurate and less distorted radiographic image than the bisecting angle technique. However, there are advantages and disadvantages to both techniques, and there are anatomical variations from patient to patient or within the oral cavity of the same patient that present circumstances for modification of the projection technique used.

## PARALLELING OR RIGHT ANGLE TECHNIQUE

The paralleling or right angle intraoral radiographic technique is based on the paralleling principle. The paralleling principle, in essence, follows the five rules of accurate image formation (discussed in Chapter 3) to minimize the undesirable image characteristics of unsharpness, magnification, and shape distortion (Fig. 5-12).

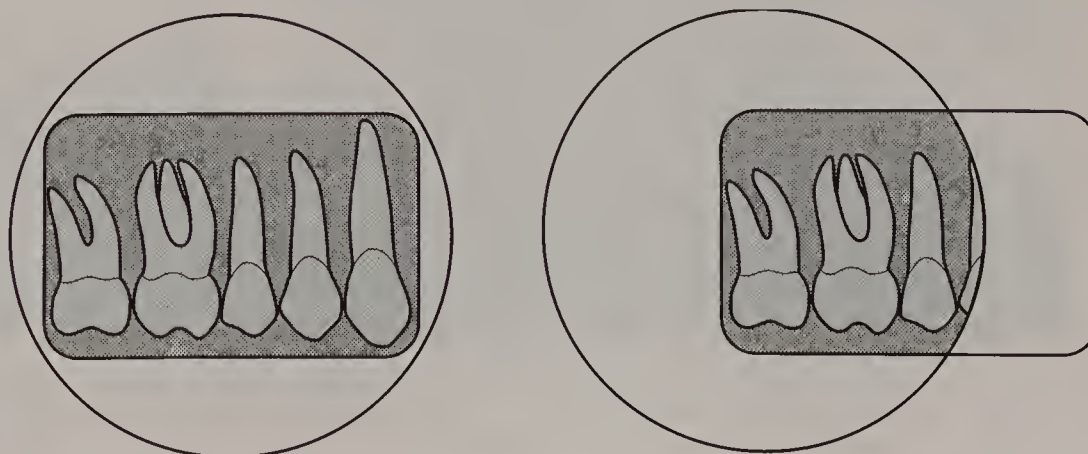
The two fundamental rules for the paralleling technique are:

1. The film is placed in the mouth in a position that is parallel to the long axes of the teeth.
2. The central ray of the x-ray beam is directed perpendicular or at right angles to both the long axes of the teeth and the plane of the film.

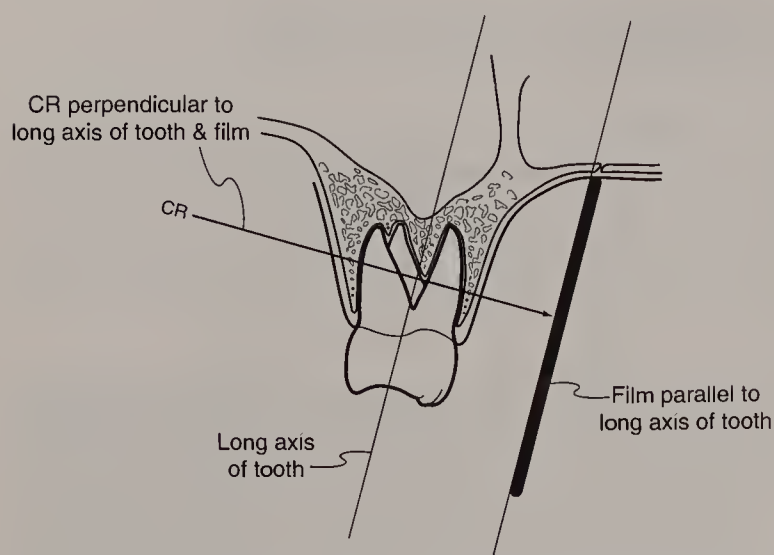
To achieve parallelism between the film and the long axes of the teeth, the object-film distance will have to be increased (especially in the maxillary arch). Of course, this goes against one of the five rules of accurate image formation, which states that the film should be as close as possible to the object being radiographed. Therefore, to compensate for the undesirable image characteristics of geometric unsharpness and magnification caused by this modification, the source-film distance is *increased* as much as possible. This is probably why this technique has been referred to as the “long cone” technique in the past. The source-film distance of 16 inches is the most practical distance to be used in most dental offices. If the room is small, an x-ray machine with a recessed beam indicating device (BID) can be used. A typical FMX using the paralleling technique consists of 16 periapical and 4 bitewing projections, as shown in Figure 5-2A.

### Film-Holders (Paralleling Technique)

According to technique, the film must be placed as nearly parallel to the long axes of the teeth as possible, keeping



**Figure 5.11 “Cone-Cut” or Partial Image.** If the film is not completely covered with beam of radiation, a cone-cut or partial image will be seen on the radiograph. Round BID in the right diagram is positioned too far posteriorly for film placed in premolar region.



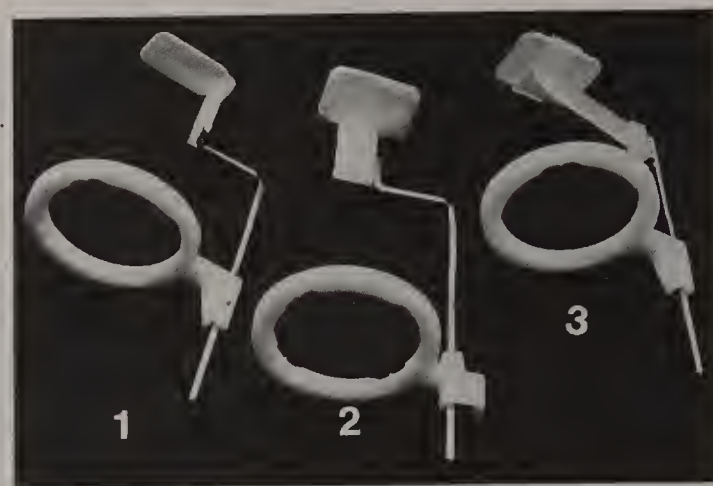
**Figure 5.12 Paralleling Technique.** Diagram of paralleling technique illustrating the relationship of the film and teeth in the paralleling (right-angle) technique.

the film flat at all times and retaining it in position until it is properly exposed.

Various film-holders have been designed to enable the operator to accomplish the paralleling technique and overcome problems associated with film retention and alignment.

1. The Dentsply/Rinn XCP instruments (extension BID paralleling) (Fig. 5-13).
2. The Masel Precision rectangular collimating instruments (Fig. 5-14).
3. The Stabe disposable film-holder (Dentsply/Rinn) (Fig. 5-15).
4. The Snap-A-Ray film-holder (Dentsply/Rinn) (Fig. 5-16).

The first two instruments (Dentsply/Rinn XCP and Masel Precision) have an added benefit in radiation reduction to



**Figure 5.13 Dentsply/Rinn XCP Instruments.** (1) Anterior No. 1 film instrument. (2) Posterior No. 2 film instrument. (3) Bitewing instrument with No. 2 film.

the patient by rectangular collimation. This will be discussed more completely in Chapter 13. The Dentsply/Rinn XCP instruments must be used with a rectangular BID, such as the Margraph BID, to collimate the beam of radiation rectangularly (Fig. 5-17C). However, a stainless steel collimator (Dentsply/Rinn) can be attached to the XCP alignment ring, or a Universal Rectangular Collimator (Dentsply/Rinn) can be attached to a round BID to provide rectangular collimation when using a round BID (Fig. 5-17A, B). The Masel Precision instrument collimates the x-ray beam at the skin surface (Fig. 5-14).

#### Stabe Disposable Film-Holder (Dentsply/Rinn)

The Stabe Film-Holder is a disposable film-holder made of a rigid polystyrene material. It can be used in the paralleling technique (Fig. 5-15) or the bisecting technique (Fig. 5-42).

The biteblock is scored so that it can be shortened easily. It is shortened to avoid the cheek in posterior mandibu-

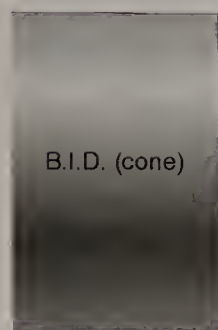


**Figure 5.14 Masel Precision Rectangular Collimation Instruments.** (A) Masel instruments: (1) posterior instrument; (2) posterior instrument; (3) bitewing instrument; (4) anterior instrument. (B) Use of Masel Precision Instrument in right maxillary posterior region.

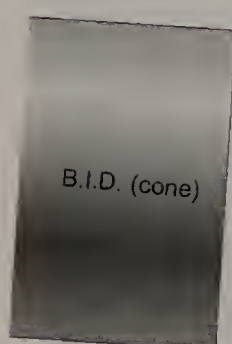




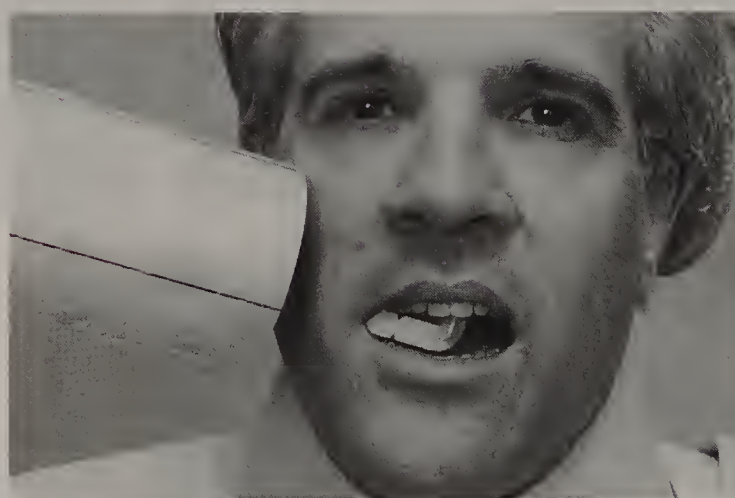
**Figure 5.15 Stabe Disposable Film-Holder (Dentsply/Rinn) for Paralleling Technique.** (A) (Left) Bite portion of the Stabe is scored so it may be shortened easily if necessary to avoid the cheek in mandibular projections or when used with children. (Right) Film in Stabe film-holder ready for positioning in the maxillary posterior region. (B) Diagram illustrating mandibular molar paralleling projection. (C) Film positioned for mandibular molar paralleling projection. (D) Diagram illustrating maxillary molar paralleling projection. (E) Film positioned for maxillary molar paralleling projection.

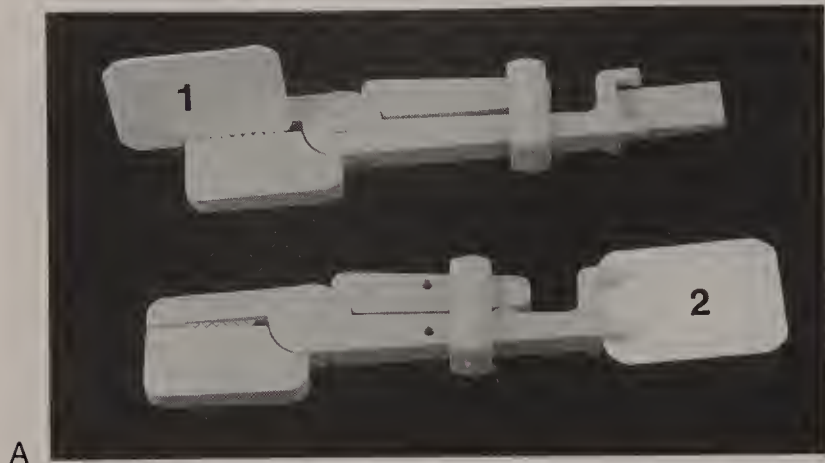


**Mandibular Molar Projection**

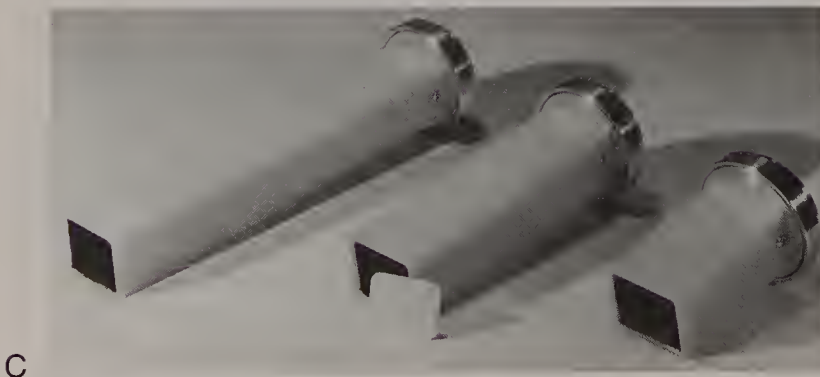


**Maxillary Molar Projection**





**Figure 5.16 Snap-A-Ray (Dentsply/Rinn) Film-Holder for Parallelizing Technique.** (A) Dentsply/Rinn Snap-A-Ray: (1) posterior projection; (2) anterior projection. (B) Maxillary posterior projection (Snap-A-Ray). (C) Maxillary anterior projection (Snap-A-Ray).



**Figure 5.17 Rectangular Collimators.** (A) A long, cylindrical BID with a Dentsply/Rinn Universal Collimator attached to provide rectangular collimation to a cylindrical BID. (B) Dentsply/Rinn XCP instrument with stainless steel collimator attachment. (C) Margraph Rectangular BIDs of various lengths.



lar paralleling technique projections and to make it more functional when used in intraoral projections in children.

### Snap-A-Ray Film-Holder (Dentsply/Rinn)

The Snap-A-Ray film-holder is a simple plastic film-holder that can be used in both the posterior and the anterior regions of the mouth. It does *not* use a film backing device; therefore, the film may bend and cause image distortion. When the film bends using the Snap-A-Ray (particularly in the maxillary arch), the film position resembles the film position in the bisecting angle technique rather than the paralleling technique, and the BID must be aligned accordingly. In addition, the problem is compounded because the film-holders do *not* have an alignment device to aid in the determination of the vertical and horizontal angulations of the BID. However, it is a useful instrument, particularly in patients who cannot tolerate the use of the film backing device of the biteblock in various regions of the oral cavity (Fig. 5-16).

The Dentsply/Rinn Snap-A-Ray is particularly useful for the following:

1. Mandibular premolar and molar projections. Because these teeth have almost perpendicular root axes, the film can be positioned parallel to the teeth without increasing the object-film distance.
2. Maxillary and mandibular third molar projections.
3. Patients with hypersensitive gag reflexes.
4. Children.
5. Edentulous projections.
6. Endodontic projections.

### Six Rules of Good Paralleling Technique

The paralleling technique can be accomplished more easily by keeping these six rules in mind. The paralleling radiographic technique requires a film-holder to retain the film in a proper position and guide the placement of the

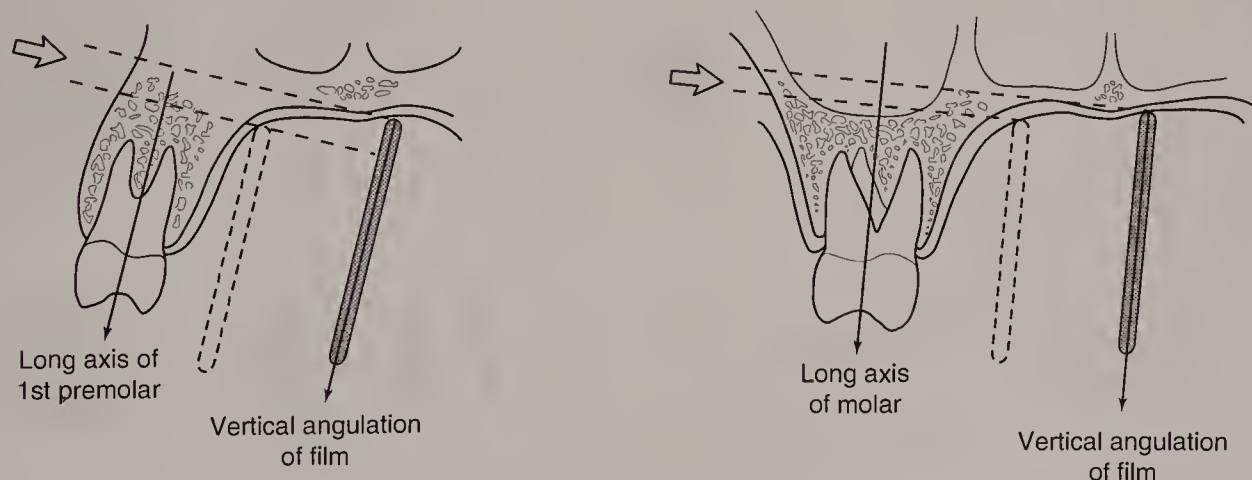
BID. The first three rules deal with film placement and the last three rules deal with BID positioning.

**Rule 1.** The film must be placed so that it covers the particular teeth to be examined for each region of the oral cavity. The specific film positions for each area of the oral cavity are shown in Figure 5-2A.

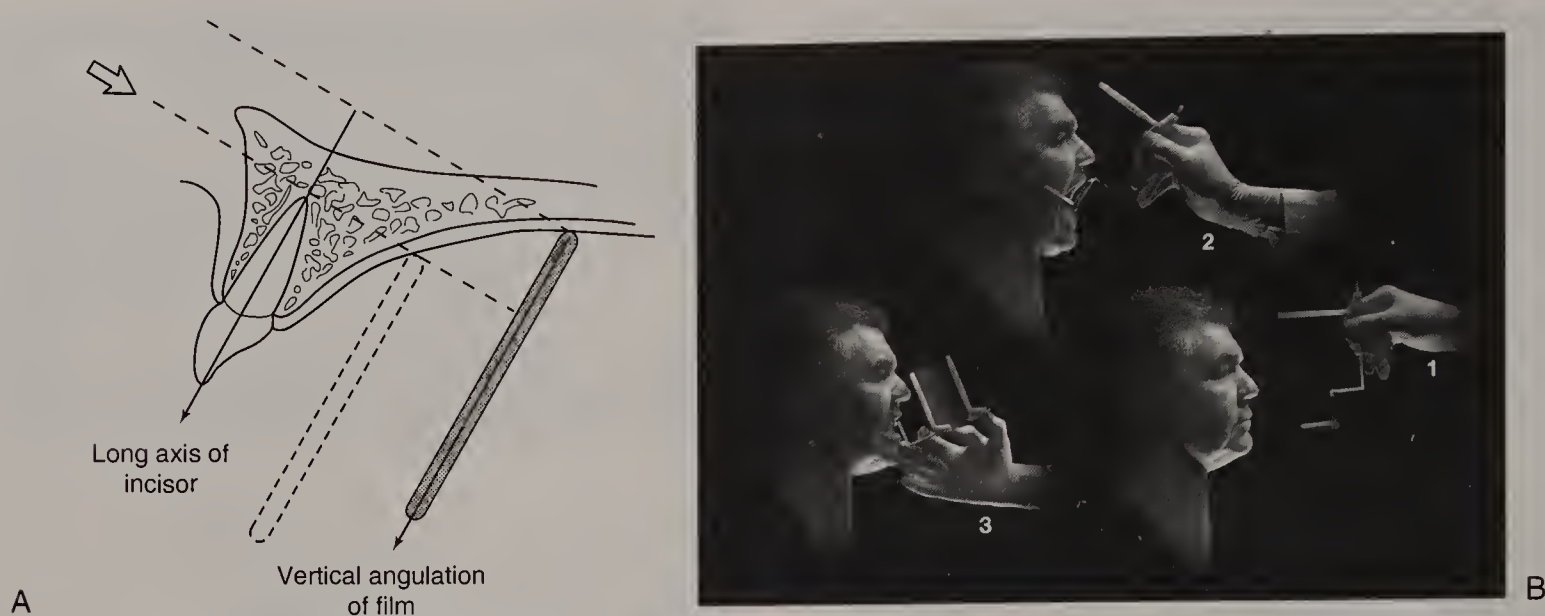
**Rule 2.** The vertical plane of the film should be positioned parallel to the long axes of the teeth being radiographed. In the maxillary arch, because of the slight facial inclination of the teeth, it will be necessary to increase the tooth-film distance to achieve parallelism.

When the film is positioned parallel to the long axis of the posterior maxillary teeth, the apical or tissue edge of the film packet is at or beyond the median palatal suture line away from the teeth being radiographed (Fig. 5-18). In the mandibular posterior region, the molars tilt slightly inward toward the sagittal plane while the premolars are nearly parallel to the midsagittal plane. Therefore, the film packet can be positioned closer to the alveolar ridge and still remain parallel to the long axes of the teeth. In the maxillary and mandibular incisor regions, because of the facial inclinations of the teeth, the film must be placed well back into the mouth. The apical or tissue edge of the anterior maxillary film packet will approximate the posterior palatal area (Fig. 5-19), and the apical edge of the mandibular film packet will be placed under the tongue near its anterior base to achieve parallelism of the film and the long axes of the teeth. In either case, the patient must bite on the outer edge of the biteblock to achieve parallelism.

**Rule 3.** The horizontal plane of the film must be parallel to the horizontal planes of the teeth. The correct horizontal position of the film in relation to the teeth differs in various regions of the mouth because the teeth form a curved arch and all teeth will not have the same horizontal position or mean tangent. The mean tangent is defined as the plane joining the most exterior points of the curved

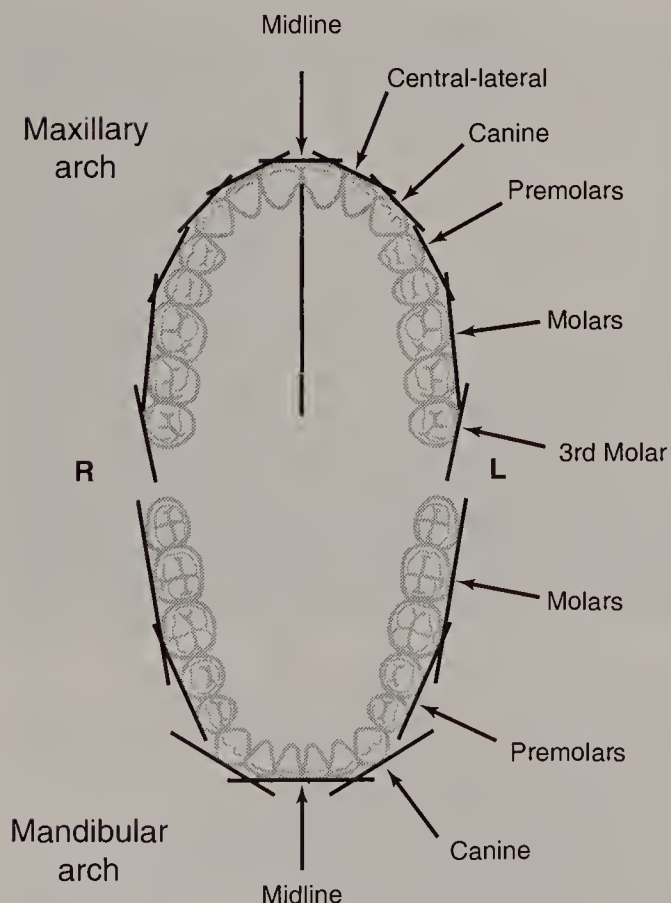


**Figure 5.18 Maxillary Premolar/Molar Vertical Angulation of Film.** In maxillary premolar and molar film placement, the object-film distance should be increased from the first position (dashed line) to the second position. The film can then be positioned vertically to approach parallelism between the long axis of the tooth and the vertical plane of the film. This prevents the apices of the teeth from being cut off.



**Figure 5.19 Placement of Film in Maxillary Incisor Region: Maxillary Incisor Vertical Angulation of Film.**

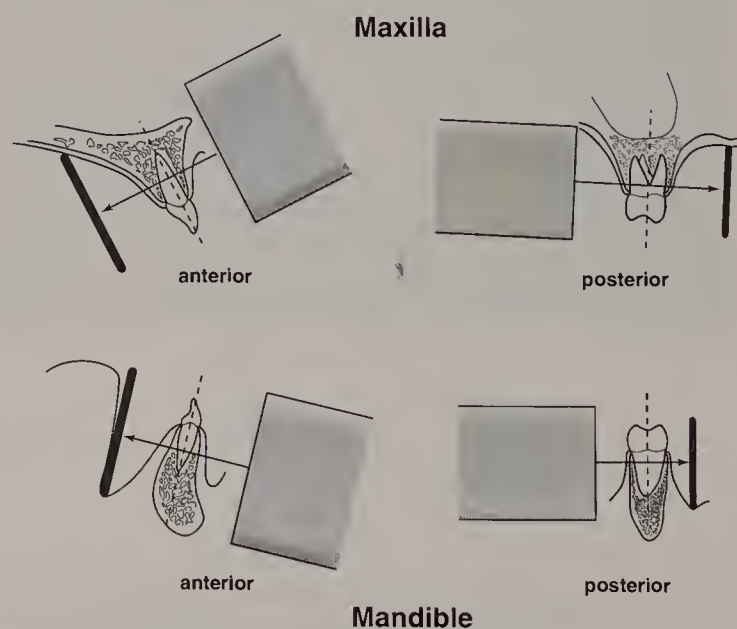
(A) The tooth apices will not show in the radiograph when the film packet is placed in the first position (*dashed lines*). By increasing the object-film distance, as shown in the second position, it is possible to reveal the apices of the teeth and structures beyond on the radiograph. (B) Summary of placing film in incisor region: (1) the film should be positioned horizontally as the operator approaches the patient's mouth; (2) the outer edge of biteblock should make contact with incisal edge of teeth; the film should then be rotated into proper position; (3) patient closes on the biteblock, and the operator slides the locator ring adjacent to patient's skin.



**Figure 5.20 Mean Tangents: Horizontal Angulation of BID.** Proper maxillary and mandibular mean targets and horizontal beam angulation for each region.

facial surfaces in a particular region of the oral cavity. In Figure 5-20, the mean tangents are demonstrated for each film placement. The horizontal placement of the film packet must be parallel to the mean tangent of each region.

**Rule 4.** The vertical angulation of the BID is such that the open-ended flat surface of the BID is positioned parallel to the film packet, which will direct the central ray perpendicular to the plane of the film and the long axes of the teeth. Proper vertical angulation of the BID will help reduce shape distortion of the radiographic image, such as elongation and foreshortening (Fig. 5-21).



**Figure 5.21 Vertical Angulations of BID.** Summary of proper vertical angulation of the BID for each region of the jaws.



**Rule 5.** The horizontal positioning of the BID directs the x-rays through the embrasures or contacts between the teeth. After correct horizontal placement of the film, the horizontal angulation is easily determined by positioning the open-ended flat surface of the BID parallel to the horizontal plane of the film, thus directing the x-rays perpendicular to the film (Fig. 5-20). Incorrect horizontal angulation results in the overlapping of tooth interproximal surfaces (Fig. 5-10).

**Rule 6.** The central ray of the x-ray beam must be directed to the center of the film to completely cover the film (Fig. 5-9). Incorrect placement of the central ray results in cone-cutting or a partial exposure of the radiograph (Fig. 5-11).

### **Procedure for Using the Dentsply/Rinn XCP Instruments and Margraph Rectangular BID**

This procedure should be followed to take a complete radiographic series using the Dentsply/Rinn XCP paralleling instruments. The same principles illustrated may be applied to the other film-holders listed previously. A Margraph rectangular BID is used because it collimates the beam to the size of the film and reduces the absorbed dose to the patient by approximately 52% compared with round BID collimation (see Chapter 13). A Margraph rectangular long BID can be purchased from Margraph Corporation, 611 Harper Avenue, Jenkintown, PA 19046, telephone, 1-800-762-2641. If a rectangular BID is not available, the same procedure may be used for the long, round BID by use of the Dentsply/Rinn Universal Rectangular Collimator attached to the round, cylindrical BID (Fig. 5-17A) or a stainless steel collimator attached to a Dentsply/Rinn XCP aiming ring (Fig. 5-17B).

A routine sequence of taking radiographs for an FMX should be decided by the operator. This will save time and make certain that all radiographs are taken for a proposed FMX.

**Dentsply/Rinn XCP Instruments (Long BID Paralleling).** Film-holding instruments such as the Dentsply/Rinn XCP instruments provide an external guide for positioning of the BID vertically and horizontally as well as automatically establishing the point of entry of the x-ray beam (Fig. 5-13).

The Dentsply/Rinn XCP instrument consists of three parts:

1. **Anterior and posterior plastic biteblocks.** These are designed to retain the film packet by means of tension created by a semiflexible plastic backing and a groove or slot within which the film is inserted.
2. **Indicator rods.** These are made of stainless steel and are used to align the x-ray BID with the film. There is an anterior offset rod and a posterior right angle rod designed to insert into the holes of their respective biteblocks for the periapical projections.
3. **Aiming ring.** Aiming rings are made for sliding onto the rods to establish alignment of the BID with the film. This prevents cone-cutting.

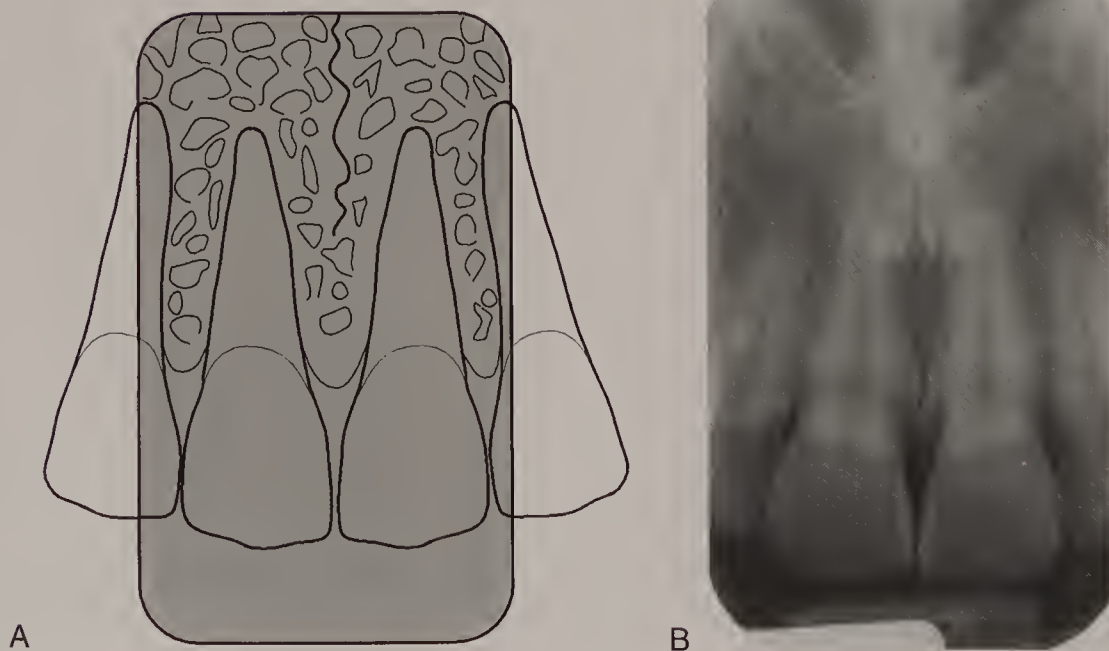
The Dentsply/Rinn XCP aiming or locator ring can accept either a round BID or a rectangular BID (Fig. 5-13). To aid in the alignment of the rectangular BID with the aiming or locator ring, the rectangular BID can be rotated on its own axis. This modification simplifies the use of the rectangular BID and film alignment. The following sections explain the recommended procedures for the long BID paralleling technique using the Dentsply/Rinn XCP instruments and a Margraph rectangular BID for each region of the oral cavity (Figs. 5-22 to 5-32).

## PARALLELING TECHNIQUE

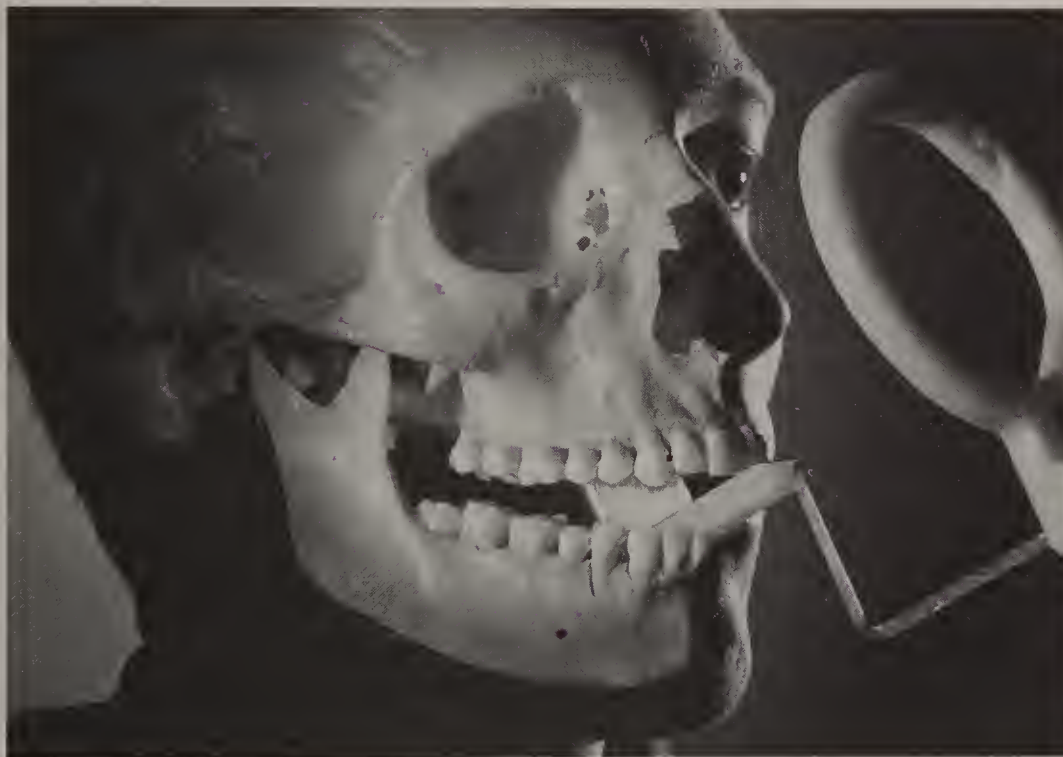
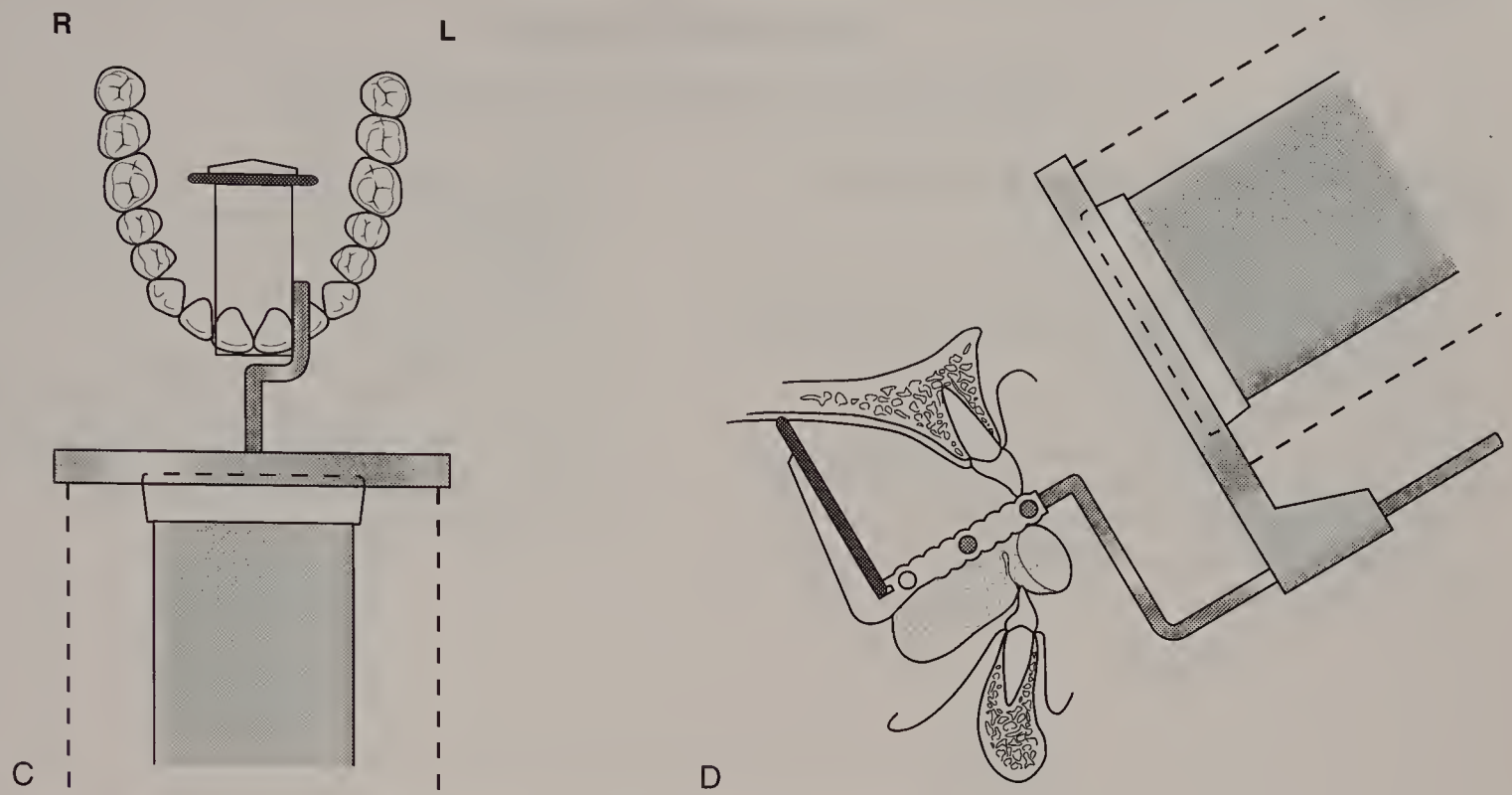
## MAXILLARY CENTRAL INCISOR REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-22)**

1. Assemble the anterior instrument and insert a No. 1 film vertically into the anterior biteblock with the plain side of the film facing out.
2. Select the correct exposure factors.
3. Center the film to the maxillary midline and parallel to the long axes of the central incisors. The entire length of the biteblock should be used to position the film back to the palatal region lingual to the first molar.
4. With the biteblock resting on the incisal edges of the teeth to be radiographed, insert a cotton roll between the mandibular incisors and biteblock. Instruct the patient to close firmly to retain the film in the desired position.
5. Slide the aiming ring down the indicator rod to approximate the skin surface and turn the BID vertically. Align the BID with the indicator rod and aiming ring in both the vertical and horizontal planes.
6. Make the exposure.







**Figure 5.22 Maxillary Central Incisor Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Proper alignment of BID with Dentsply/Rinn XCP instrument.

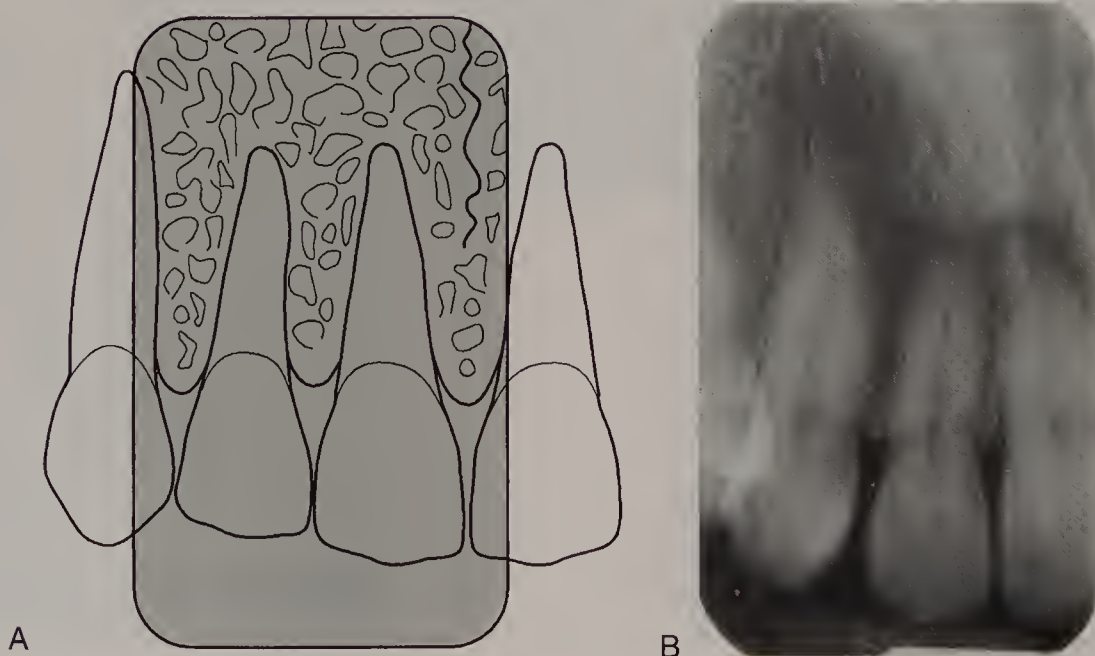
F

## PARALLELING TECHNIQUE

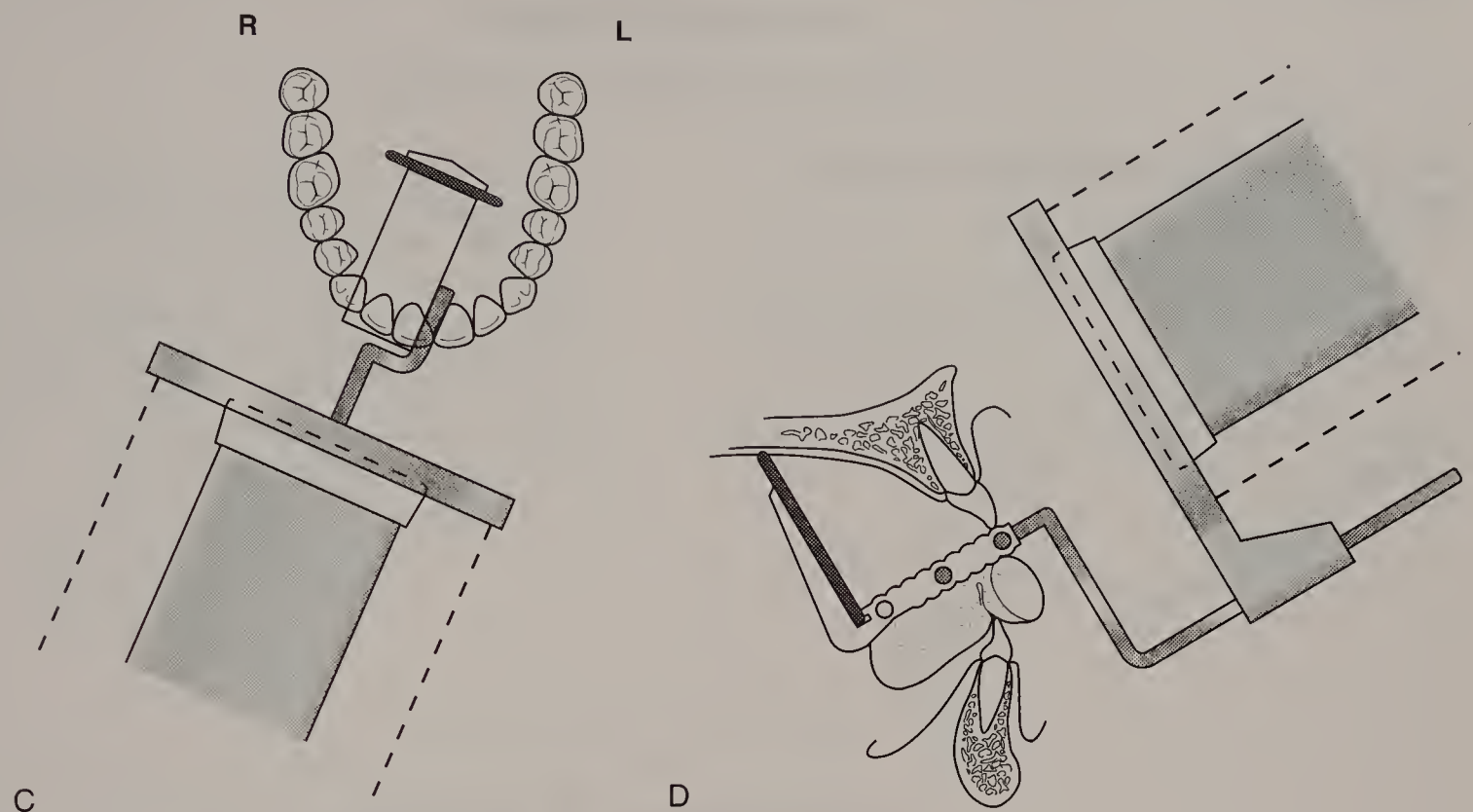
## MAXILLARY LATERAL INCISOR REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-23)**

1. Assemble the anterior instrument and insert a No. 1 film vertically into the anterior biteblock with the plain side facing out.
2. Select the correct exposure factors.
3. Center the lateral incisor on the biteblock and position the film parallel to the long axis of the lateral incisor. The entire length of the biteblock should be used to position the film back to the palatal region lingual to the first molars.
4. With the biteblock resting on the incisal edges of the teeth to be radiographed, insert a cotton roll between mandibular incisors and biteblock. Instruct the patient to close firmly to retain the established position of the film.
5. Slide the aiming ring down the indicator rod to approximate the skin surface. Turn the BID vertically and align it with the indicator rod and aiming ring in both the vertical and horizontal planes.
6. Make the exposure.







E



F

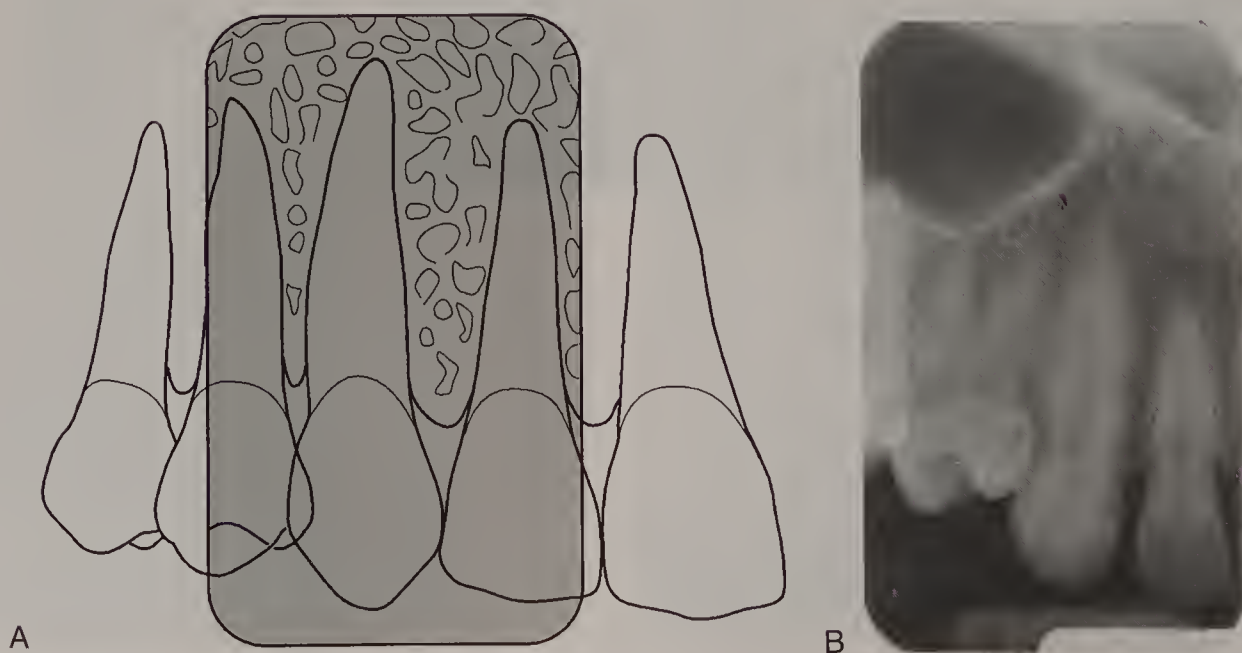
**Figure 5.23 Maxillary Lateral Incisor Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with Dentsply/Rinn XCP instrument.

## PARALLELING TECHNIQUE

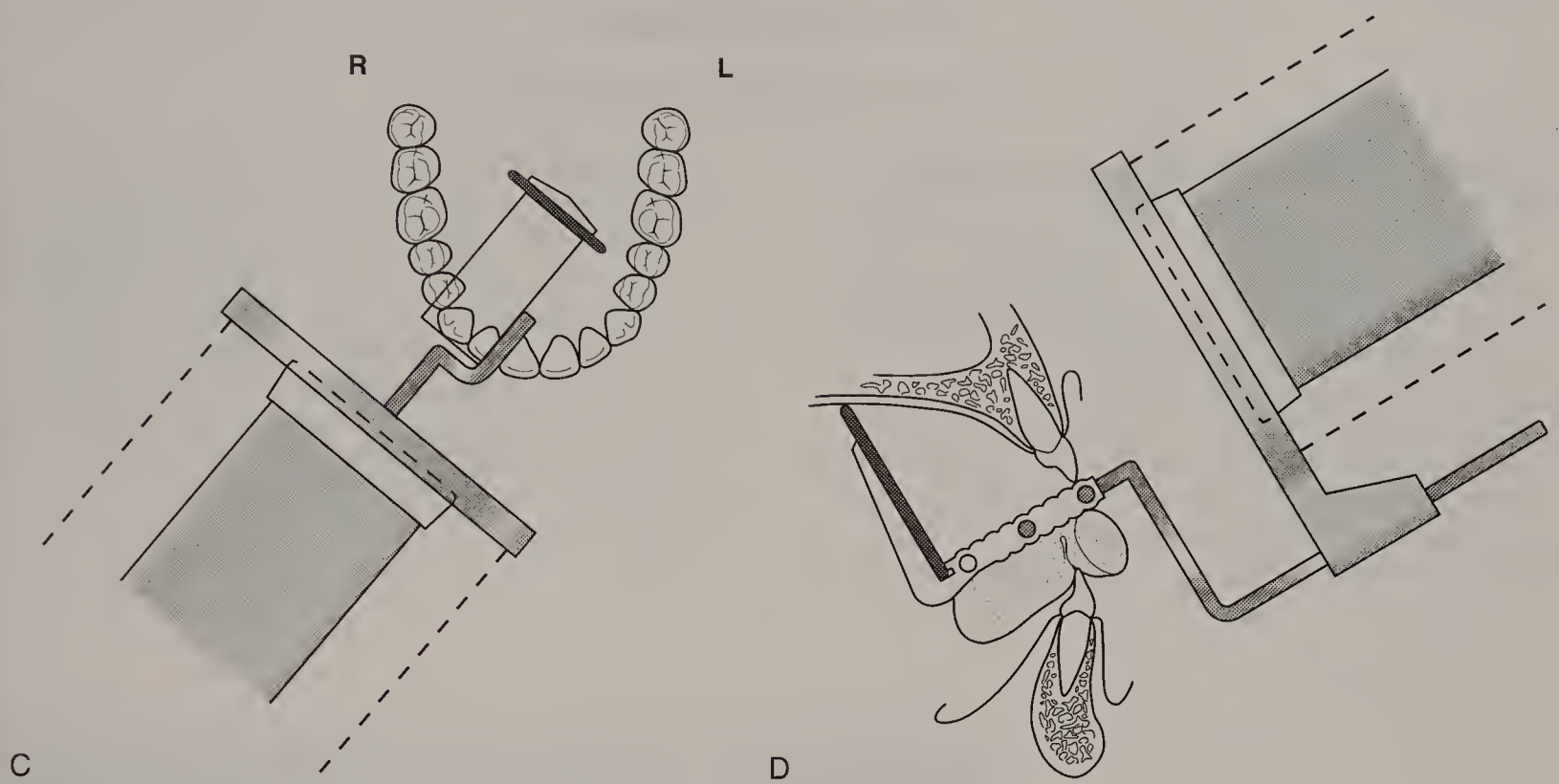
## MAXILLARY CANINE REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-24)**

1. Assemble the anterior instrument and insert a No. 1 film vertically into the anterior biteblock with the plain side facing out.
2. Select the correct exposure factors.
3. Center the canine on the film, parallel with the long axis of the maxillary canine.
4. With the biteblock resting on the maxillary canine, insert a cotton roll between the mandibular teeth and biteblock. Instruct the patient to close firmly to retain the established position of the film.
5. Slide the aiming ring down the indicator rod to approximate the skin surface. Turn the BID vertically and align it with the indicator rod and aiming ring in both the vertical and horizontal planes.
6. Make the exposure.







**Figure 5.24 Maxillary Canine Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Placement of Dentsply/Rinn XCP instrument.

F

## PARALLELING TECHNIQUE

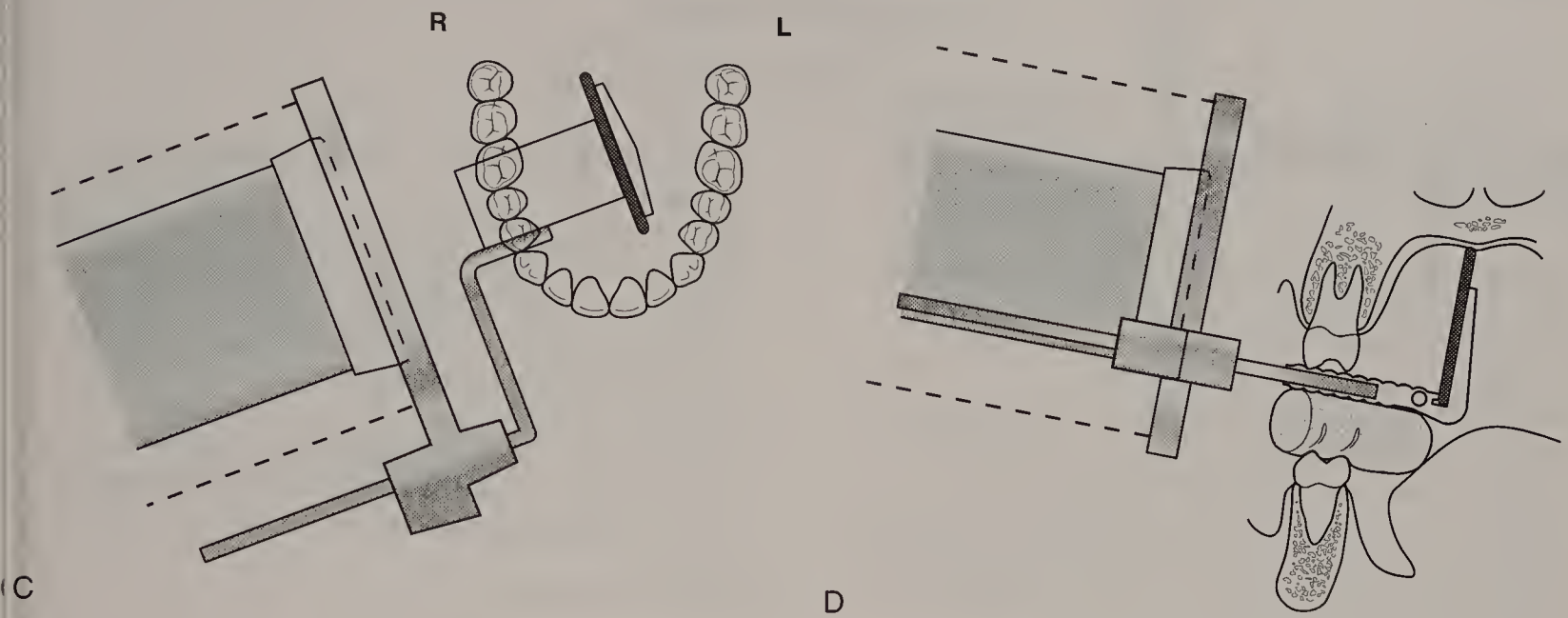
## MAXILLARY PREMOLAR REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-25)**

1. Assemble the posterior periapical instrument and insert a No. 2 film horizontally into the posterior biteblock with the plain side facing out.
2. Select the correct exposure factors.
3. Position the film-holder in the mouth with the second premolar centered on the film. The distal of the canine must be seen on this projection. Parallel the film horizontally with the mean tangent of the premolars, and vertically with the long axis of the premolars.
4. With the biteblock held against the occlusal surfaces of the premolars and first molar, insert a cotton roll between the underside of the biteblock and mandibular teeth. Instruct the patient to close firmly to retain the established position of the film.
5. Slide the aiming ring or locator ring down the indicator rod to approximate the skin surface. Rotate the BID to the horizontal position and align it with both the indicator rod and aiming ring in both the horizontal and vertical planes.
6. Make the exposure.







**Figure 5.25 Maxillary Premolar Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with XCP instrument.

## PARALLELING TECHNIQUE

## MAXILLARY MOLAR REGION

**Dentsply/Rinn XCP Paralleling Procedure  
(Figure 5-26)**

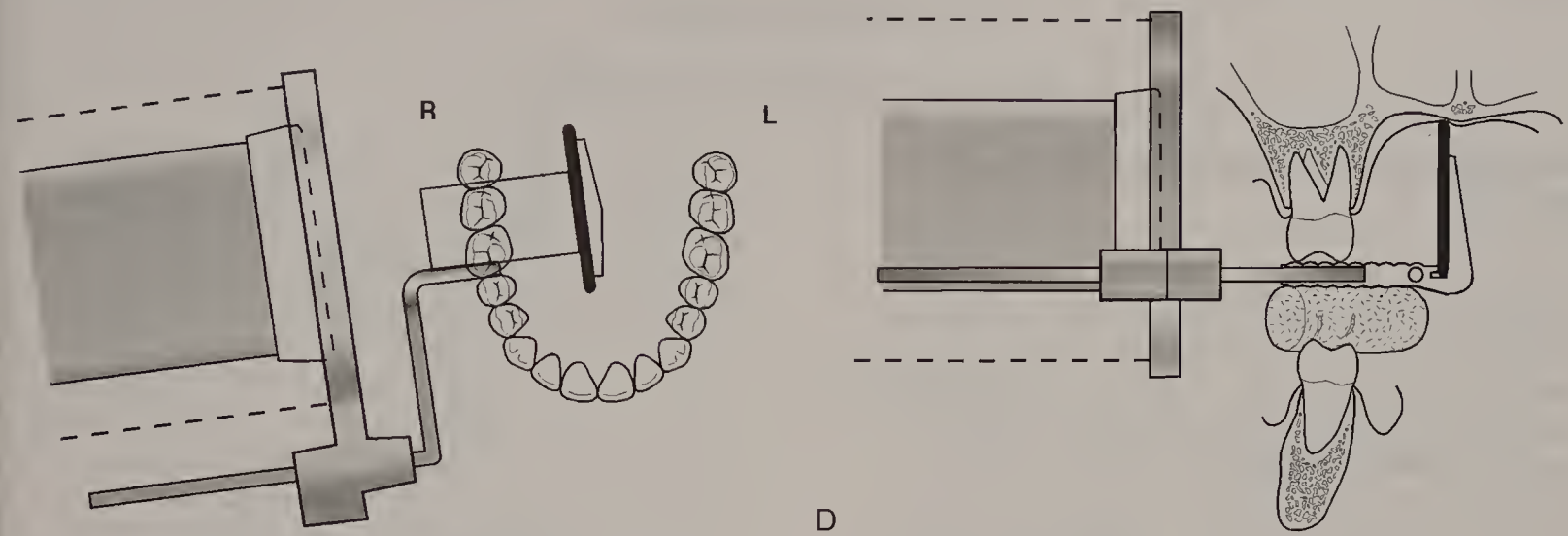
1. Assemble the posterior instrument and insert a No. 2 film horizontally into the posterior biteblock with the plain side of the film facing out.
2. Select the correct exposure factors.
3. Position the film-holder in the mouth with the anterior edge of the film at the middle of the second premolar. If necessary, move the film posteriorly to cover the maxillary third molar or maxillary tuberosity if the third molar is not visible clinically. Position the film at or past the midpalatal suture line and parallel to the mean tangent of the molars. Then make certain that the

vertical plane of the film is parallel to the long axes of the molars.

4. With the biteblock held against the occlusal surfaces of the first and second molars, insert a cotton roll between the underside of the biteblock and mandibular teeth. Instruct the patient to close firmly to retain the established position of the film.
5. Slide the aiming ring down the indicator rod to approximate the skin surface. Rotate the BID to the horizontal position and align it with both the indicator rod and aiming ring on the horizontal and vertical planes.
6. Make the exposure.







**Figure 5.26 Maxillary Molar Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with XCP instrument.

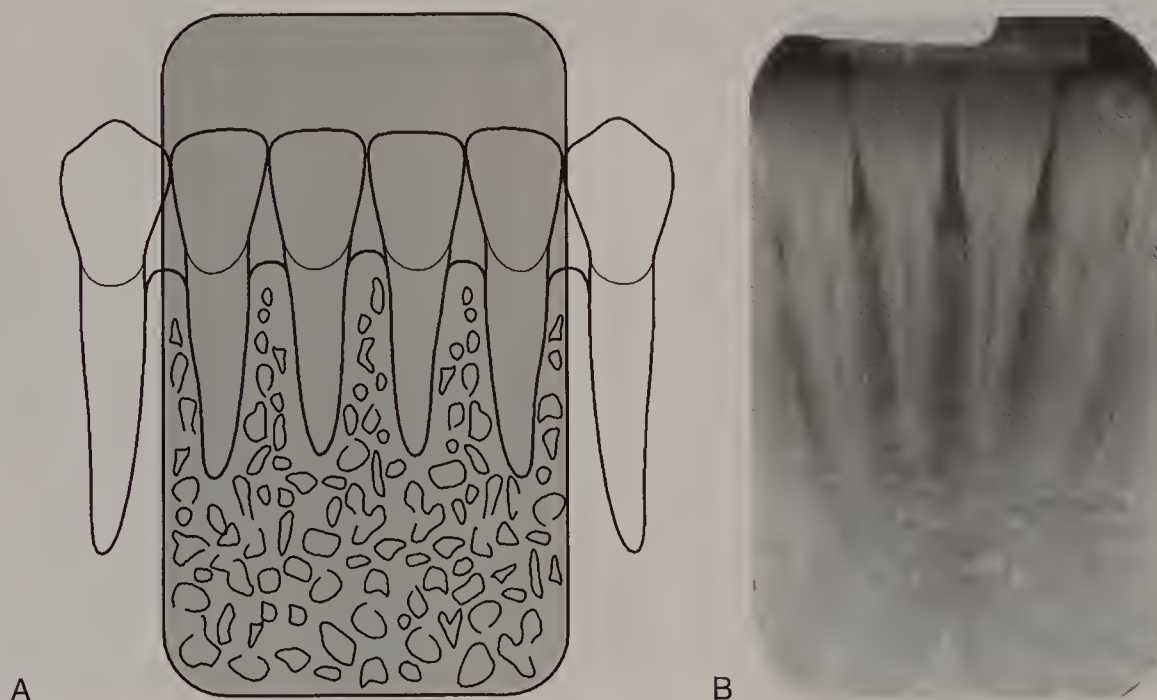
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## PARALLELING TECHNIQUE

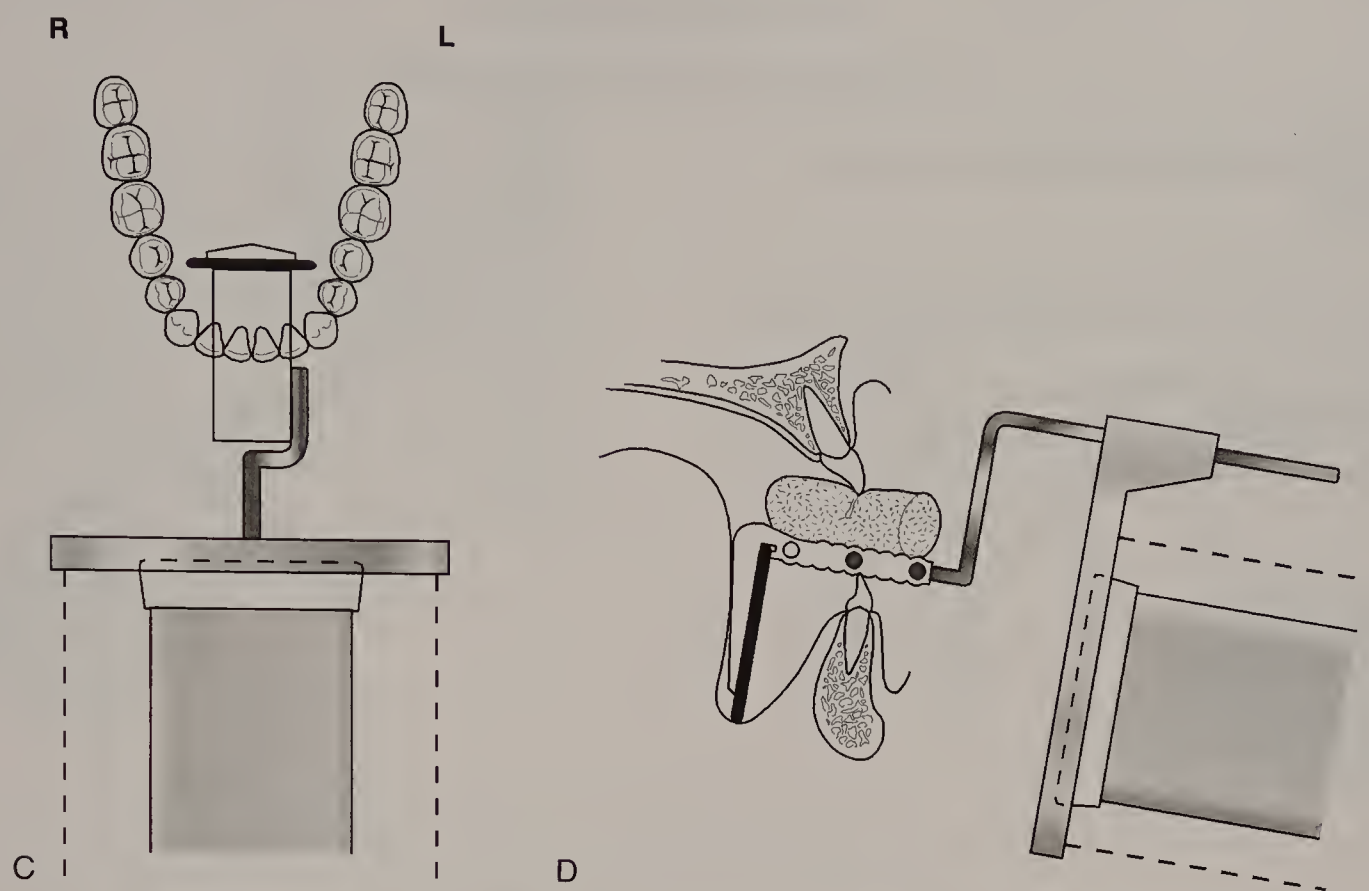
## MANDIBULAR INCISOR REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-27)**

1. Assemble the anterior instrument and insert a No. 1 film vertically into the anterior biteblock with the plain side of the film facing out. The procedure is similar to the maxillary anterior technique, except for the inversion of the film-holder to position the film lingual to the mandibular anterior teeth.
2. Select the correct exposure factors.
3. Center the film with the patient's midline parallel to the long axes of the central incisors. The lingual placement of the film packet in the region of the second premolars will accomplish this relationship, and the patient will bite on the outer edge of the biteblock.
4. With the biteblock resting on the incisal edges of the teeth to be radiographed, insert a cotton roll between the top of the biteblock and the maxillary incisors.
5. Instruct the patient to close firmly to retain the established position of the film. Place the film against the floor of the mouth and rotate the film into position as the patient bites on the biteblock. Do not force this procedure. Film placement may be simplified by raising the chair and tilting the patient's head backward.
6. Make the exposure.







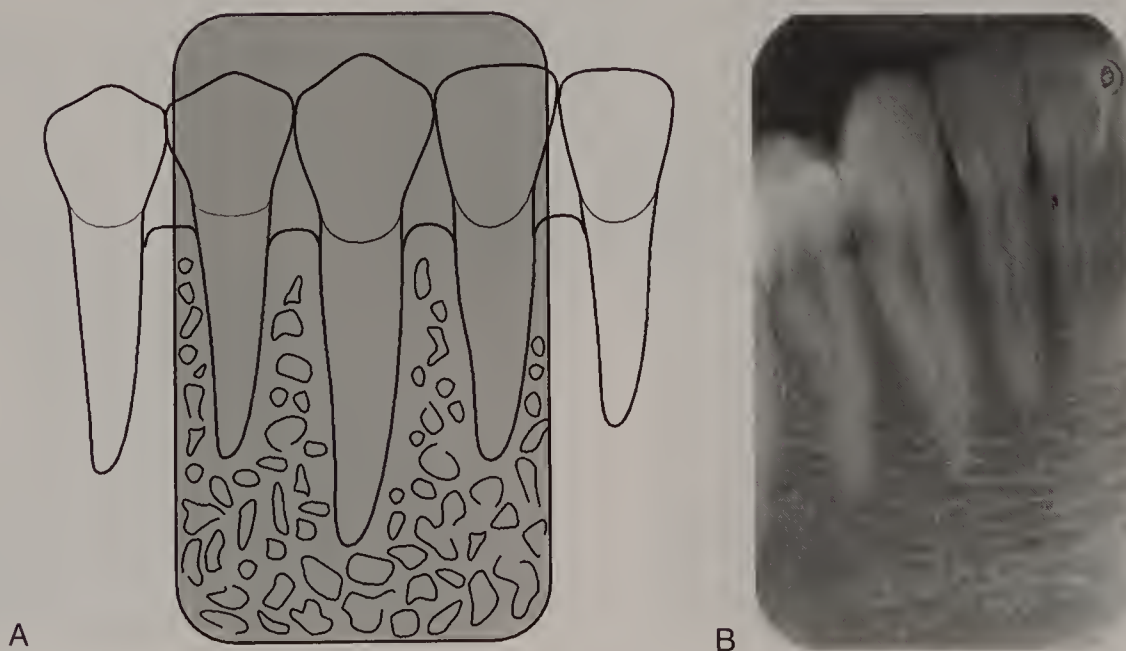
**Figure 5.27 Mandibular Incisor Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with XCP instrument.

## PARALLELING TECHNIQUE

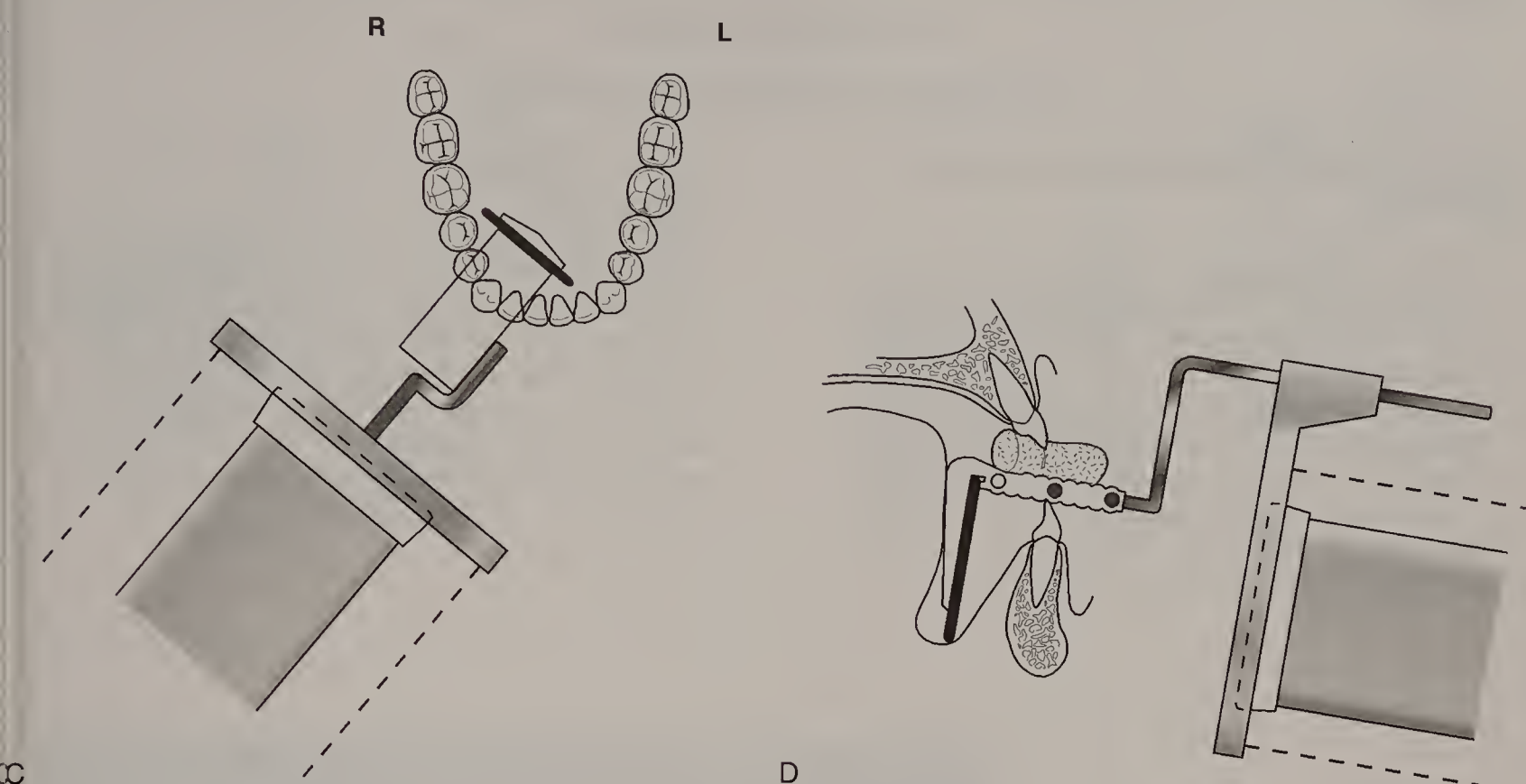
## MANDIBULAR CANINE REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-28)**

1. Assemble the anterior instrument and insert a No. 1 film vertically into the anterior biteblock with the plain side facing out.
2. Select the correct exposure factors.
3. Center the canine on the film, parallel to the long axis of the canine.
4. With the biteblock resting on the mandibular canine, insert a cotton roll between the biteblock and the maxillary teeth. Instruct the patient to close firmly to maintain the established position of the film.
5. Slide the aiming ring down the indicator rod to approximate the skin surface. Align the BID with the indicator rod and aiming ring on the vertical and horizontal planes. Make certain the BID is rotated vertically.
6. Make the exposure.







**Figure 5.28 Mandibular Canine Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with XCP instrument.

## PARALLELING TECHNIQUE

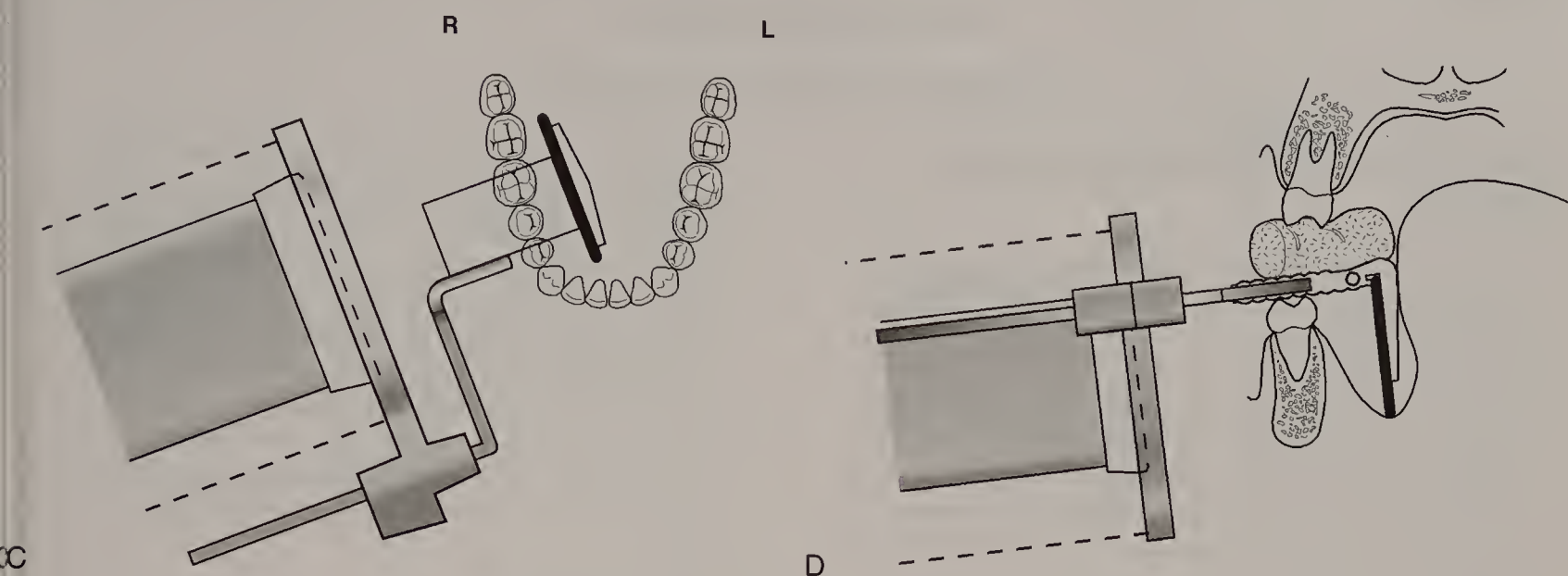
## MANDIBULAR PREMOLAR REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-29)**

1. Assemble the posterior instrument and insert a No. 2 film horizontally into the posterior biteblock with the plain side of the film facing out.
2. Select the correct exposure factors.
3. Position the film-holder in the mouth with the second premolar centered on the film. Bending or curving of the lower anterior corner of the film packet will facilitate positioning in some patients, although this procedure is recommended only in extreme circumstances. Parallel the film horizontally to the mean tangent of the premolars and vertically to the long axes of the premolars.
4. With the biteblock held on the occlusal surfaces of the mandibular premolars, insert a cotton roll between the biteblock and the maxillary teeth. Instruct the patient to close firmly to retain the established position of the film.
5. Slide the aiming ring down the indicator rod to approximate the skin surface. Rotate the BID horizontally and align it with both the indicator rod and aiming ring in both the horizontal and vertical planes.
6. Make the exposure.







**Figure 5.29 Mandibular Premolar Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with XCP instrument.

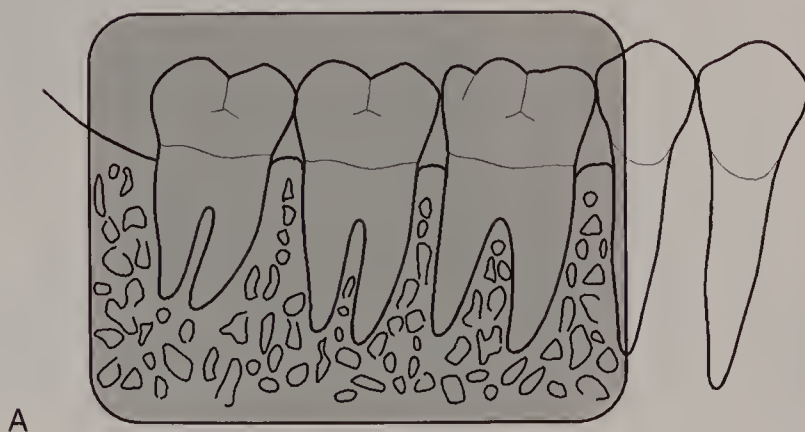
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## PARALLELING TECHNIQUE

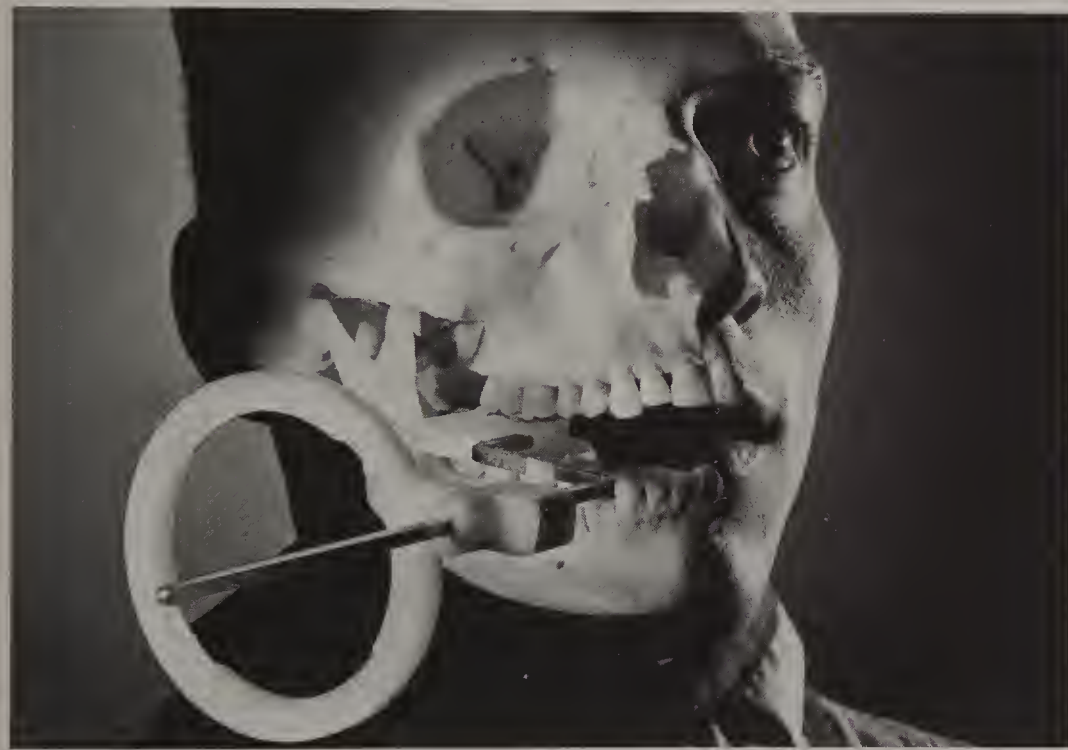
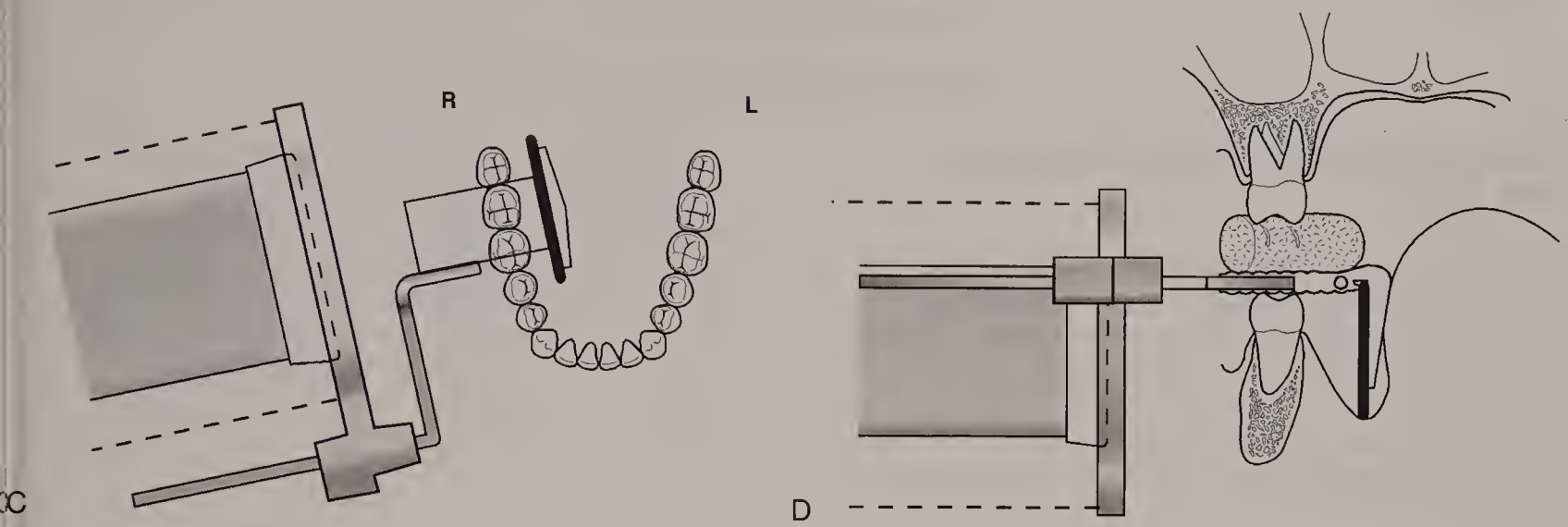
## MANDIBULAR MOLAR REGION

**Dentsply/Rinn XCP Paralleling Procedure (Fig. 5-30)**

1. Assemble the posterior instrument and insert a No. 2 film horizontally into the posterior biteblock with the plain side facing out.
2. Select the correct exposure factors.
3. Position the film-holder in the mouth with the anterior edge of the film in the vicinity of the first molar-second premolar embrasure; however, the film must cover all of the third molar. Parallel the film vertically with the long axes of the molars. (The occlusal surfaces of molars are usually at right angles to their long axes. Therefore, if
- the biteblock is placed flat across the occlusal surfaces, the plane of the film automatically assumes a position parallel to the long axes of the teeth.) Position the film packet in the sulcus between the teeth and tongue.
4. Place a cotton roll between the biteblock and opposing maxillary teeth. Instruct the patient to close firmly to retain the established position of the film.
5. Slide the aiming ring down the indicator rod to approximate the skin surface. Rotate the BID to the horizontal position and align it with the indicator rod and aiming ring in both the horizontal and vertical planes.
6. Make the exposure.







E



F

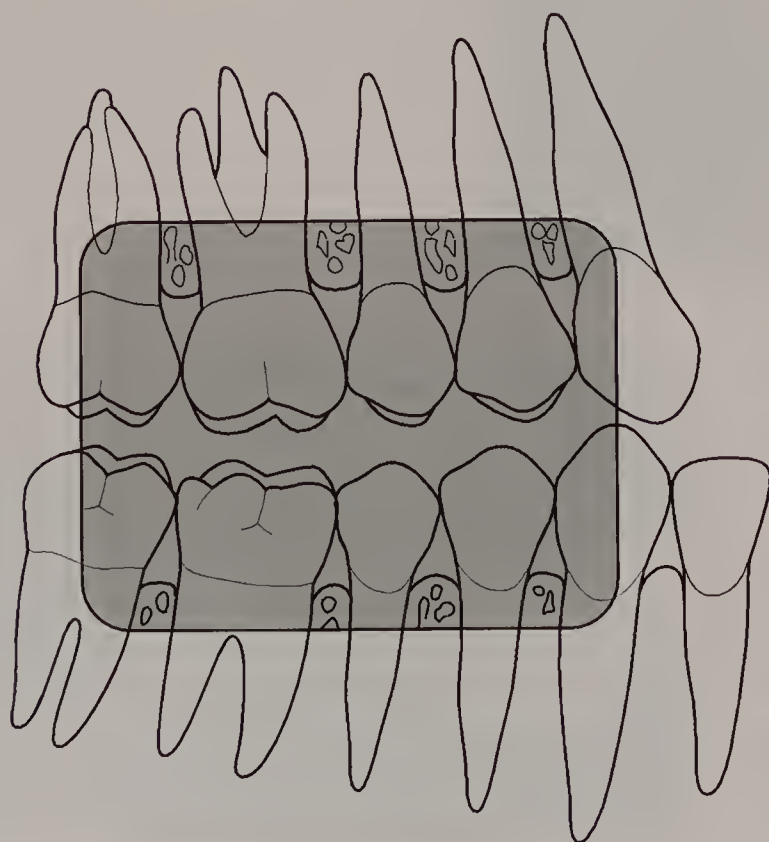
**Figure 5.30 Mandibular Molar Region.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Vertical film and BID placement. (E) Proper placement of film. (F) Alignment of BID with XCP instrument.

## PARALLELING TECHNIQUE

## PREMOLAR BITEWINGS

**Dentsply/Rinn XCP Bitewing Procedure (Fig. 5-31)**

1. Assemble the bitewing instrument. Center a No. 2 film into the biteblock in the horizontal position. The pebbled or plain side of the film should face outward with the plastic film-holder positioned across the face of the film.
2. Select the correct exposure factors.
3. With the biting portion of the film-holder resting on the occlusal surfaces of the mandibular teeth, position the film as shown for premolar bitewings. Instruct the patient to close firmly to retain the film in position.
4. Slide the aiming ring down the indicator rod to approximate the skin surface. Rotate the BID to the horizontal position and align it with the indicator rod and aiming ring in both the horizontal and vertical planes.
5. Make the exposure.

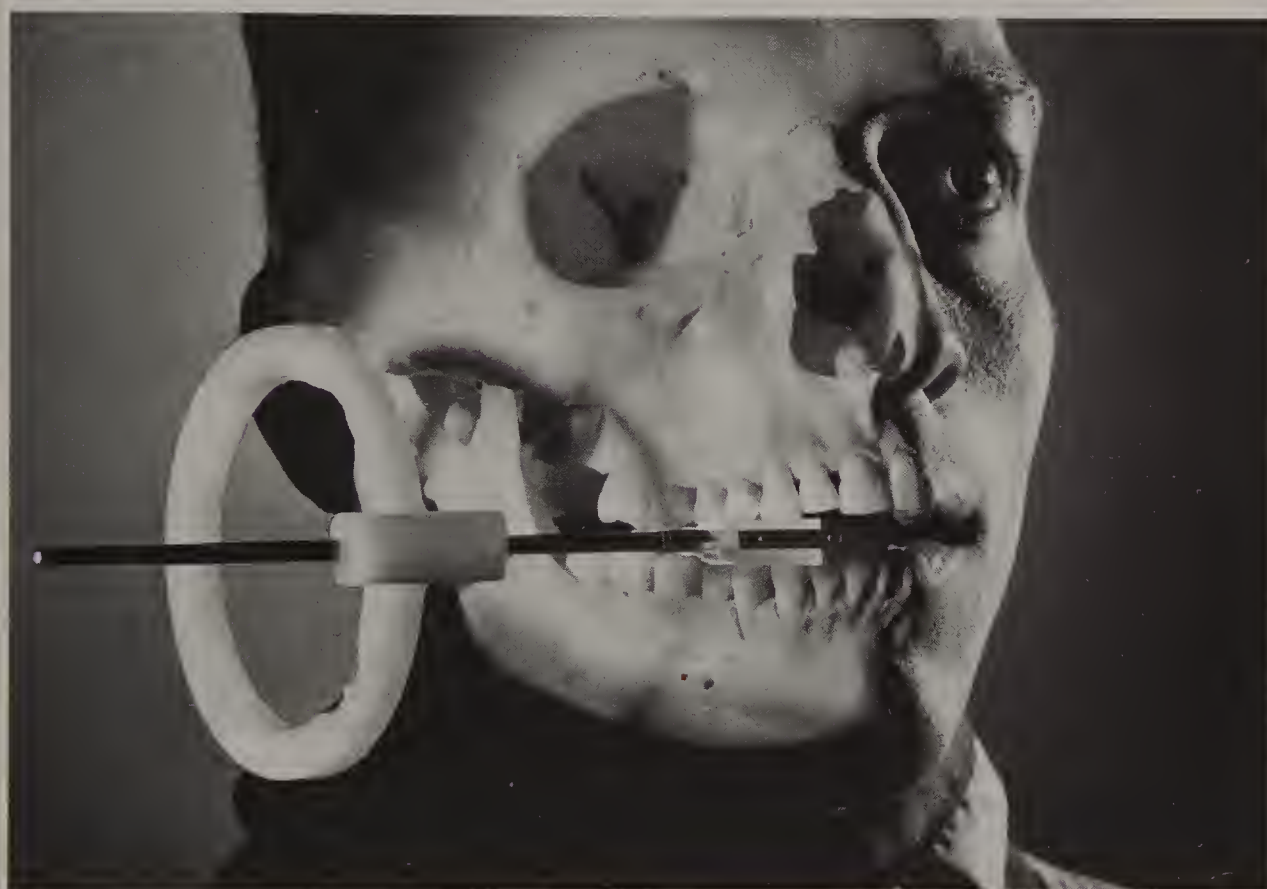
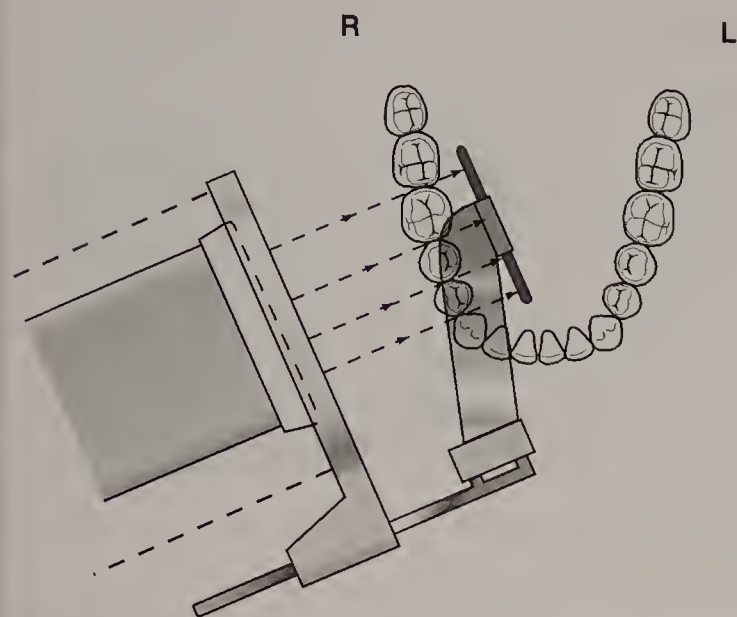


A



B





D



**Figure 5.31 Premolar Bitewing.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal film and BID placement. (D) Proper placement of the film. (E) Alignment of BID and bitewing XCP instrument.

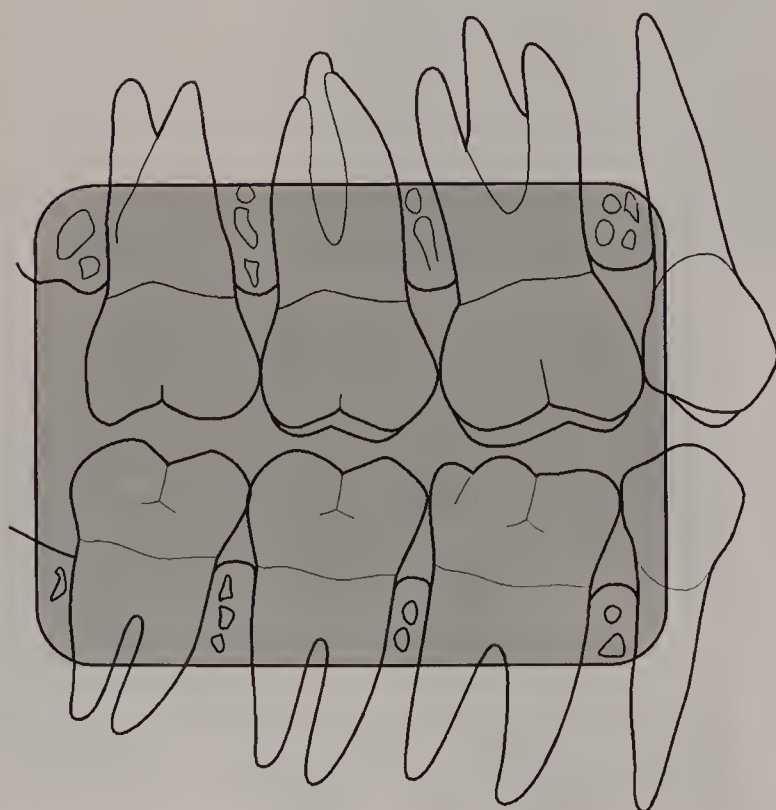
E

## PARALLELING TECHNIQUE

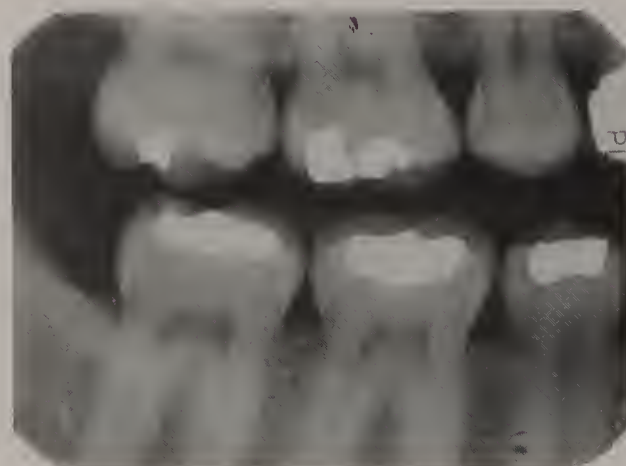
## MOLAR BITEWINGS

**Dentsply/Rinn XCP Bitewing Procedure  
(Fig. 5-32)**

1. Assemble the bitewing instrument. Center a No. 2 film into the biteblock in the horizontal position. The pebbled or plain side of the film should face outward with the plastic film-holder positioned across the face of the film.
2. Select the correct exposure factors.
3. With the biting portion of the film-holder resting on the occlusal surfaces of the mandibular teeth, position the film as shown for molar bitewings. Instruct the patient to close firmly to retain the film in position.
4. Slide the aiming ring down the indicator rod to approximate the skin surface. Rotate the BID to the horizontal position and align it with the indicator rod and aiming ring in both the horizontal and vertical planes.
5. Make the exposure.

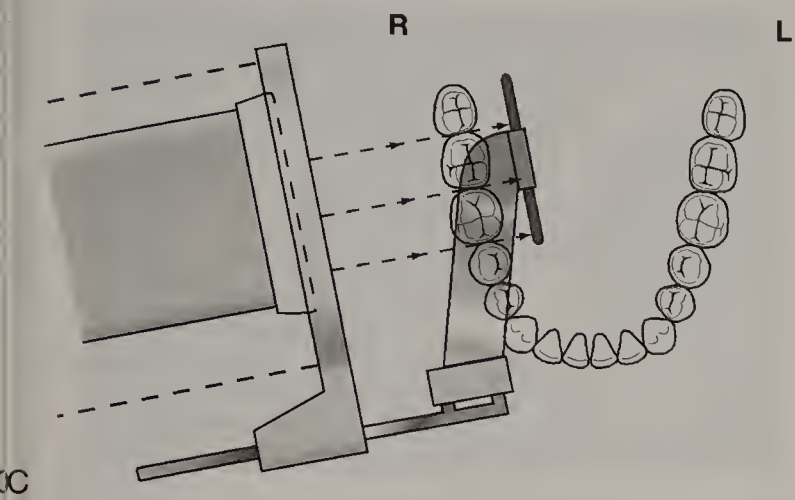


A



B





**Figure 5.32 Molar Bitewing.** (A) Region coverage. (B) Resultant radiograph. (C) Horizontal and BID placement. (D) Proper placement of film. (E) Alignment of BID and bitewing XCP instrument.

E

## BITEWING TECHNIQUE

### Dentsply/Rinn XCP Bitewing Instrument

The interproximal examination is considered the least difficult of the intraoral techniques, yet the results of incorrect alignment of the film, teeth, and x-ray beam are frequently seen on the finished radiograph. These errors are manifested as cone-cutting, overlapping of crowns of teeth, and occlusal surfaces recorded diagonally on the film. Bitewing instruments such as the Dentsply/Rinn Bitewing Instrument were designed to reduce these errors to a minimum (Fig. 5-33). If vertical bitewings are ordered, the vertical bitewing biteblock must be assembled with the indicator rod and aiming or locator ring as shown in Figure 5-34.

### BITEWING TAB TECHNIQUE USED WITH ROUND BID

#### Film Size

A bitewing film has a wing or tab attached to the pebbled side of the film. When the tab is placed on the occlusal surfaces of the mandibular posterior teeth and the patient closes on the tab, the film will be held in a lingual position to the maxillary and mandibular crowns.

There are two sizes of adult bitewing films

1. Adult or No. 3 (2.3) bitewing film is designed to record the crowns of all posterior teeth, both maxillary and mandibular. This type of bitewing film is *not* recommended for two reasons. First, there is a slight amount of distortion in the film from conforming to a curved arch. Second, many times this film does not reveal all the interproximal surfaces of all posterior teeth (from the distal of the canines to the mesial of the third molars).
2. No. 2 (2.2) or standard size bitewing film, one of which is not long enough to record all posterior crowns in an adult mouth. Thus, in the adult, one No. 2 bitewing film should be used in the molar region and one No. 2 bitewing film should be used in the premolar region, including the distal of the canines.

#### Head Position

Regardless of the type of BID being used, the sagittal plane should be perpendicular to the floor, and the ala-tragus line should be parallel to the floor.

#### Film Placement and Retention

**Step 1.** The bitewing tab or wing should be placed on the occlusal surface of the mandibular molars or premolars, with the lower edge of the film packet placed in the vestibule between the tongue and the teeth. The anterior edge of the premolar bitewing film should extend to the mesial surface of the mandibular canine, and the anterior



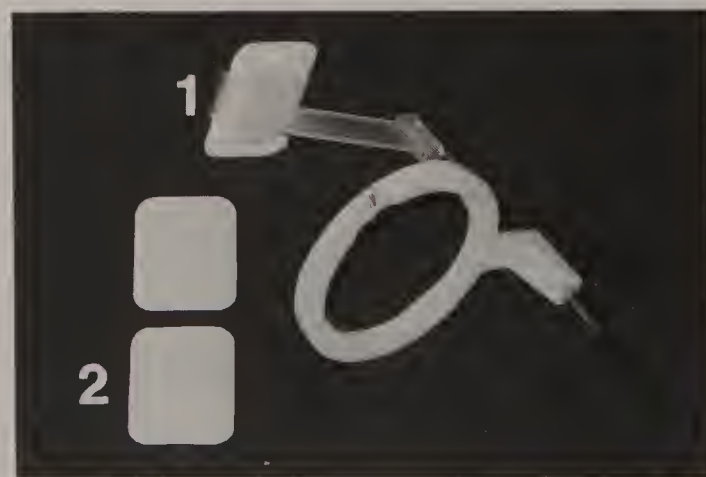
**Figure 5.33 Dentsply/Rinn Horizontal Posterior Bitewing Instrument.** Bitewing instrument assembled correctly with No. 2 film in horizontal position to take a posterior bitewing radiograph.

edge of the molar bitewing film should be placed at the midline of the mandibular second premolar.

If the patient has a shallow vault, the film should be placed even a greater distance away from the lingual surfaces of the teeth. This will enable the patient to close down on the bitewing tab with less difficulty.

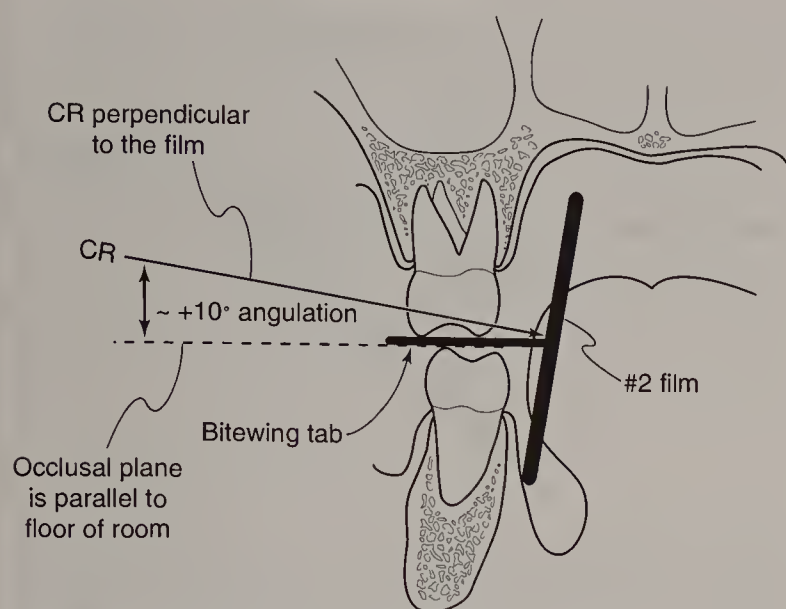
**Step 2.** Half of the bitewing tab should be folded down over the buccal surface of the teeth. This should be done before the tab is placed on the occlusal surfaces of the teeth. With the index finger of one hand, the operator should press against the lower lingual border of the film to keep it upright. The index finger of the other hand should be used to press the tab against the buccal surface of the mandibular teeth.

**Step 3.** The operator should remove the finger that is pressing against the back of the film and instruct the patient to close slowly against the bitewing tab in a normal



**Figure 5.34 Dentsply/Rinn Vertical Bitewing.** (1) Dentsply/Rinn XCP bitewing instrument assembled to take a vertical bitewing radiograph using No. 1 size film. A vertical biteblock is also available for No. 2 size film. (2) No. 2 size film will accept a bitewing tab to take a vertical bitewing radiograph.





**Figure 5.35 Vertical Angulation, Bitewing Tab Technique.** Recommended short BID vertical angulation for posterior bitewing radiograph using a bitewing tab is  $+10^\circ$ ; for long BID, it is  $+8^\circ$  for molar and  $+6^\circ$  for premolar projections.

bite. The patient will not close against the index finger because it is pressing against the buccal surfaces of the lower teeth. After the patient has closed against the bitewing tab, the operator can remove the finger from the tab.

### Vertical Angulation of the BID

**Short, Round BID (8-inch source-film distance):**  $+10^\circ$  vertical angulation.

**Long, Round BID (16-inch source-film distance):**  $+8^\circ$  for molar region and  $+6^\circ$  for premolar region.

If the palate is shallow, the upper border of the film will be forced lingually by the palate on closure. The vertical angle may have to be increased in this case to prevent shape distortion of the maxillary crowns. Usually the maxillary premolars and molars tilt buccally (sometimes as much as  $15^\circ$  from the vertical), while the mandibular pre-

molars and molars slant very little from the vertical. Therefore, to compensate for this discrepancy and to prevent distortion of the crowns, a compromise vertical angulation is used for the bitewing projections (Fig. 5-35).

### Horizontal Angulation

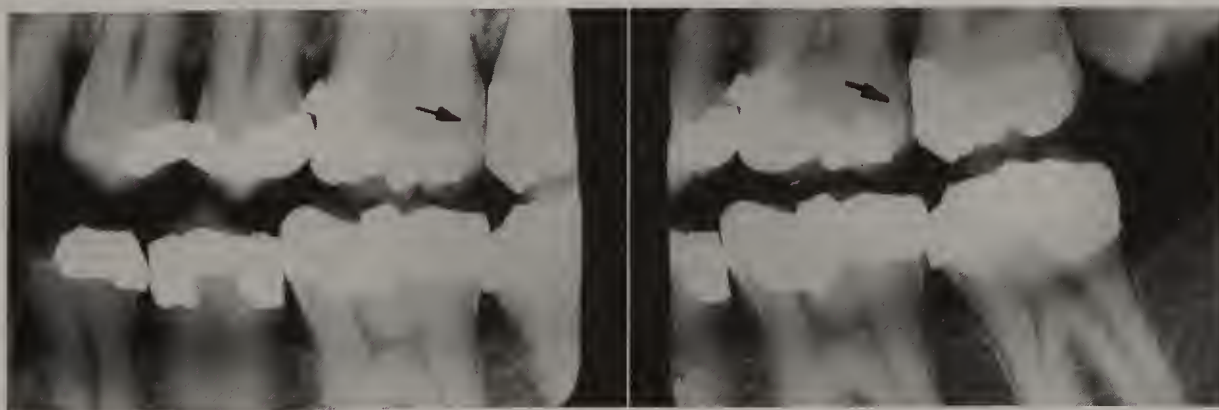
The x-ray beam should be directed through the interproximal embrasures of the crowns of the teeth under examination. The flat face of the round BID should be horizontally parallel to the film packet.

### Point of Entry

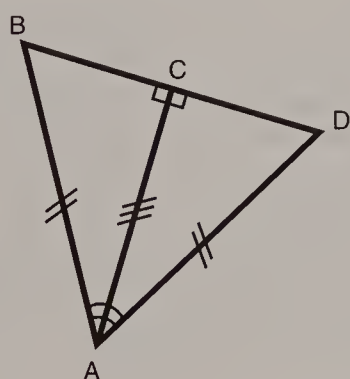
The central ray should be directed through the occlusal plane of the teeth toward the center of the film packet. To prevent cone-cutting, the operator should gently pull back the corner of the lips and observe whether the anterior periphery of the BID is covering the anterior border of the film. In the molar projection, the tab should be attached flush with the anterior margin of the film. This will serve as a landmark for the anterior border of the film when the patient's teeth are closed together. In the premolar projection, the anterior margin of the film can be readily seen (Fig. 5-36).

### BISECTING ANGLE TECHNIQUE

The **bisecting angle technique** is based on the geometric principle that states that two triangles are equal if they have two equal angles and a common side. It is called the **rule of isometry**, which is defined as equality of measurement (Fig. 5-37). When the rule of isometry is applied to dental radiography, it is used to determine the correct vertical angulation of the BID. Vertical angulation is the up and the down movement of the BID. When applied to intraoral radiography, the bisecting angle rule states that, "The central ray is directed through the median plane of the tooth, perpendicular to a line bisecting the angle formed by the plane of the long axis of the tooth and the plane of the film" (Fig. 5-38). This rule applies admirably to plane surfaces that have only length and width, but it

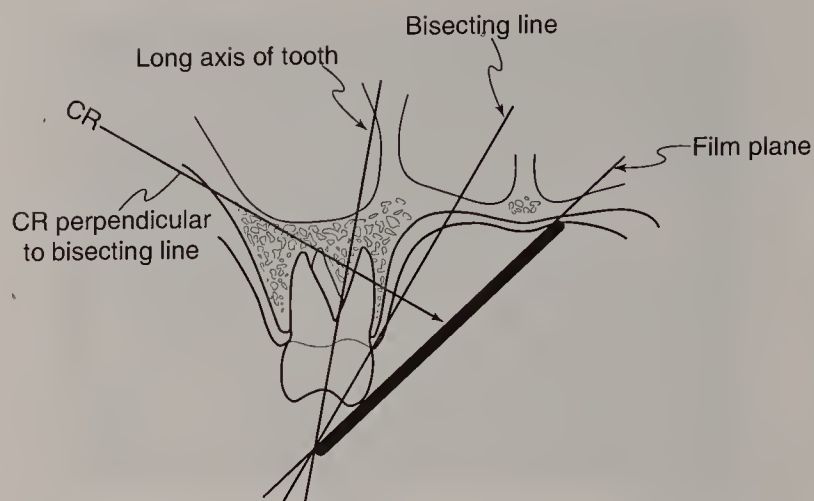


**Figure 5.36 Posterior Bitewing Tab Radiographs.** Premolar and molar posterior bitewing radiographs using a bitewing tab. Note that occlusal surfaces of the upper and lower teeth approximate one another.



**Figure 5.37 The Rule of Isometry.** Angle A is bisected by line AC. Line AC is perpendicular to line BD. Angle DAC is equal to angle CAB, and angle ACD is equal to ACB. If two triangles have two equal angles and a common side, then it can be said that the two triangles are equal. Therefore, triangle DAC is equal to triangle CAB.

has shortcomings when applied to structures, such as the teeth, that also have depth. If the bisecting angle rule is neglected in the slightest manner, the resulting radiographic image will be distorted. Elongation of the length of the actual image of the tooth will result if the x-ray beam is directed perpendicular to the plane of the long axis of the tooth rather than through the bisecting line. Foreshortening of the radiographic image will occur when the x-ray beam is directed perpendicular to the plane of the film, rather than the bisecting line (Fig. 5-39). For the most part, the bisecting technique is practiced with the short BID (8-inch source-film distance). If the short BID is used, it should have an open-ended, flat face. The long or extension BID (16-inch source-film distance) may also be used with the bisecting technique. The advantage of the ex-



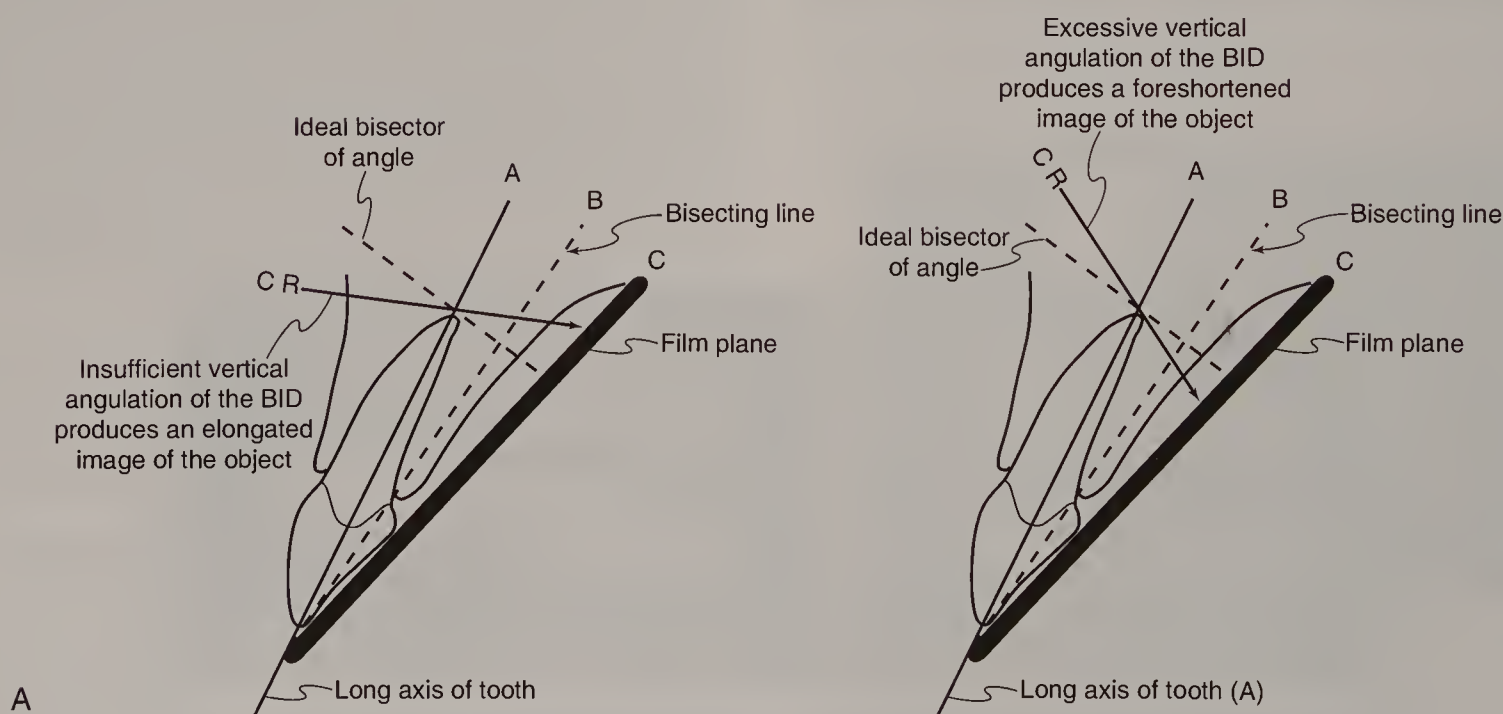
**Figure 5.38 Bisecting Angle Technique.** The rule of isometry applied to the intraoral radiographic technique commonly called the bisection-of-the-angle technique. The path the of central ray is directed perpendicular to a line bisecting the angle formed by the long axis of the tooth and the plane of the film.

tended source-film distance is that it minimizes geometric unsharpness and magnification of the radiographic image.

### Bisecting Angle Technique Procedures

To determine the correct alignment of the central beam, the film, and the teeth using the bisecting technique, the following factors must be considered:

1. Head position.
2. Film placement.
3. Vertical angulation of the BID.
4. Horizontal angulation of the BID.
5. The point of entry of the central ray.



**Figure 5.39 Elongation and Foreshortening.** (A) Elongation. (B) Foreshortening.



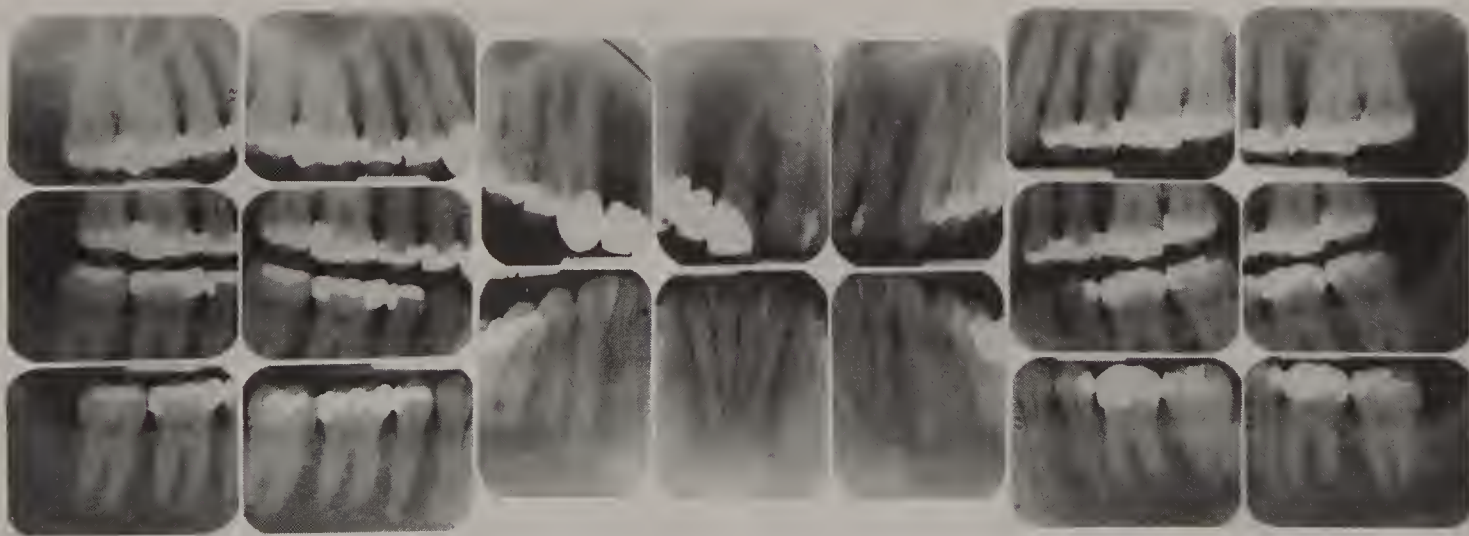
**Head Position.** When using the bisecting technique, head position is important. The rule for head position is as follows: the occlusal plane of the teeth to be radiographed should be parallel to the floor, and the sagittal plane of the head should be perpendicular to the floor for maxillary projections. Here the ala-tragus line is parallel to the floor. In mandibular projections, the mandibular occlusal plane changes when the mouth is open. Therefore, the patient's head should be tilted slightly backward so the occlusal plane of the mandible will be parallel to the floor when the mouth is opened. Here the lip commissure (corner of mouth)-tragus line is parallel to the floor.

**Film Placement.** The rule for film placement in the bisecting technique is as follows: the center of the film is positioned behind the center of the region to be radiographed. The most popular full-mouth periapical examination using the bisecting technique is the 14-film survey using all No. 2 periapical films (Fig. 5-40). For years when using the bisecting angle technique, the film packets were held in the mouth by the patient's fingers (digital method). The digital (finger) method of retaining the film in the mouth is the most undesirable method of film retention, because it places the patient's hand (usually unwashed) into the primary beam of radiation. Also, digital pressure on the film usually causes film bending, which usually results in image distortion and an unnecessary retake. In 1970, the National Council of Radiation Protection (NCRP) recommended the use of film-holders for all intraoral examinations to eliminate the need for patients to stabilize films in their mouths with their hands (NCRP No. 35, 1970).

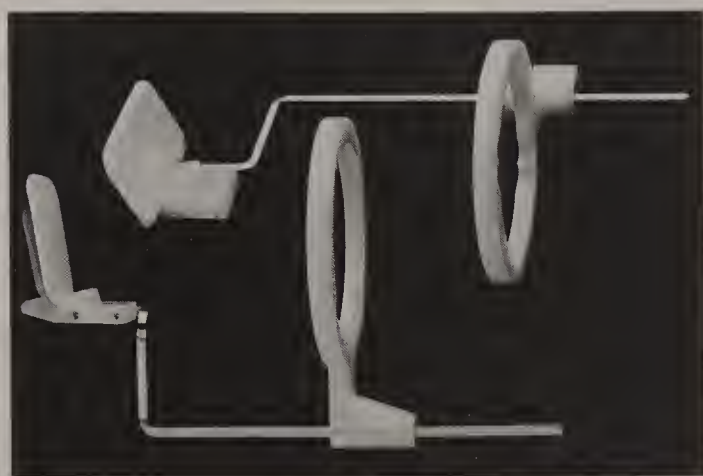
**Vertical Angulation of the BID.** As stated previously, the rule for vertical angulation in the bisecting technique is to direct the central ray through the center of the field under examination, perpendicular to the line bisecting the angle formed by the planes of the long axes of the tooth and the plane of the film. Due to variations in the arrangement,

inclination, and angulation of the teeth in the jaws, the angle formed by the plane of the film and the long axes of the teeth for any given area of the mouth varies from one patient to another. To aid the operator, average vertical angulation values that apply to most patients have been calculated. The operator uses these average values only as a guide; the exact angle to be used for each region for each patient must be determined after the film in the film-holder has been placed into the mouth. The ranges of prescribed vertical angulations for both the short and the long BID bisecting angle techniques are listed below. (A *plus* vertical angulation means the BID is above the horizontal pointed downward, and a *minus* vertical angulation means the BID is below the horizontal pointed upward.) (See Figure 5-7.)

| Average Vertical Angles, Short BID (8-inch Source-to-Film Distance), Bisecting Angle Technique |                 |                          |                   |                           |
|------------------------------------------------------------------------------------------------|-----------------|--------------------------|-------------------|---------------------------|
| Film                                                                                           | Maxillary Range | Maxillary Starting Angle | Mandibular Range  | Mandibular Starting Angle |
| Molar                                                                                          | 25 to 30°       | +30°                     | 0°                | 0°                        |
| Premolar                                                                                       | 35 to 40°       | +40°                     | -5 to -10°        | -10°                      |
| Canine                                                                                         | 45 to 50°       | +50°                     | -15 to -30°       | -15°                      |
| Incisor                                                                                        | 55 to 65°       | +55°                     | -15 to -30°       | -20°                      |
| P. Bitewing                                                                                    |                 | +10°                     |                   |                           |
| Average Vertical Angles, Long BID (16-inch Source-to-Film Distance), Bisecting Angle Technique |                 |                          |                   |                           |
| Film                                                                                           | Maxilla         |                          | Mandible          |                           |
| Molar                                                                                          | +25°            |                          | +0° (fixed angle) |                           |
| Premolar                                                                                       | +35°            |                          | -5°               |                           |
| Canine                                                                                         | +45°            |                          | -10°              |                           |
| Incisor                                                                                        | +45°            |                          | -15°              |                           |
| P. Bitewing                                                                                    |                 |                          | +6-8°             |                           |



**Figure 5.40 Bisecting Angle Full-Mouth Survey.** Typical full radiographic survey taken by bisecting angle technique using a short BID (8-inch SFD). Note that No. 2 regular film is used throughout the survey.



**Figure 5.41 Dentsply/Rinn BAI (Bisecting Angle) Instruments.** Upper: Posterior BAI instrument. Lower: Anterior BAI instrument. Note that the Dentsply/Rinn BAI instruments differ only from the Dentsply/Rinn XCP instruments in the design of the biteblocks.

**Horizontal Angulation of the BID.** The rule for horizontal angulation is as follows: as the BID moves around the arch, the x-ray beam is directed perpendicular to the mean tangents of the facial surfaces of the teeth under examination; the flat face of the BID should be placed parallel to the horizontal plane of the film. If there is an error in the horizontal angulation, overlapping of the radiographic images will result in an inadequate image that must be retaken. The mean tangents of the facial surfaces of the teeth will vary from one region to another (see Fig. 5-20).

**Point of Entry.** The rule for the point of entry in the bisecting technique is as follows: the x-ray beam is directed through the center of the area to be radiographed. The objective here is to completely cover the film with the beam of radiation. If this is *not* done, a “cone-cut” or “partial image” will be seen in the finished radiograph (Fig. 5-11).

#### Use of Film-Holders With Bisecting Angle Technique

Film-holders have been devised for use with the bisecting angle technique. Two such film-holders are the Dentsply/Rinn Bisecting Angle Instruments (BAI) film-holders and the Dentsply/Rinn Stabe disposable periapical x-ray film-holders.

**Dentsply/Rinn BAI Instruments.** The Dentsply/Rinn BAI instruments are designed to aid in the determination of horizontal and vertical angulations, minimize distortion from film bending, and prevent cone-cutting. A set of Dentsply/Rinn BAI instruments consists of anterior and posterior periapical biteblocks, indicator rods, and aiming rings (Fig. 5-41). By using the Dentsply/Rinn BAI instruments, the vertical and horizontal BID angulations need not be memorized, and head positioning is not critical. Moreover, correct film placement and retention is accomplished with less strain on the patient. A long or short BID can be used with the bisecting technique. If a 4-inch

or 8-inch short BID is all that is available for use, the bisecting angle technique is recommended over the paralleling technique. The operator needs to remember how to determine true BID length: locate the focal spot mark on the tubehead housing and measure the distance from this mark to the external tip of the BID.

**Dentsply/Rinn Stabe Film-Holder.** The Dentsply/Rinn Stabe film-holder is made of an expanded, rigid polystyrene material. It is soft, allowing the patient's teeth to penetrate the biteblock portion of the film-holder, locking it into position. The Dentsply/Rinn Stabe film-holder can be used in the bisecting angle technique by placing the film as shown in Figure 5-42. The removable end of the Dentsply/Rinn Stabe is taken off for placement of all periapical packets with the bisecting technique. With film in the Dentsply/Rinn Stabe film-holder, the operator places the film as close to the teeth as possible without bending the film. The patient then closes gently on the biteblock portion of the film-holder. The x-ray beam is directed perpendicular to the bisecting plane, bisecting the angle formed by the plane of the film and the long axes of the teeth (Fig. 5-42). The BID should be positioned horizontally so the flat portion of the x-ray BID is parallel to mean tangent of the surfaces of the teeth being radiographed. The use of the bisecting angle method (without an aiming device) requires very careful positioning of the film and BID. (The average bisecting vertical angles, as shown in the previous boxed section, should be used.)

## MANAGEMENT OF THE PATIENT DURING RADIOGRAPHIC PROCEDURES

For the procedure to progress smoothly and to avoid retakes, the operator must know how to manage each patient individually. There are certain patient variations that should be considered before beginning any radiographic procedure. After preliminary discussions and removal of intraoral appliances and eyeglasses, the patient's mouth should be examined, and a mental note made concerning any of the following factors that may have an influence on the procedure.

### ANATOMICAL VARIATIONS

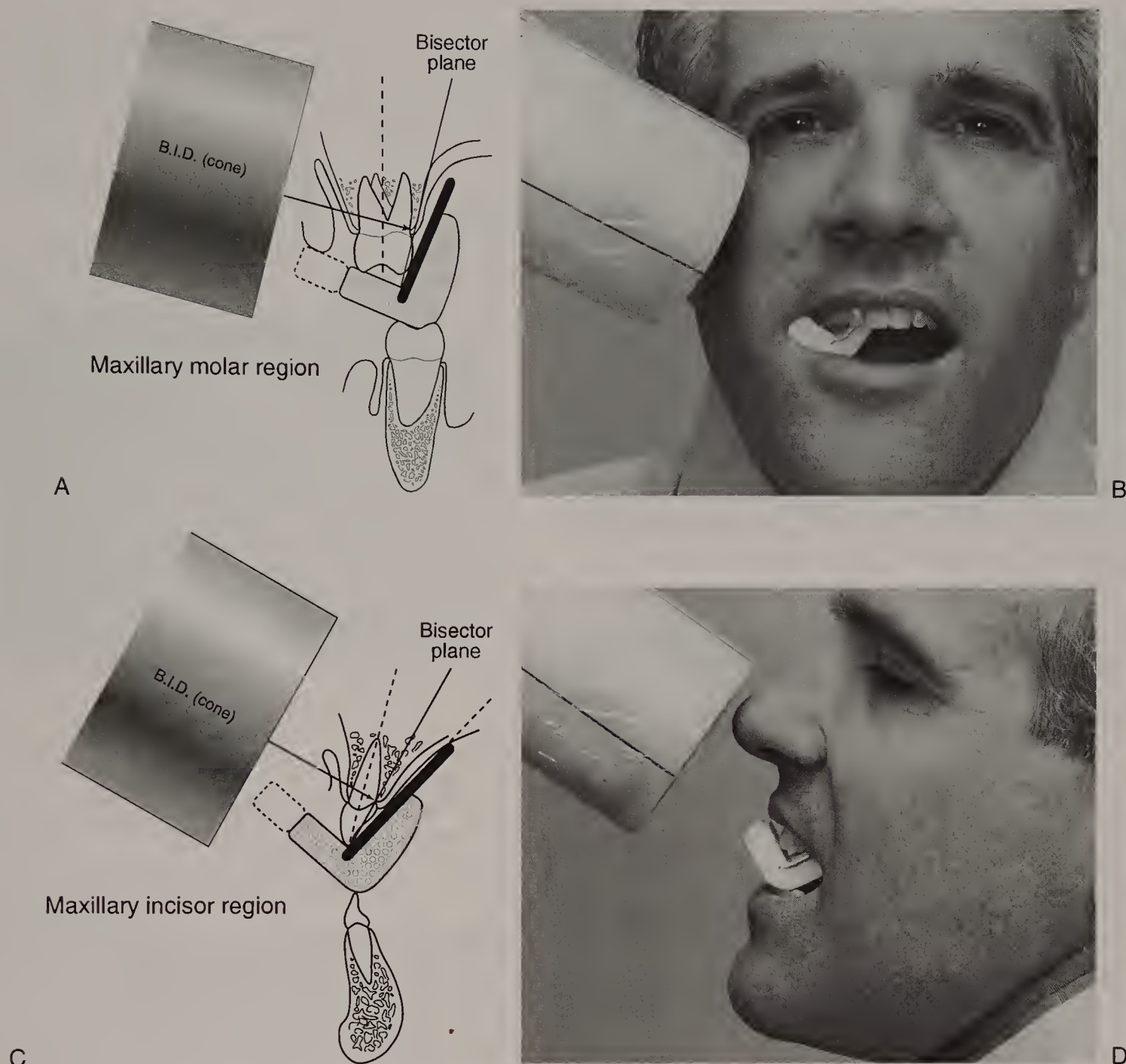
#### Tongue Variations

Large muscular tongues often interfere with placing a film for mandibular projections.

#### Shallow Maxillary Palates

In the right angle or paralleling technique, absolute parallelism between the film and long axes of the teeth is difficult to accomplish in patients with shallow maxillary palatal vaults. However, if the discrepancy of parallelism between the film and the long axis of the tooth does not





**Figure 5.42 Dentsply/Rinn Stabe Film-Holder and Bisecting Angle Technique.** (A) Maxillary molar Stabe bisecting technique. (B) Stabe bisecting angle technique in maxillary molar region. (C) Stabe bisecting angle technique in maxillary central incisor region. (D) Maxillary incisor Stabe bisecting technique.

exceed  $20^\circ$ , the resultant radiograph is usually acceptable. This angle is estimated by observing the angle between the plane of the film in place and the long axis of the teeth being imaged. In those unusual cases in which the patient has a shallow palate, the vertical angulation should be increased by 5 to  $15^\circ$  greater than the Dentsply/Rinn XCP instrument indicates. However, by increasing the vertical angulation, foreshortening of the teeth in the region will result and sometimes a portion of the cusp tips of the teeth may be cut off (Fig. 5-43).

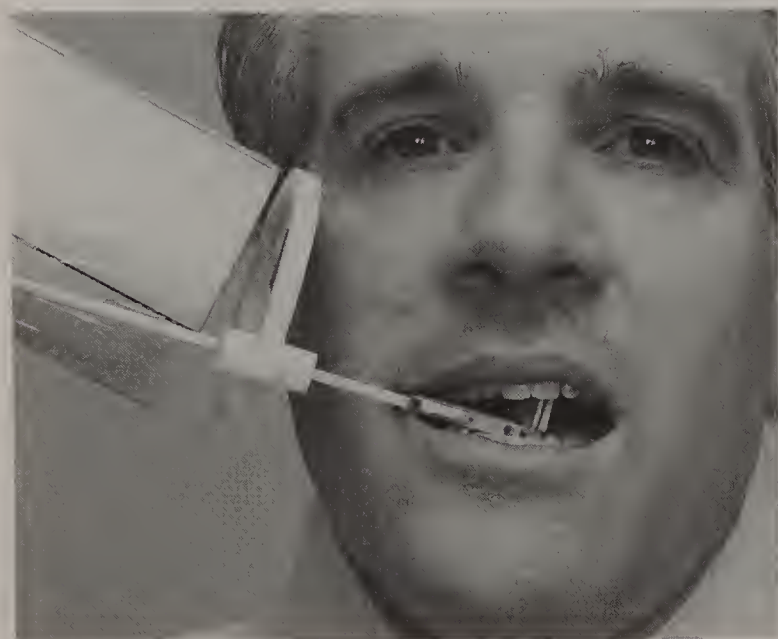
#### **Torus Palatinus**

This is a form of exostosis or bony outgrowth in the mid-line of the hard palate seen quite frequently in the general

population (20%). When it becomes sufficiently large, it causes a problem in taking radiographs of the maxillary molars with the paralleling technique. The film should be placed on the far side of the torus before exposing the film. The film should not be placed on the torus itself (Fig. 5-44).

#### **Torus Mandibularis**

Torus mandibularis is an exostosis or outgrowth of bone found on the lingual surface of the mandible, usually bilateral, and in the canine-premolar area (Fig. 5-45). The reported incidence in the United States is 6 to 8%, with no difference between sexes. The onset is usually at 30 years of age. It is important *not* to place the apical border of the

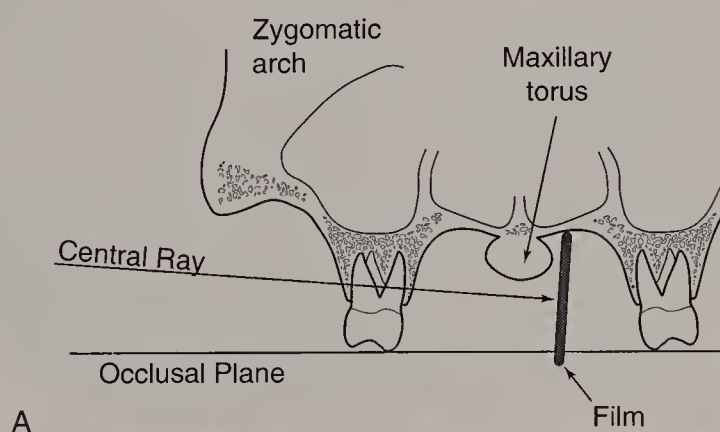


**Figure 5.43 Shallow or Low Maxillary Palates.** Increasing vertical angulation of round or rectangular BID in patients with a low or shallow palate to increase periapical coverage.

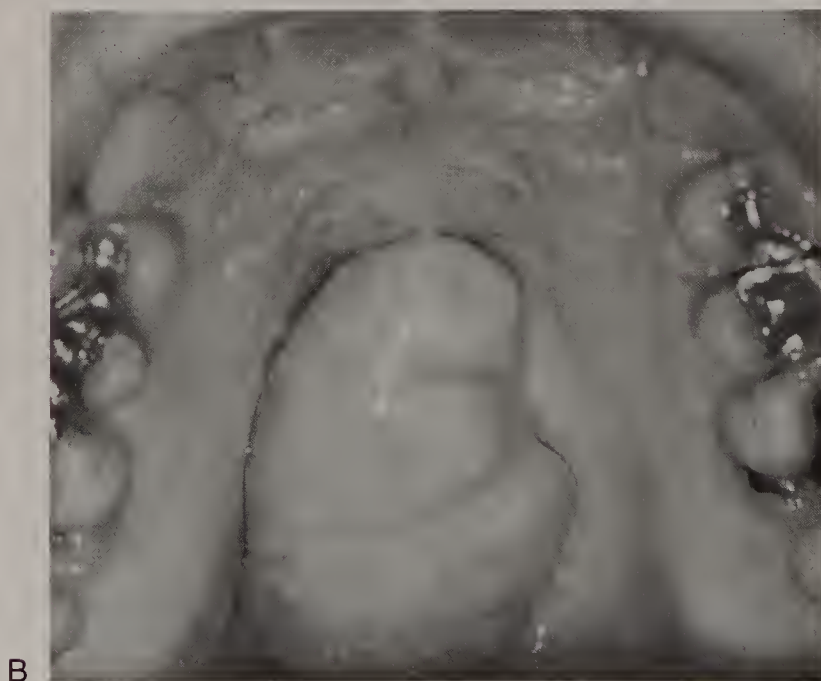
film on top of a mandibular torus, as it will result in a partial image of the roots of the teeth. The film should be inserted between the lingual torus and the tongue, away from the torus and teeth, thus increasing the object-film distance (Fig. 5-45).

#### **Sensitive Mucosa in the Mandibular Premolar Region**

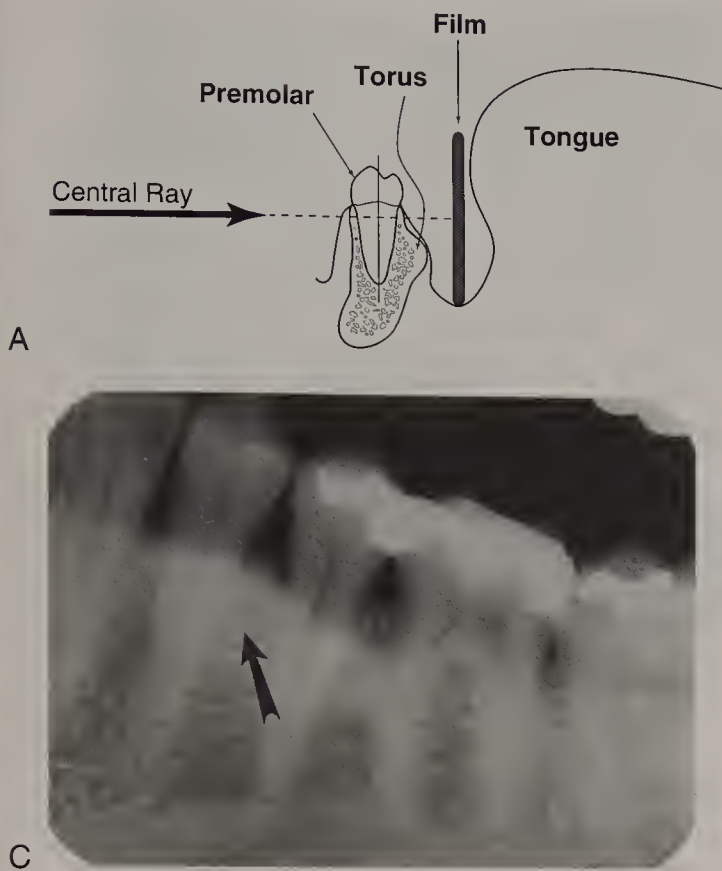
The preferred method to place films into the sensitive premolar vestibular region using the Dentsply/Rinn XCP instrument is as follows. First, the XCP biteblock is brought in firm contact with the teeth to be examined; the apical end of the film packet at this stage should exert very little pressure on the vestibular soft tissues between the tongue and the teeth (Fig. 5-46). The film is brought to its terminal position by a tilting action of the instrument using the biteblock as a fulcrum when the patient closes on the biteblock. The operator coordinates the movement of the film with the patient's jaw movements. As the patient closes, the muscles of the floor of the mouth relax, enabling the film to be brought into place without discomfort. Sometimes moving the tongue or swallowing helps to further



**Figure 5.44 Maxillary Torus.** (A) Maxillary torus and placement of film using posterior XCP instrument. (B) Photograph of an extremely large maxillary torus. (C) Radiograph of maxillary torus (arrow) taken with anterior XCP instrument.







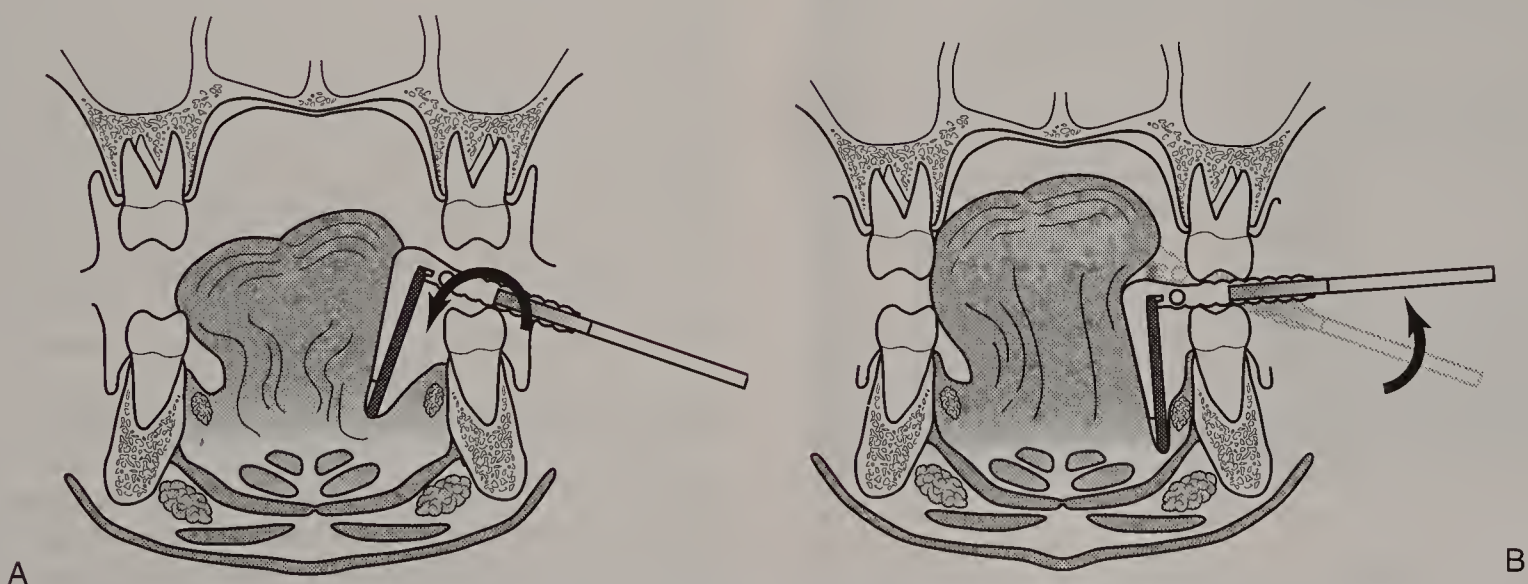
**Figure 5.45 Mandibular Torus.** (A) Mandibular torus and placement of film. (B) Photograph of large mandibular tori. (C) Radiograph of mandibular torus (arrow).

relax these muscles. If necessary, topical anesthetic can be used to desensitize these tissues.

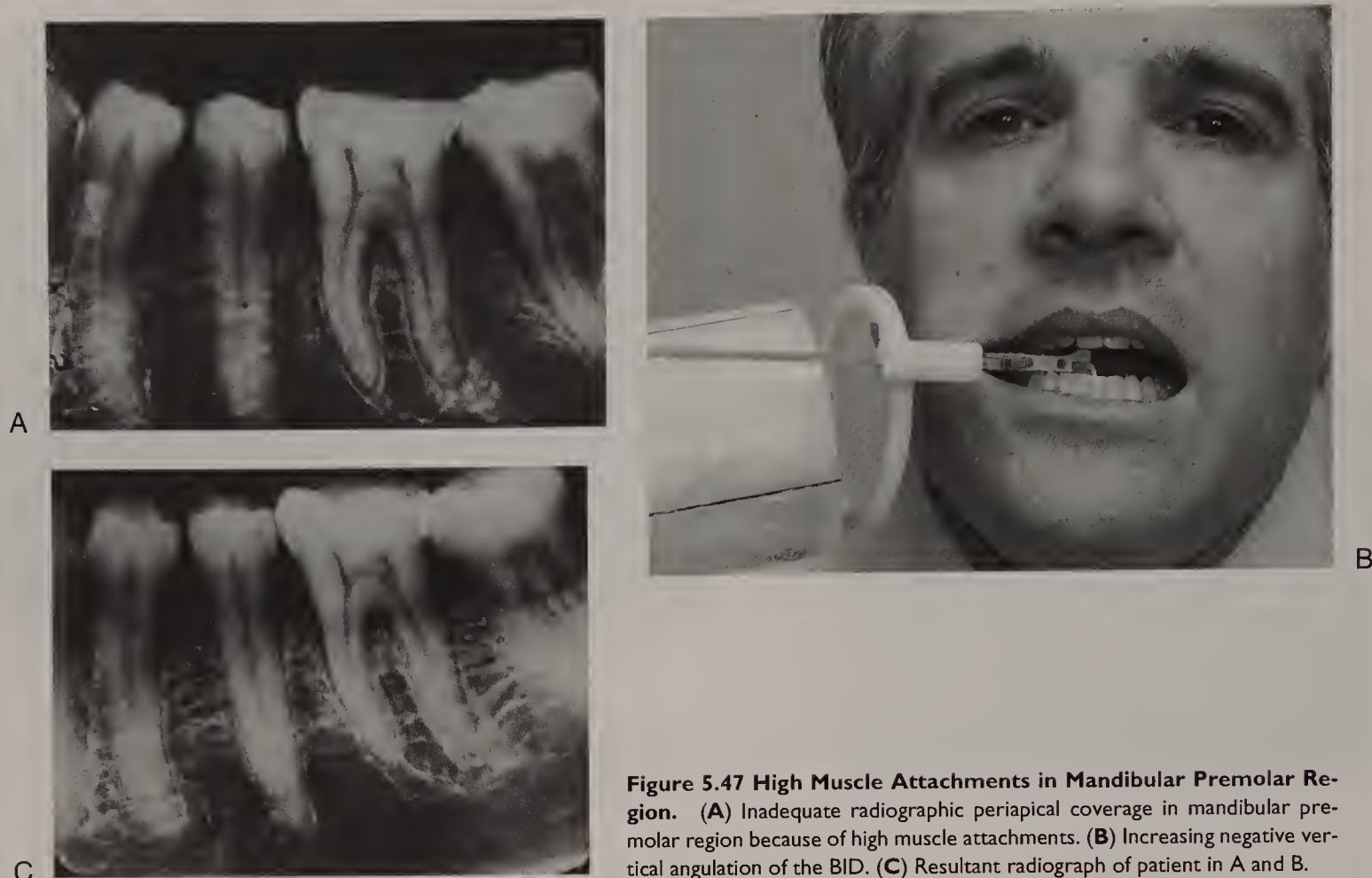
#### High Muscle Attachments in Mandibular Premolar Region

When there are high muscle attachments along with an excessive mandibular occlusal curve and long roots, the

conventional Dentsply/Rinn XCP paralleling technique may result in inadequate periapical coverage in the premolar region (Fig. 5-47). One way to overcome this problem is to increase the negative vertical angle of the BID (upward movement of the BID tip)  $-5$  to  $-15^\circ$  greater than the instrument indicates (Fig. 5-47). The Snap-A-Ray may be substituted for the Dentsply/Rinn XCP in-



**Figure 5.46 Sensitive Mucosa Region in Mandibular Premolar Region.** (A) Initial position. (B) Terminal position (a cotton roll between opposing teeth and biteblock may sometimes be used).



**Figure 5.47 High Muscle Attachments in Mandibular Premolar Region.** (A) Inadequate radiographic periapical coverage in mandibular premolar region because of high muscle attachments. (B) Increasing negative vertical angulation of the BID. (C) Resultant radiograph of patient in A and B.

strument in the mandibular premolar region with some success, because the mandibular premolars are positioned more vertically in the alveolar bone with very little lingual inclination. This allows for adequate paralleling of the film with the long axes of the teeth without increasing the object-film distance.

#### **Sensitive Mandibular Incisor Region**

Mandibular incisor intraoral radiography using the Dentsply/Rinn XCP instrument can be very sensitive to a patient if the Dentsply/Rinn XCP film-holder is not positioned correctly. The XCP biteblock should first be brought into firm contact with the incisal edge of the mandibular incisor teeth. At this stage, the apical portion of the film packet should exert little or no pressure on the soft tissues of the floor of the mouth (Fig. 5-48). Next, the film is brought into the final position by a rotating movement of the Dentsply/Rinn XCP instrument as the patient slowly closes the mouth. With this maneuver, film can be placed into position without sensitivity, by coordination of the movement of the film with the patient's jaw movement. The muscles of the floor of the mouth relax as the mouth closes and provide adequate room for the film packet (Fig. 5-48).

#### **Edentulous Ridges**

Edentulous patients will require less exposure time to produce the radiographic image. Usually, one timer setting

lower is a suitable adjustment. When available, the panoramic radiograph is the simplest, quickest, and least uncomfortable radiographic procedure for edentulous patients.

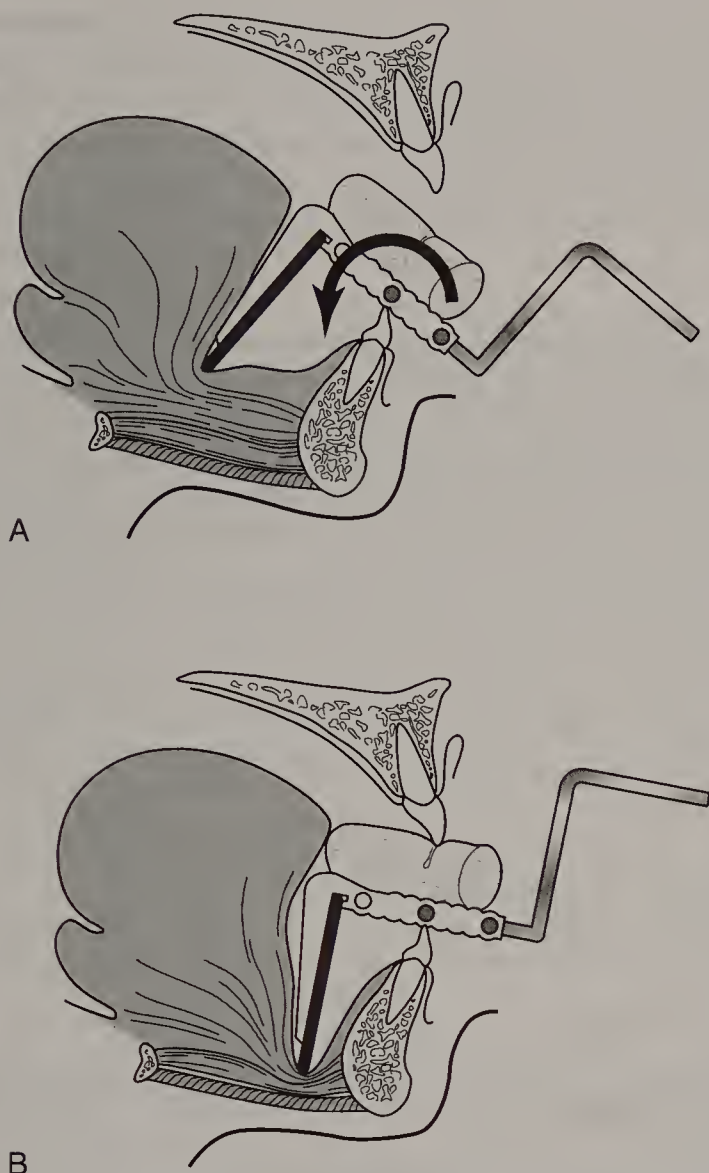
#### **SUBSTITUTING THE PANORAMIC RADIOGRAPH FOR DIFFICULT PATIENTS**

The panoramic radiograph is an excellent substitute for intraoral radiography in certain instances. It is quick and easy and usually causes very little problems in difficult-to-manage patients. Alleviating an unpleasant experience and still obtaining the needed image information can increase the patient's confidence. If further dental hygiene and dental procedures are needed, the anxious patient will be better prepared to undergo these procedures because the preliminary radiographs were well tolerated. A carefully exposed and properly processed panoramic radiograph is an excellent and often desirable substitute for the complete-mouth intraoral periapical radiographic survey.

#### **MANAGING THE APPREHENSIVE PATIENT**

Apprehensive patients are usually nervous or anxious individuals who tend to have a hypersensitive mouth and a low pain threshold. These patients often avoid the dental office and do not have regular check-ups. The first contact with the patient should be a pleasant, reassuring one. It is imper-





**Figure 5.48 Sensitive Mandibular Incisor Region.** Positioning anterior Dentsply/Rinn XCP instrument in mandibular incisor region. (A) Starting position. (B) Terminal position.

ative to be organized for the procedure so that exposures can be made rapidly but as accurately as possible. Extreme care must be used in the placement of the films. It is best to begin the procedure in the maxillary anterior region and work progressively posterior. Be encouraging and compliment patient cooperation. Many patients have difficulty maintaining the film in the proper position due to a low pain threshold or nervousness. The following procedures can reduce the level of pain induction, thus accommodating the patient and producing a diagnostic radiograph.

### Film Bending

It is preferable not to bend the film. However, conservative bends on certain aspects of the film can make the difference in proper film positioning and patient comfort. The allowable bends are strategically located so that they do not interfere with the teeth of interest on the film. In processing bent films, the unbent edge of the film should be placed in the processor first. The usual problem spots are the lower anterior edge of the mandibular premolar periapicals and the upper anterior corner of the maxillary canine film.

### Edge-Ease Tissue Protectors (Strong Dental Products, Saratoga, CA)

In the lower premolar region, if the film feels sharp to the patient on closing, the operator should try placing the film closer to the lingual of the teeth and have the patient relax the muscles in this area, or perform appropriate film bending. If these steps do not diminish the sensitivity, the saliva should be wiped from the film packet and a sponge tissue protector placed on the apical film edge. These tissue sponges have a peel-off backing that exposes a sticky surface, allowing the sponge to adhere to the film packet (Fig. 5-49). The sponge does not interfere with the image. Use of the tissue protectors should reduce the discomfort experienced by the patient.

### Topical Anesthetic

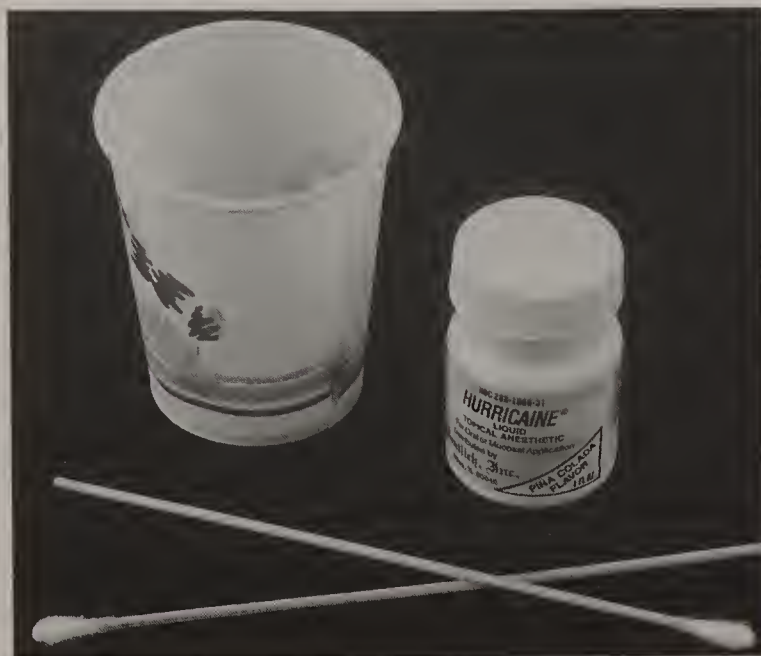
If tissue protectors are not available or are not effective, film placement sensitivity can be reduced by use of a topical anesthetic agent. The patient's medical history should be checked before use of a topical anesthetic. Using a cotton-tipped swab, the topical solution can be painted on the tissues where the film is to be placed (Fig. 5-50). This should reduce the pain sensation long enough to expose the film. The patient should be instructed to rinse and empty the mouth once finished.

### Prescribed Anxiolytics

Prescribing tranquilizers, such as diazepam or lorazepam, can go a long way in reducing patient anxiety and increasing cooperation and tolerance of minor discomfort.



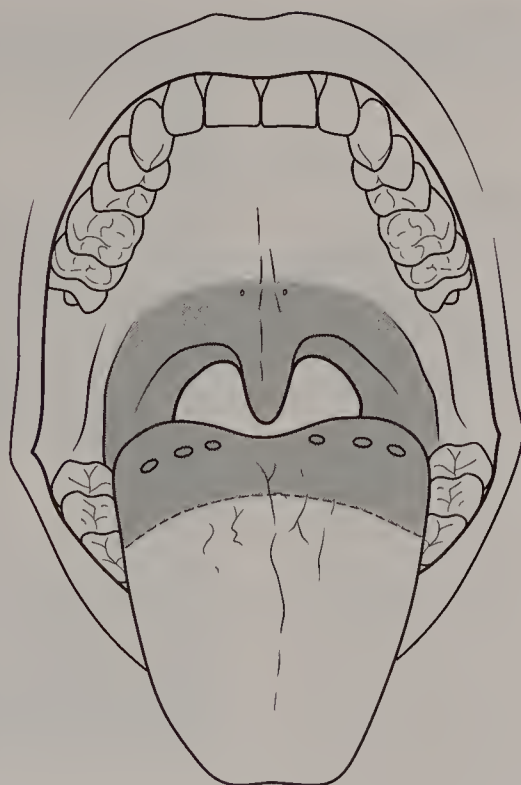
**Figure 5.49 Edge-Ease Tissue Protectors (Strong Dental Products).** Soft-technique tissue protectors that have been available since 1988 are used to protect patients from discomfort resulting from the inferior border of the periapical film packets encroaching on sensitive intraoral tissues during intraoral radiographic procedures.



**Figure 5.50 Topical Anesthetic Agent for Sensitive Oral Tissues.** Liquid Topical Hurricane Anesthetic Agent (Beutlich Co, Waukegan, IL) and cotton-tipped swabs to apply the liquid topical anesthetic.

## MANAGING THE GAGGING PATIENT

Gagging is the involuntary effort to vomit. It is caused by the gag reflex and is very annoying in intraoral radiography. Some patients have an extremely low threshold for the gag reflex. The receptors for the gag reflex are located in the soft palate, the lateral posterior one-third of the



**Figure 5.51 Receptors of Ninth or Glossopharyngeal Nerve in Oral Cavity.** Areas of the oral pharynx and the posterior one third of the tongue where the receptors of the gag reflex are located. These areas (dark areas) are innervated by the ninth or glossopharyngeal nerve.

tongue, and the region of the retromolar mylohyoid space. The ninth or glossopharyngeal nerve governs the sensitivity of these areas and also controls the reflex movements of swallowing, gagging, and vomiting (Fig. 5-51). The mechanism of the gag reflex is set off by initial irritation to the soft palate or the posterior third of the tongue, and is subsequently conveyed by afferent (toward the brain) nerves to the gag center in the medulla oblongata (lower portion of the brain). There is an outflow from this nerve center of the medulla oblongata by way of efferent (away from the brain) nerve fibers to the muscles involved in gagging. The gag reflex proceeds by a series of reactions. First there is the cessation of respiration. This is followed by the contraction of the thoracoabdominal and oropharyngeal muscles. (Sometimes, but not often, food is regurgitated [vomited] into the larynx, the oropharynx, and the mouth.)

The two stimuli that commonly initiate the gag reflex are psychic stimuli and tactile stimuli. To eliminate or diminish the gag reflex, these stimuli must be eliminated or diminished.

## Reducing Psychic Stimuli

Persons with an accentuated gag reflex are usually nervous and high-strung individuals with hypersensitive oral tissues.

The following suggestions will aid in the alleviation of psychic stimuli:

1. The first contact should be a pleasant one, and every effort should be made to give the patient confidence in the dental health care worker's ability to perform the service about to be rendered. The problem should be discussed in a kindly and sympathetic manner. The dental health care worker should try to gain the patient's confidence, which reduces anxiety.
2. The anterior regions of the oral cavity should be radiographed first, and the most sensitive maxillary molar regions radiographed last. Perhaps by then the patient's fears from psychic stimuli will be forgotten, and these sensitive areas in the oral cavity may be radiographed without incident. The operator should avoid describing where the film will be placed.
3. The health care worker should try to divert the patient's attention away from the procedure. This can be done in several ways. A running dialogue can be maintained, and the health care worker can coach the patient through each film. The patient should be encouraged and told to imagine a favorite place or person and focus on that mental picture.
4. The patient should be given a task to perform. For instance, he or she could raise one leg and maintain that position, or flex the toes toward the body and hold that position.
5. The patient could be premedicated with the use of anxiolytic agents as prescribed by the dentist.



### Reducing Tactile Stimuli

Some persons have an accentuated gag reflex because of hypersensitive pharyngeal (throat) areas. Patients suffering from chronic sinus trouble (the well-known postnasal drip) are the worst gaggers. An accumulation of mucus and saliva into the nasopharynx or oropharynx may initiate the gag reflex in these patients.

Methods to alleviate tactile stimuli are as follows:

1. The film should be placed positively and be retained in position without movement. Film-holders, such as the Dentsply/Rinn Snap-A-Ray, are very useful in this situation.
2. Exposure of the film should be accomplished as quickly as possible. Organizing the procedure can do this. The x-ray machine settings (timer, kVp and mA) and BID angulation for the approximate anticipated vertical and horizontal angles should be preset. The films should be placed quickly but with precision, and the film exposed with the aid of a helper.
3. If the operator is still experiencing difficulty, use of an agent to desensitize the tissue may be necessary. Ice water, salt placed on the tip of the tongue, or a topical anesthetic applied to the sensitive area often resolves the problem.
4. In cases of an extreme gag reflex, it may be impossible to obtain a complete intraoral survey. The operator should try to obtain as many intraoral projections as possible and then supplement them with extraoral radiographs. Some of the following combinations of films may be suitable alternatives.
  - a. Maxillary and mandibular occlusal radiographs.
  - b. Bitewings using No. 1 or 0 size film.
  - c. Panoramic radiograph.

## OCCLUSAL RADIOGRAPHY

The occlusal film is much larger than the regular periapical film. It is  $3 \times 2.25$  inches, and its film emulsion speed is the same as the speed of periapical films (D, E+, and F speed film). The film is placed between the occlusal surfaces of the teeth and held in place by the patient's teeth. In general, the occlusal radiograph is used to visualize large areas of the maxilla and mandible that cannot be seen on the smaller periapical film. Occlusal radiography is based on the bisecting angle technique theory. Therefore, the central ray will be directed perpendicular to the bisector of the angle formed by the film plane and the long axes of the teeth under examination. Indications for occlusal radiographs have been discussed previously in this chapter. Occlusal radiographs are most often taken to examine the anterior aspects of the maxilla and mandible. The most typical projections will be presented. However, the basics of the technique can be applied to posterior aspects of the mouth by making adjustments in film placement, horizontal angulation, and central ray entry.

## MAXILLARY TOPOGRAPHIC PROJECTION

### PURPOSE

The purpose of maxillary topographic projection is to observe a much larger area of the maxilla than can be observed with intraoral periapical radiographs (Fig. 5-52).

### FILM PLACEMENT

The film is placed in the mouth with the longer axis of the film running laterally from side to side, with the pebbled side against the maxillary teeth and inserted posteriorly as the inner vestibule will permit. The patient bites down gently to hold the film in position. If edentulous, the patient uses the thumbs to hold the film against the edentulous ridges.

### HEAD POSITION

The line from the tragus of the ear to the ala of the nose is horizontal and parallel to the floor. The midsagittal plane is perpendicular to the floor.

### PROJECTION OF CENTRAL RAY

The central ray enters perpendicular to the bisector of the angle formed by the film plane and the long axes of the maxillary incisor teeth. The central ray entry point is 0.5 inches above the tip of the nose (Fig. 5-52)

### RADIOGRAPHIC FACTORS

Film: Kodak Occlusal Film (D, E+, and F speed film) (Rochester, NY).

Source-Film Distance: Long 16-inch BID.

Vertical Angulation BID:  $+65^\circ$

### EXPOSURE FACTORS E+ SPEED FILM

65 kVp and 15 mA

30 impulses—adult.

24 impulses—child.

21 to 24 impulses—edentulous.

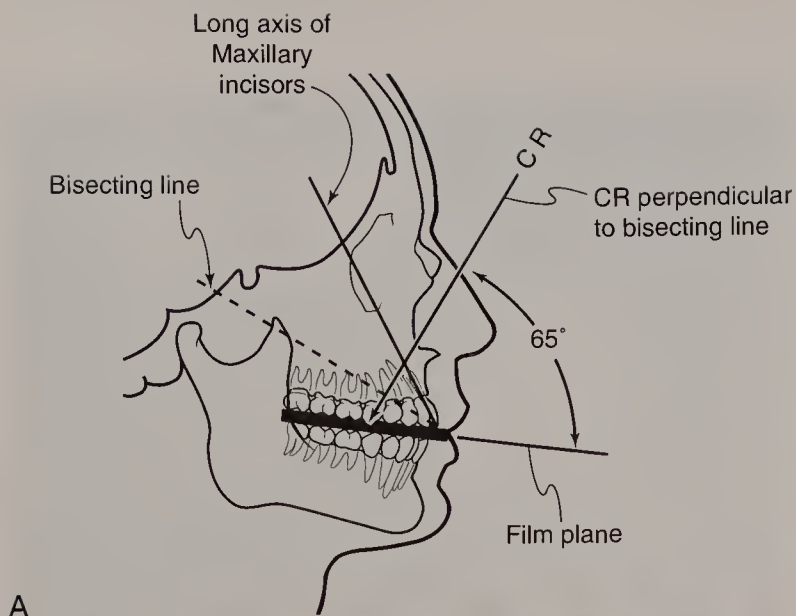
Note: For the short 8-inch BID, one quarter of these exposure times can be used.

## MANDIBULAR SYMPHYSIS PROJECTION

### PURPOSE

This film is used to record a broad area of the mandibular incisor region (Fig. 5-53). It can also be substituted for anterior periapicals when periapical film placement is not possible.

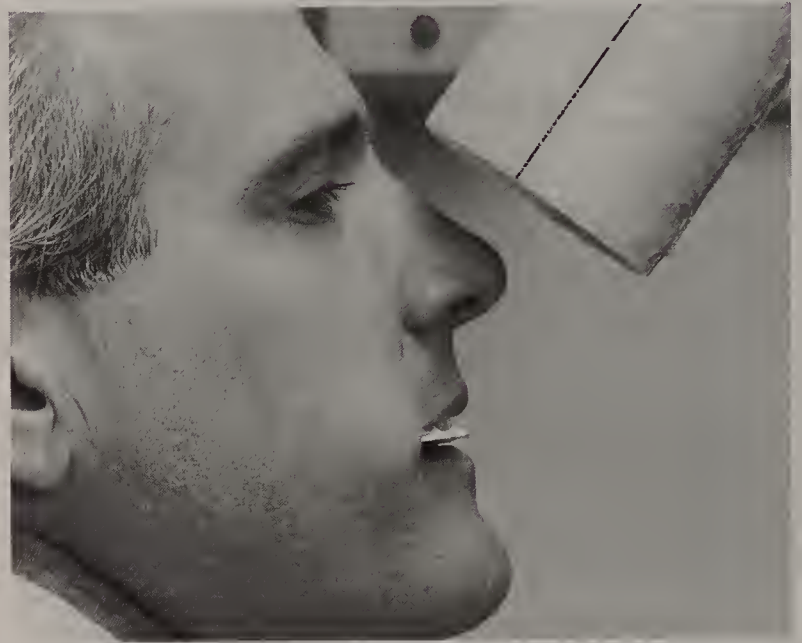
**Figure 5.52 Maxillary Occlusal Topographic Radiograph.** (A) Diagram of maxillary occlusal topographic projection. (B) Radiograph of maxillary occlusal topographic projection. (C) Side view with the vertical angle of the BID approximately  $+65^\circ$  through the point in the midsagittal plane between the nose and the nasal bridge to center of film packet.



A

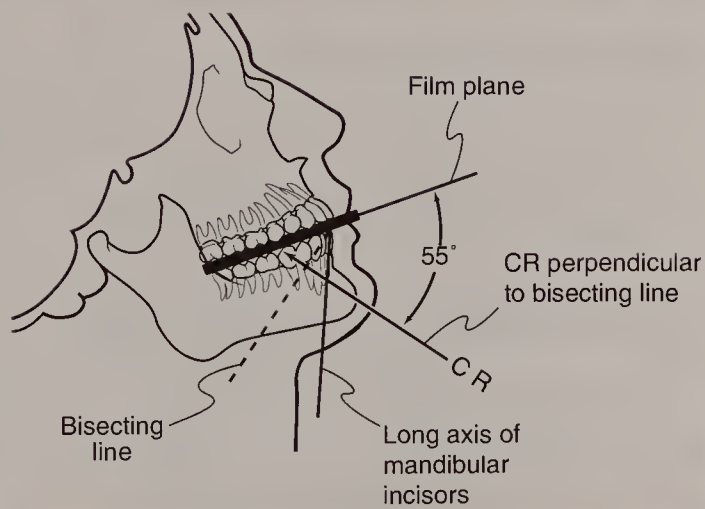


B

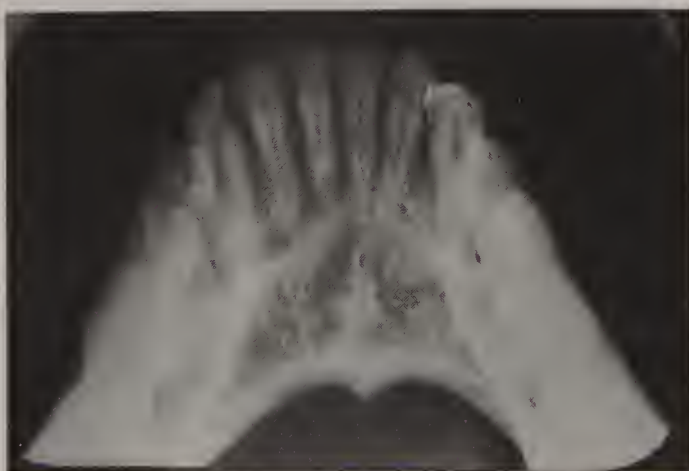


C

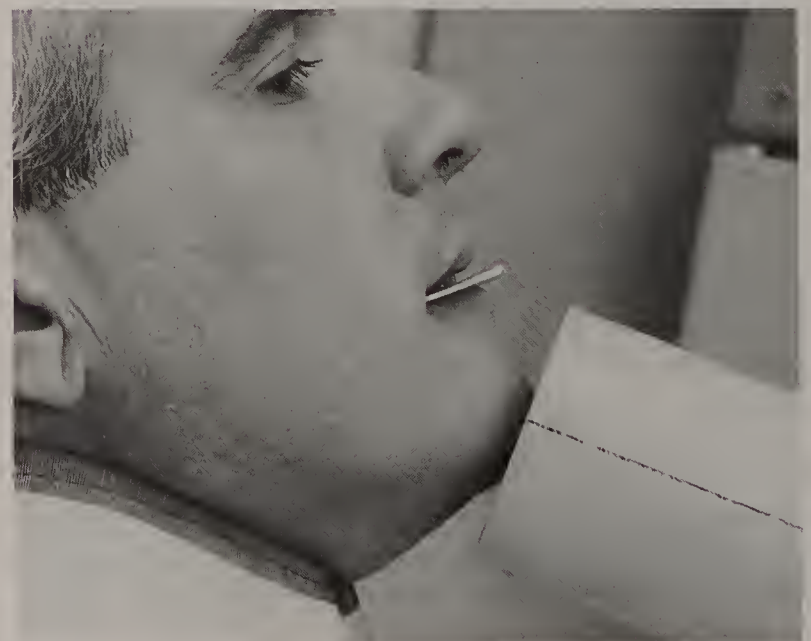
**Figure 5.53 Mandibular Occlusal Symphysis Radiograph.** (A) Diagram of occlusal symphysis projection. (B) Symphysis radiograph revealing the lower anterior incisors and the lower border of the anterior mandible. (C) BID and film placement. The patient's head should be tilted back until the occlusal plane of the film forms an angle of  $45^\circ$  with the floor. A  $-20^\circ$  vertical angulation of the BID should be used, and the path of the central ray should be directed through the symphysis of the mandible to the center of the occlusal film.



A



B



C



## FILM PLACEMENT

The film is inserted into the mouth with the pebbled or plain side of the film facing the mandibular occlusal surfaces. The film is placed with the longer axis of the film placed coincidental with the midsagittal plane. The patient slowly closes down on the film packet with a gentle end-to-end bite.

## HEAD POSITION

The patient's head is tilted way back until the occlusal plane of the maxillary teeth forms an angle of  $45^\circ$  with the floor. The midsagittal plane should be perpendicular to the floor.

## PROJECTION OF CENTRAL RAY

A  $-20^\circ$  vertical angulation of the BID should be used, and the central ray should be directed parallel to the sagittal plane through the symphysis of the mandible to the approximate center of the packet. The film packet and the central ray should form an approximate angle of  $55^\circ$  (Fig. 5-53). This is a difficult concept; use the bisecting angle procedure to make the projection.

## RADIOGRAPHIC FACTORS

Film: Kodak Occlusal Film (D, E+, and F speed film).  
Source-Film Distance: Long BID, 16 inches.

## EXPOSURE FACTORS E+ SPEED FILM

65 kVp and 15 mA  
24 impulses—adult.  
21 impulses—child.

Note: These exposure times can be reduced to one-quarter the exposure time if an 8-inch BID is used.

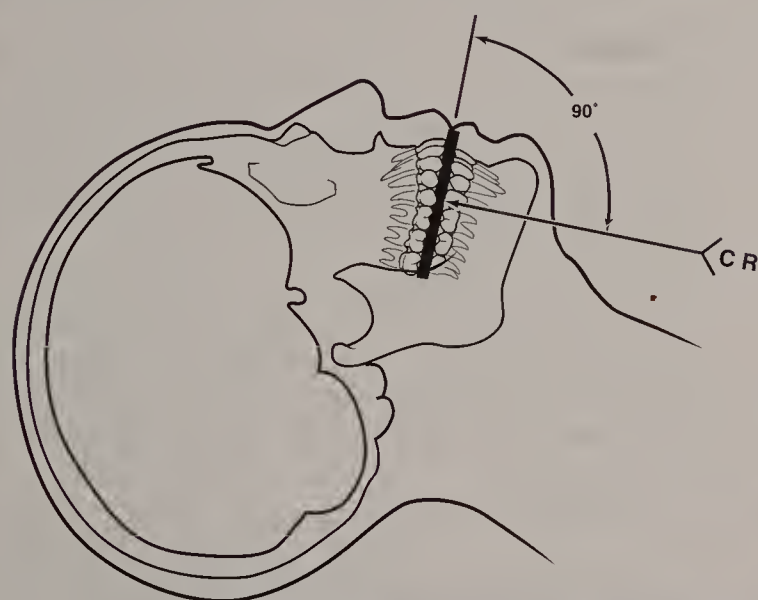
## MANDIBULAR CROSS-SECTIONAL PROJECTION

### PURPOSE

Mandibular cross-sectional projection shows the relationship of an object to the teeth in the horizontal plane. Thus, it provides the information that, when coupled with information obtained from the intraoral periapical survey, accurately localizes the position of an object within the mandible. It is also very important in the diagnosis of sialoliths (stones) in the submandibular gland duct (Wharton's duct) and of calcifications within the salivary gland itself (Fig. 5-54).

### FILM PLACEMENT

An occlusal packet is inserted with the pebbled side adjacent to the mandibular occlusal surfaces; the short center



**Figure 5.54 Mandibular Cross-Sectional Occlusal Projection.** (A) Diagram of the mandibular cross-sectional occlusal projection. (B) Radiograph of the mandibular cross-sectional occlusal projection. (C) BID and film placement. The head is tipped back until the occlusal plane of the maxillary teeth is at a right angle to the floor. The path of the central ray is directed 1 inch posterior to the symphysis and at right angles to the film.



axis is coincident with the midsagittal plane. The posterior edge of the packet is against the anterior aspect of the rami, bilaterally. The patient slowly closes on the packet with a gentle end-to-end bite. Edentulous patients should hold the film against the ridge with their forefingers.

## HEAD POSITION

The head is tipped backward until the occlusal plane of the maxillary teeth is vertical and at a right angle to the floor.

## PROJECTION OF CENTRAL RAY

The central ray enters beneath the chin approximately 1 inch posterior to the mandibular symphysis at the midline. The central ray is directed perpendicular to the occlusal film (Fig. 5-54).

## RADIOGRAPHIC FACTORS

Film: Kodak Occlusal (D E+ and F speed film).

## EXPOSURE FACTORS E+ SPEED FILM

65 kVp and 15 mA  
24 impulses—adult.  
21 impulses—child.  
21 impulses—edentulous.

Note: If an 8-inch BID is used, the above exposures may be reduced to one-quarter of the above settings.

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 5.1. THE DENTSPLY/RINN XCP LONG-BID PARALLELING TECHNIQUE

#### Materials and Equipment Needed

1. Dentsply/Rinn XCP paralleling instrument set.
2. Twelve No. 2 and eight No. 1 films.
3. Skull or manikin.
4. X-ray machine.
5. Proper exposure chart.

#### Instructions

**Step 1:** Using the anterior instrument set up, expose the maxillary centrals, right lateral, and right canine; repeat for the maxillary left lateral and canine. Using the same anterior instrument setup, expose the mandibular incisors and right and left canines.

**Step 2:** Expose the maxillary right premolars and molars; using the same posterior instrument setup,

expose the mandibular left premolars and molars. Repeat for the maxillary left posterior teeth and mandibular right posterior teeth.

**Step 3:** Using the XCP bitewing instrument, expose the premolar and molar bitewing films on the right side. Repeat this procedure on the left side.

#### Notes:

1. Use the exposure chart for the proper machine settings for each anatomical region.  
Remember, exposure settings need to be matched with true source-film distance length, and this should be 16 inches. The source-film distance is the distance between the source (marked on the tubehead by a black dot) and the film in the patient's mouth.
2. For each exposure, center the biteblock on the tooth or teeth to be radiographed. Look at the diagrams in this chapter to see which teeth need to be included in each film.
3. Practice the one-two-three motion of placing the film. One, bring the outer edge of the biteblock in contact with the incisal or occlusal edge of the teeth. Two, rotate the film into place with the biteblock still contacting the tooth or teeth. Three, ease the film in place as the patient bites down or the manikin is repositioned for closing and move the locator ring in.
4. Make small film positioning adjustments once the film is down by asking the patient to open slightly or by opening the manikin's bite slightly and adjust the film forward or backward to obtain the final correct position.
5. Make certain the plane at the end of the BID is parallel to the plane of the positioning ring. Make certain the positioning rod is parallel to the edge of the long BID. Look at the BID tip and rod from the side and from the top or bottom to check all planes for parallelism.
6. According to your instructor and the time available, expose either half a full-mouth survey (one side only), including maxillary and mandibular central incisors, or expose the full complete-mouth survey.

**Step 4:** Carefully save these films for a future laboratory exercise.

## CASE-BASED QUESTIONS FOR LABORATORY EXERCISE

There are no questions for this session. The objective is to obtain the exposed full-mouth survey of either the half-patient or full-patient's mouth.



## CASE-BASED PROBLEM-SOLVING

When taking a full-mouth survey using the Dentsply/Rinn XCP long BID paralleling technique, you note that you can get the film very close to the mandibular posterior teeth and, to a slightly lesser degree, in the anterior region. However, you note you cannot maintain film and tooth parallelism in any part of the upper jaw with a close tooth-film distance. First, if only a long BID is available, how would you overcome this problem? Second, if only a short 8-inch BID is available, how does this complicate your answer and how would you modify your solution?

## REVIEW QUESTIONS

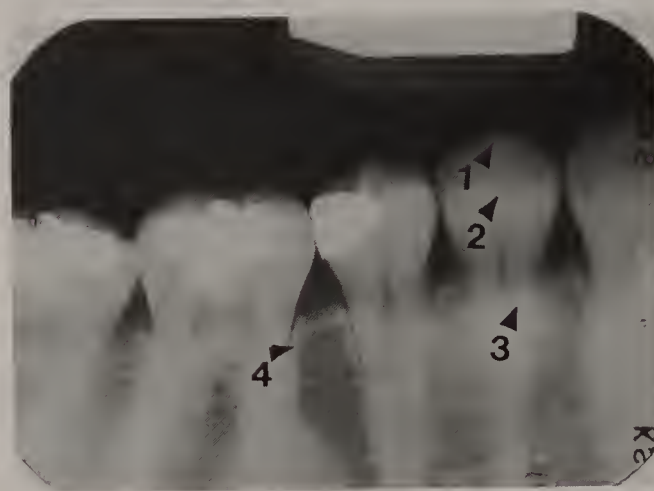
- Dental radiographic film has a special code number to indicate the film function (purpose) and the size (dimensions) of the film. A box of film with a code designation of 3.4 would indicate films of an appropriate size for:
  - Periapical radiographs.
  - Occlusal radiographs.
  - Interproximal radiographs.
  - Pedodontic periapical radiographs.
- What is the main cause of foreshortening in the bisecting angle technique?
  - Improper placement of the film.
  - Improper horizontal angulation of the BID.
  - Vertical angulation of the BID is too flat or obtuse. (–)
  - Vertical angulation of the BID is too acute or sharp. (+)
- When bitewing x-rays are taken without an alignment instrument, the midsagittal plane of the patient's head should be:
  - Parallel to the floor.
  - Parallel to the tube.
  - Perpendicular to the floor.
  - Perpendicular to the tube.
- The embossed dot on the film packet should always be placed in which direction from the x-ray source?
  - Away from the source.
  - Toward the source.
  - It does not matter.
  - Away from the source on the mandibular arch and toward the source on the maxillary arch.
- The standard film size used for adult bitewings and posterior periapicals is number:
  - 1.1.
  - 1.2.
  - 2.2.
  - 3.4.
  - Any of the above size films could be used for bitewings.
- On a premolar periapical, it is critical to obtain which of the following anatomical structures?
  - Complete view of the premolars and the first molar with an open contact between the premolar and first molar.
  - Complete view of the premolars and at least one-third of the canine.
  - Complete view of the premolars plus the first and second molar with an open contact between the two premolars.
  - Complete view of premolars and the canine. Premolars should be centered on the film.
- The technique that shows the upper and lower crowns on the same radiograph is called the:
  - Bisecting angle technique.
  - Bitewing technique.
  - Paralleling technique.
  - Occlusal technique.
- If a satisfactory radiograph was produced using a source-film distance of 8 inches and an exposure time of 1 second, what would be the correct exposure time for a source-film distance of 16 inches?
  - 2 seconds.
  - 4 seconds.
  - 6 seconds.
  - 8 seconds.
- At 90 kVp and 15 mA at a BID distance of 8 inches, the exposure time for a film is 0.50 seconds. In the same situation, the exposure time at 16 inches would be:
  - 0.25 seconds.
  - 1.00 seconds.
  - 2.00 seconds.
  - 4.00 seconds.
- A hygienist is currently using 90 kVp, 15 mA, 2.50 mm aluminum filtration, and 0.20-second exposure time. His radiation source-film distance is 8 inches. He decides to change the radiation source-film distance to 12 inches. What should be the new exposure time?
  - 0.30 seconds.
  - 0.45 seconds.
  - 0.60 seconds.
  - 0.80 seconds.

11. Why is the extension or long BID a necessary adjunct to the paralleling technique?
  - A. To avoid magnification of the image.
  - B. To avoid shape distortion of the image.
  - C. To reduce secondary radiation.
  - D. To facilitate correct vertical angulation of the BID.
  - E. To avoid superimposition of structures.
12. Compared with the short BID (bisecting angle) technique, the right angle (paralleling) technique using the extension BID involves:
  1. Greater vertical angulations.
  2. Greater object-film distances.
  3. Shorter developing times.
  4. Greater anode-film distances.
  - A. 1 and 2.
  - B. 1 and 3.
  - C. 2 and 3.
  - D. 2 and 4.
  - E. 3 and 4.
13. Which statement is most correct?
  - A. The long BID can be used correctly with either the paralleling or the bisecting angle technique.
  - B. The long BID is used with the paralleling technique only.
  - C. The short BID is used correctly with either the paralleling or the bisecting angle technique.
  - D. Film-holders are not necessary with the paralleling technique.
14. In order to increase the periapical coverage in the mandibular premolar area the:
  - A. Positive (+) vertical angulation should be increased.
  - B. Negative (–) vertical angulation should be increased.
  - C. Positive (+) vertical angulation should be decreased.
  - D. Negative (–) vertical angulation should be decreased.
15. As used in intraoral radiography, the bisecting angle technique is one in which the central x-ray beam is directed:
  - A. Perpendicular to the long axis of the object.
  - B. Parallel to the long axis of the object.
  - C. Perpendicular to a line bisecting the angle formed by the object and the film packet.
  - D. Perpendicular to the long plane of the film packet.

## CASE-BASED QUESTIONS

### CASE 5.1

The patient is a 35-five-year old woman and a long-standing, usually cooperative patient. She complained of discomfort when the film was being placed. This is a mandibular premolar radiograph.



## QUESTIONS

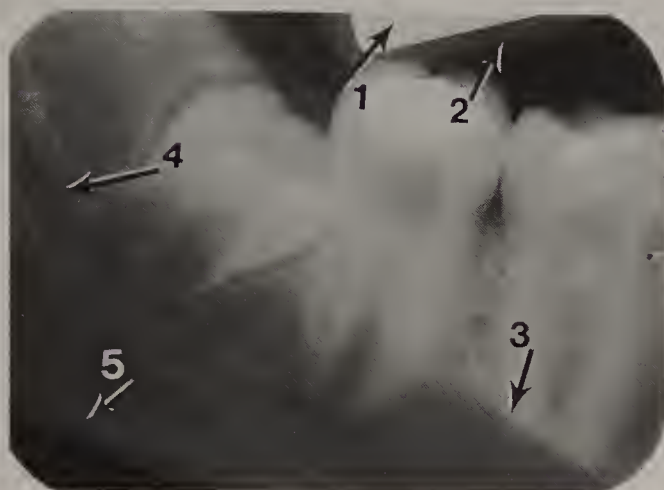
1. Forgetting for now that the apices are not showing, mesiodistally the film is:
  - A. Poorly placed because part of the canine is missing.
  - B. Poorly placed because the second premolar is not centered on the biteblock.
  - C. Well placed because the second premolar is in the middle of the film.
  - D. Well placed because the distal of the canine and first molar are in the image.
2. With respect to the apices, the problem could be best corrected by:
  - A. Increasing the negative vertical angulation, because this will also align the lingual and buccal cusp tips.
  - B. Asking the patient to raise the tongue for better film placement.
  - C. Asking the patient to bite down more firmly on the biteblock.
  - D. Positioning the film more lingually to avoid traumatizing the lingual torus.
3. Match the columns by identifying the following.
 

|               |                      |
|---------------|----------------------|
| Arrow 1 _____ | A. Mandibular torus. |
| Arrow 2 _____ | B. Buccal cusp tip.  |
| Arrow 3 _____ | C. Lingual cusp tip. |
| Arrow 4 _____ | D. Lamina dura.      |



**CASE 5.2**

The patient is a 15-year-old boy who needed to have a radiograph taken of his lower third molar.

**QUESTIONS**

- Most likely, the biteblock is not centered on the film because:
  - The film was positioned distally in the biteblock for improved film placement.
  - The film slipped out of the biteblock groove during placement.
  - The patient pushed the film forward with his tongue.
  - The patient loosened his bite on the biteblock after film placement.
- Match the columns by identifying the anatomical structures.

|               |                                   |
|---------------|-----------------------------------|
| Arrow 1 _____ | A. Mylohyoid ridge.               |
| Arrow 2 _____ | B. Metallic part of biteblock.    |
| Arrow 3 _____ | C. Inferior alveolar canal.       |
| Arrow 4 _____ | D. Plastic part of the biteblock. |
| Arrow 5 _____ | E. Inferior cortex of mandible.   |

(See Figs. 14-24 and 14-26 and Discussion of Alveolar Bone in Chapter 14 for the Answer.)

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# Processing and Film Mounting Procedures

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Discuss the proper film processing technique and the effect of the processing steps on the radiographic film.
2. Identify the components of the processing solutions and the purpose of the components.
3. Discuss manual and/or automatic processing of radiographs.
4. List the advantages of automatic processing.
5. List ways to prevent automatic processor problems.
6. Compare manual versus automatic processing procedures.
7. Describe the care and maintenance of the darkroom.
8. Demonstrate how to mount a full-mouth survey.
9. Duplicate a radiograph.
10. Process and mount a full-mouth or half-mouth survey using the Workshop/Laboratory Exercises format.
11. Explain one method of film duplication using the Case-Based Problem-Solving format.
12. Test his or her knowledge by answering the Review Questions.

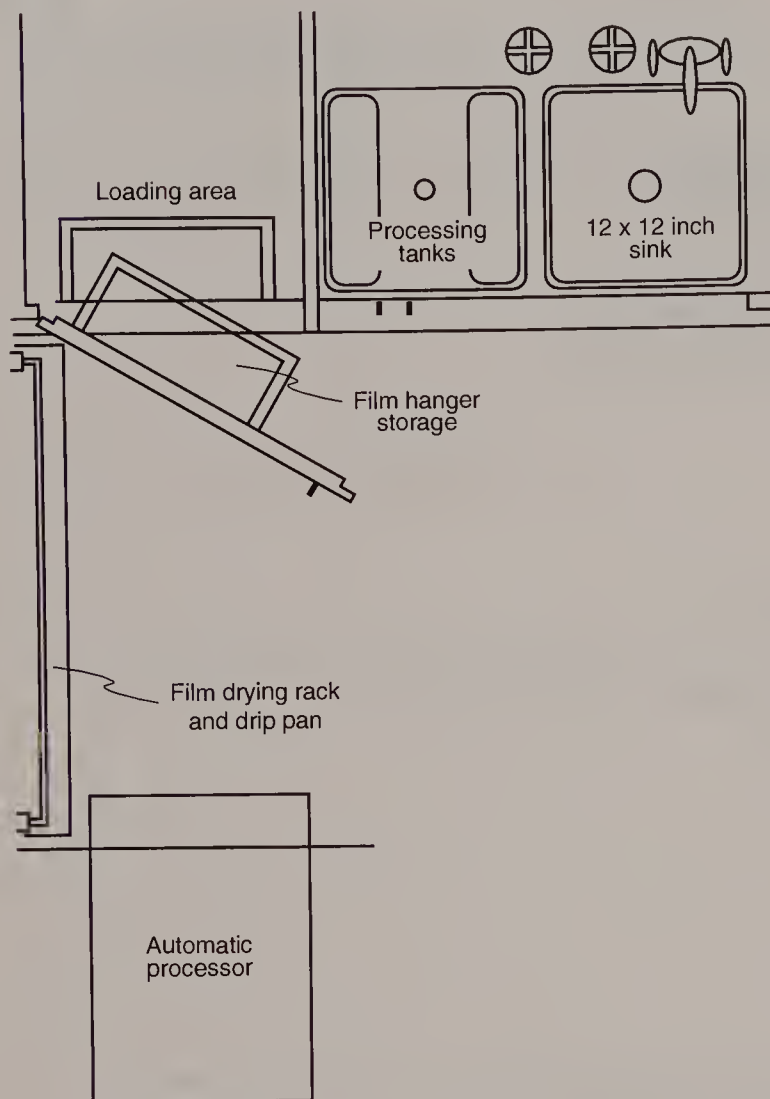
## KEY WORDS/PHRASES

|                               |                      |                                 |                    |
|-------------------------------|----------------------|---------------------------------|--------------------|
| automatic processing          | darkroom             | fog(ging)                       | processing hangers |
| automatic processing rollers  | daylight loader      | gadolinium                      | replenisher        |
| automatic processor           | developer solutions  | GBX-2 filter                    | safelight          |
| maintenance                   | direct-reversal film | halation                        | solarized film     |
| automatic processor solutions | duplicating films    | latent image                    | thermometer        |
| calcium tungstate screens     | emulsion             | manual processing (basic steps) | timer              |
| clearing time                 | film emulsion        | ML-2 filter                     | Wratten-6B filter  |
|                               | film mounting        |                                 |                    |
|                               | fixer solutions      |                                 |                    |

## INTRODUCTION

Even if the finest x-ray equipment is used and the most exacting radiographic technique is employed, the radiograph produced may be of inferior quality if the processing of the exposed x-ray film is carelessly executed. Processing the film completes what the exposure started. It produces a visible, lasting image of the latent image cre-

ated by the x-rays. When the x-rays or light strike the x-ray or light-sensitive silver salts (silver iodo-bromide [Ag-IBr]) in the **film emulsion**, the energy is stored in the form of a **latent image**. The latent image becomes visible after the film is immersed in certain chemical solutions that change the exposed silver halide salts into particles of metallic silver. The term for the several operations that collectively produce the visible, permanent images is pro-



**Figure 6.1 Well-Designed Processing Darkroom.** Note that this darkroom is designed for manual and automatic processing.

cessing. Processing, automatic or manual, consists of the following stages: developing, fixing, washing, and drying. In manual processing, the film is rinsed before fixing. These operations are all performed in a darkroom, unless an automatic processor with a daylight loader is used. Otherwise, the automatic or manual processor must be placed in the darkroom.

## DARKROOM

The darkroom or processing room should be clean, efficient, and well equipped. Spots, streaks, fog, and other artifacts on the processed radiograph can be traced to poor darkroom conditions. It is very important that the darkroom be designed to make film processing an efficient, precise, and standardized procedure. Because the processing operations are performed under conditions of reduced visibility, every piece of equipment must be in its specific place. Figure 6-1 illustrates a well-designed darkroom.

## PROCESSING METHODS

There are two methods used in processing x-ray film: manual and automatic processing. Most automatic processors use a roller transport or track system to move the film through the developer, fixer, wash, and dry cycles (Fig. 6-2).

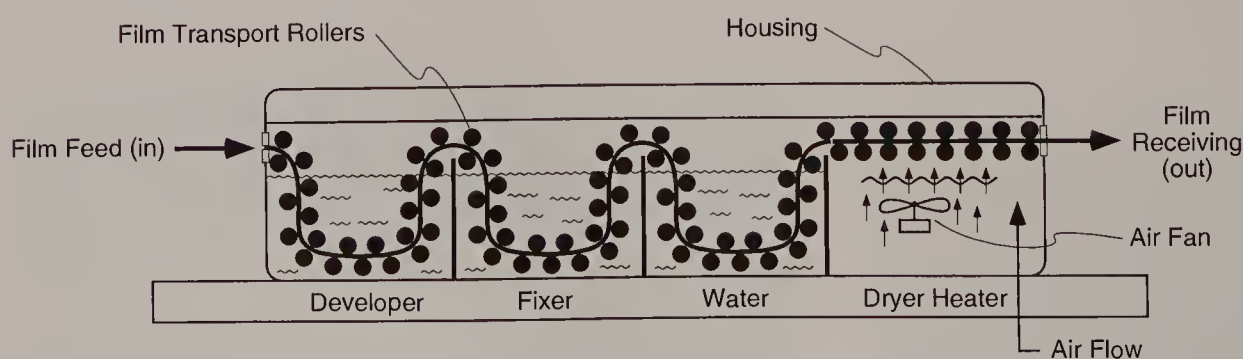
### MANUAL PROCESSING

Manual processing is the simplest method to develop, rinse, fix, and wash dental films. The most practical processing tank for a dental office consists of a master tank and two removable insert tanks, each with a 1-gallon capacity. The master tank holds running water for rinsing, washing, and maintaining the temperature of the insert tanks. The insert tanks are for the developer and fixer solutions (Fig. 6-3).

### MANUAL PROCESSING EQUIPMENT

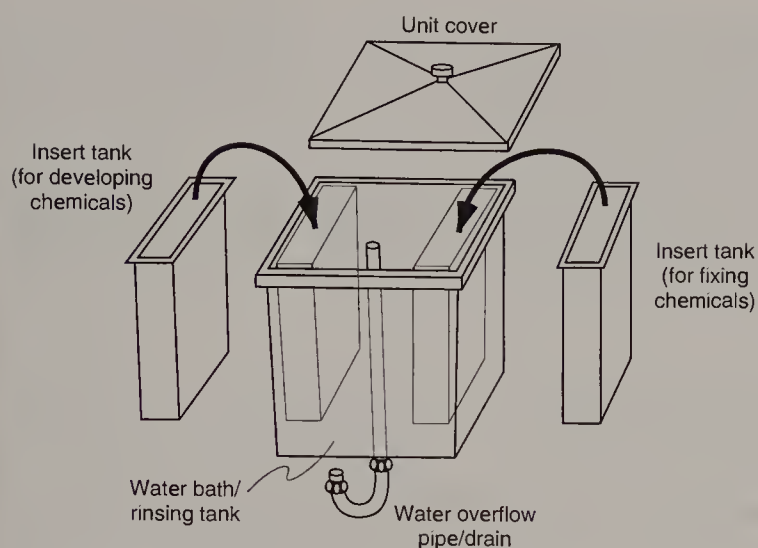
#### Running Hot and Cold Water

Manual x-ray processing solutions are most effective when used with a comparatively narrow range of temperatures. Below 60°F, some of the chemicals are definitely sluggish in action, which may cause underdevelopment and inadequate fixation. Above 75°F, they work too rapidly and may produce fogging (unwanted density) of the film.



**Figure 6.2 Automatic Processor Diagram.** The automatic processor uses a roller system that transports film through the developer, fixer, wash, and dryer cycles.





**Figure 6.3 Typical Dental Manual Processing Tanks.** Master tank and two insert tanks. Drainage is through an overflow pipe that empties into waste line. The master tank can be emptied for cleaning.

In manual processing, a temperature of processing solutions in the insert tanks of 70°F is recommended for three reasons:

1. The optimum quality of the radiograph is attained at this temperature. The contrast and density of the film are more satisfactory, and fog (unwanted density) is kept to an acceptable low level.
  2. The processing time is practical.
  3. With contemporary solution-temperature devices, a temperature of 70°F is usually conveniently maintained.
- The temperature of the water in the master tank is controlled by a thermostatic or manual mixing valve in the water supply (Fig. 6-4). This is the reason hot and cold running water are essential. In turn, the temperature of the master tank controls the temperature of the processing solutions in the insert tanks.



**Figure 6.4 Temperature in the Master Tank is Controlled by Mixing Valve.** Typical mixing valve to blend incoming hot and cold water to correct temperature is shown. The water is piped into the bottom of the master tank.

### Thermometers and Timer

The processing time is dependent on the temperature of the solutions; thus, proper control of processing time is essential, and a good thermometer is an indispensable item. There are two types: (1) a tank thermometer that is plainly marked with both Centigrade and Fahrenheit scales and that has a steel clip on the back formed into a hook to hold the thermometer in the tank, and (2) the floating, stirring rod type of thermometer that is all glass and can also be used for stirring processing solutions. An interval timer is also important to control time of development and fixation (Fig. 6-5).



A



B

**Figure 6.5 Thermometers and Timer.** (A) Upper: tank thermometer. Lower: floating thermometer. (B) Timer.

### Safelighting

The function of a safelight is to provide enough illumination in the darkroom so that essential processing activities can be accomplished with a minimum amount of errors but without fogging the film. X-ray film emulsions are primarily sensitive to blue and green light and are less sensitive to light in the opposite region of the spectrum—yellow and red light. Therefore, safelights are safest when made with amber (dark orange-yellow) or red filters. However, most films have some sensitivity to all colors of light transmitted by filters. Therefore, it is necessary to keep safelight illumination (wattage of bulb) and film handling times under the safelights at a safe, practical, minimum time that should not exceed 5 to 8 minutes. The Kodak (Rochester, NY) safelight filter GBX-2 (red) is a universal filter that can be used in darkrooms, in which both intraoral and extraoral films are used (Fig. 6-6). The **GBX-2 filter** permits higher levels of illumination than the older **Wratten-6B (brown) filter**, but lower levels of illumination than the **ML-2 (light orange) filter**. ML-2 (light orange) filters should be used **only** for intraoral dental film and **never** for panoramic films (screen film), because they transmit light in the color-sensitive range of the screen film emulsions. The Wratten-6B filter is safe only with D speed intraoral film and older extraoral films exposed with calcium tungstate screens.

Safe illumination in the darkroom is also dependent on the wattage of the bulb and the distance the safelight is from the workbench (Fig. 6-6). Direct-light safelights require a standard 7.5- or 15-watt bulb for most intraoral,

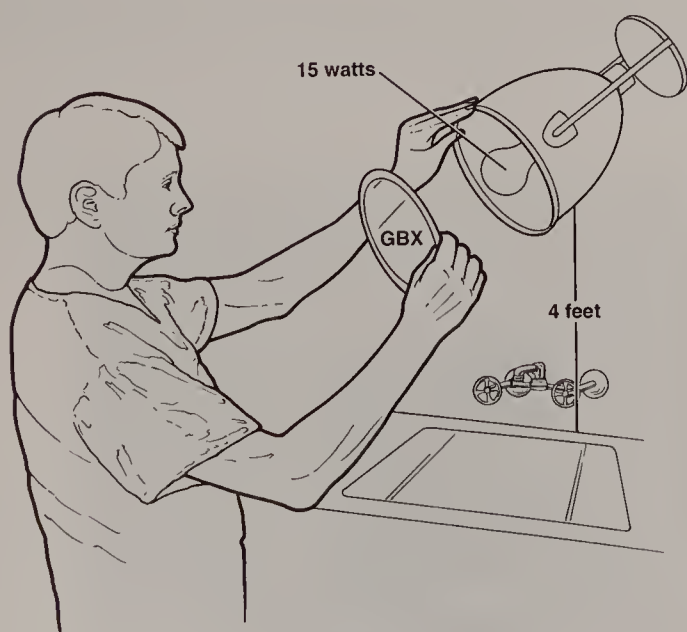
panoramic, and extraoral films; a 25-watt bulb may be used for indirect (reflected from ceiling) light. Currently, the GBX-2 filter is recommended for Kodak E+/IN-SIGHT F speed intraoral film and extraoral films using rare-earth phosphors such as **gadolinium**. The direct safelight should be placed at a minimum of 4 feet from the workbench. This distance should not be shortened unless absolutely necessary.

### Processing Hangers

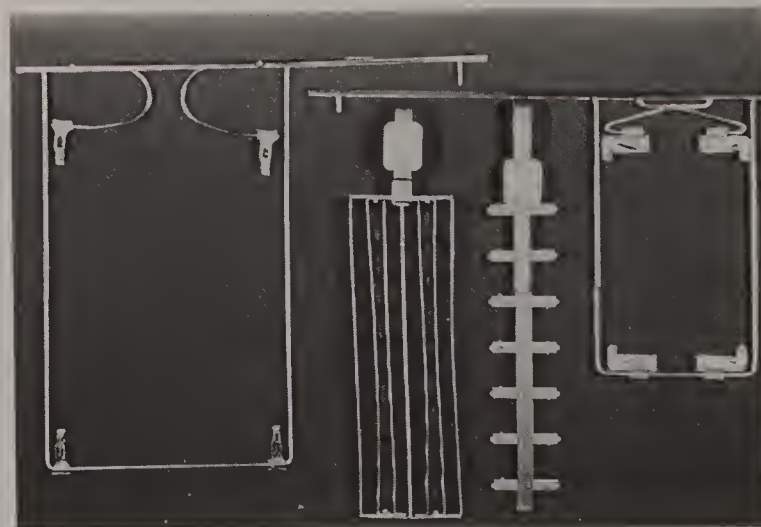
Processing hangers for manual processing are available in several sizes to accommodate intraoral and extraoral films (Fig. 6-7). The intraoral film hangers are made of stainless steel with white celluloid identification tabs. In most darkrooms, the developer solution will always be in the left-hand tank as one is facing the tank, the water bath will be in the center, and the fixer will be in the right-hand tank. In unfamiliar darkrooms, the developing solution can be identified by its slippery feeling (alkaline solution), and the fixer by its vinegary odor (acid solution) when fresh.

### MANUAL PROCESSING PROCEDURE

As previously mentioned, film processing refers to the entire procedure of conversion of the latent image to a visible image (Fig. 6-8) and preservation of the visible image. In manual processing, the film processing involves developing, rinsing, fixing, washing, and drying. The sequence of steps in manual processing are outlined below.



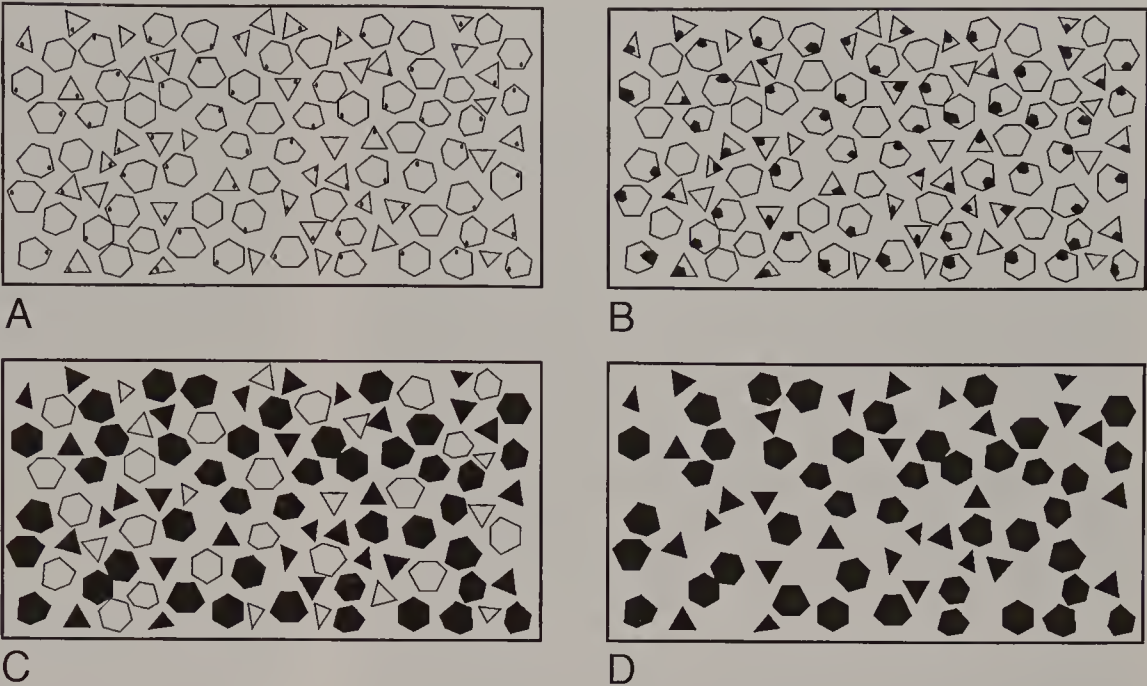
**Figure 6.6 Safelighting Specifications.** For direct safelighting, use a minimum distance from the workbench of 4 feet, a 7.5- to 15-W bulb, and a GBX-2 filter. Film handling time should not exceed 5 to 8 minutes.



**Figure 6.7 Intraoral and Extraoral Processing Hangers.** Assortment of intraoral and extraoral processing hangers. Left to right: 8- to 10-inch screen film hanger, intraoral periapical film hanger without clips, intraoral periapical film hanger with clips, and 5- to 7-inch screen film hanger.



**Figure 6.8 Conversion of Latent Image Into Visible Image.** (A) Schematic distribution of flat, T-grain silver halide crystals found in E+ film. The dots indicate latent image produced by exposure—the silver halide crystals that have been exposed to x-radiation. (B) Partial development begins to produce metallic silver black dots in exposed grains. (C) Development completed. The greater the action of the x-rays on the film, the greater the amount of metallic silver left. (D) Unexposed silver halide crystals have been removed by fixing. The fixing solution dissolves the excess silver salts and fixes the metallic silver on the film by stopping the action of the developer.



| Sequence of Steps in Manual Processing |                                                                                                                                                                     |                            |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Step                                   | Purpose                                                                                                                                                             | Approximate Time (68–70°F) |
| Wetting                                | Alkaline developing solution softens and opens up gelatin so developing agents can act on silver halide crystals.                                                   | 30 sec                     |
| Development                            | Production of visible image from latent image; exposed silver halide crystals are reduced to metallic silver, forming radiographic image.                           | 4.5–5 min                  |
| Rinsing                                | Termination of development and removal of excess chemicals from emulsion.                                                                                           | 30 sec.                    |
| Fixation                               | Removal of unexposed silver halide crystals from emulsion; hardening of gelatin.                                                                                    | 10 min                     |
| Washing                                | Removal of excess chemicals (if fixing agent [ammonium thiosulfate] is left in emulsion, it will eventually change deposited black silver to brown silver sulfide). | 15 min                     |
| Drying                                 | Removal of water and preparation of radiograph for viewing.                                                                                                         | 30 min                     |

SEQUENCE OF STEPS IN MANUAL PROCESSING

Steps in Manual Processing

The steps used in the manual processing of x-ray films are summarized in the following paragraphs (Fig. 6-9).

**Stir the Solutions.** The developer and fixer solutions are stirred. A separate paddle is used for each tank to avoid possible contamination. This mixes the chemicals and equalizes the temperature of the solution.

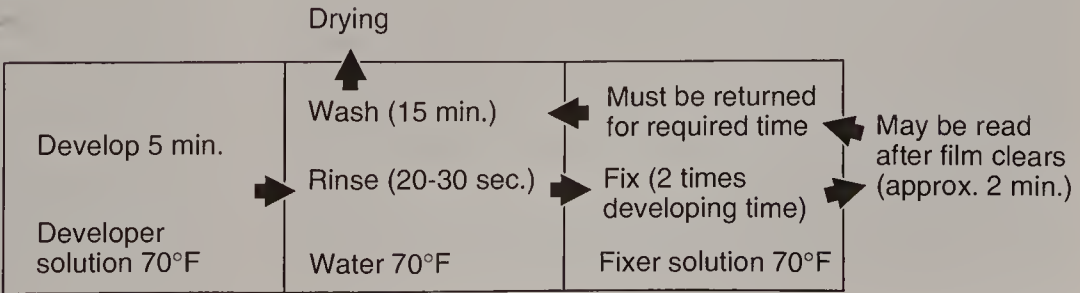
**Check the Solution Level of Developer and Fixer.** If the solution levels are low, the correct level should be maintained by adding fresh solution.

**Check the Temperature of the Solutions.** If possible, the temperature should be adjusted to 70°F before development. Ice should never be placed in the solutions to cool them—this will dilute the solution. One way to cool the solutions in warm weather is to place ice cubes in a rubber glove and then place the glove in the solutions.

**Turn on the Safelight(s).** All white light should be excluded in the processing room.

**Unwrap the Exposed Film.** The operator should carefully remove the exposed film from its packet while wearing unpowdered gloves. Then, he or she should clip the film

**Figure 6.9 Basic Steps in Manual Processing.** Developer (5 minutes at 70°F), rinse (30 seconds), fixer (10 minutes), wash (15 minutes), and drying (30 minutes). Total time (dry-to-dry): 1 hour and 30 seconds.



or films onto processing hangers with clean, bare hands, carefully holding the film by its edges.

**Set the Interval Timer.** The timer is set so it will ring at the end of the desired time of development. The manufacturer’s table, which is based on the temperature of the developer, must be known. When using manual x-ray developer solutions, the time of development is 5 minutes at 70°F.

**Develop the Film.** The film should be immersed quickly into the developer solution, and the timer started. The film hanger is agitated by raising and lowering it vigorously for 5 seconds to break up residual air bubbles and permit the solution to bathe both surfaces of the film. The films should not be agitated during development. The composition of the developer solution is shown below.

**Typical Developer Composition: Manual X-Ray Developer (Normally Used at 68–70°F)**

| General Function | Chemical          | Special Function                                                                                                                       |
|------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Reducing agents  | Metol             | Quickly build up gray tones in the image. The developing agents convert the exposed silver halide crystals into black metallic silver. |
|                  | Hydroquinone      | Slowly builds up black tones and contrast in the image.                                                                                |
| Activator        | Sodium carbonate  | Swells and softens the emulsion so that the reducing agents may work more effectively.                                                 |
| Activator        | Sodium carbonate  | Provides required alkalinity for reducing agents.                                                                                      |
| Restrainer       | Potassium bromide | Restrains the reducing agents from developing unexposed silver halide to produce fog.                                                  |
| Preservative     | Sodium sulfite    | Prevents rapid oxidation of the developing agents.                                                                                     |
| Solvent          | Water             | Liquid for dissolving chemicals.                                                                                                       |

The main action of the developer is to chemically reduce the silver in the radiation-exposed silver halide crystals into black metallic silver. The unexposed silver halide crystals are not developed.

**Rinse the Film.** The hanger is removed from the developer when the timer rings. Excess developer solution should not be drained back into the developer tank. The film is immersed in the circulating rinse water and agitated continuously for 30 seconds. This will remove most of the adhering developer chemicals. Without thorough rinsing after development, the alkaline developer solution on the film will in time gradually neutralize the acidic fixer. The neutralized fixer will then not act evenly on the emulsion, and the radiograph will become streaked and sometimes stained (brown).

**Fix the Film.** After rinsing, the films are placed in the fixer solution, and the hanger is agitated by raising and lowering it for 5 seconds. The film should be fixed for 8

to 10 minutes, or twice the developing time, or twice the clearing time. Fixing, like developing, must be timed properly. A temperature of 70°F is recommended. Too short a fixing time can result in inadequate hardening, slower drying, and possible loss of permanence of the image. Prolonged fixing (hyperfixing) may cause the fixer solution to be bound to the emulsion so it cannot be removed in washing, thereby causing an eventual brown discoloration on the radiograph. If the film is left in the fixer for several days, all the image will be removed. The film should not be exposed to white light until the film has cleared. If one can hold films up to the safelight and see through the white (clear) areas on the film, the emulsion has cleared. It usually takes approximately 2 minutes before the films “clear” in the fixer. At this time, the films can be “wet read” in emergency situations. During fixation, the unexposed silver salts are dissolved out of the emulsion, and the gelatin in the emulsion is hardened to prevent damage from future handling. The fixer is called the clearing agent because it clears out the milky appearance of the film. It changes the unexposed and undeveloped silver halide crystals in the emulsion (milky appearance) to soluble silver salts, which are readily removed by washing the film in water. The composition of the fixer solution is shown below.

**Typical Fixer Composition: Manual X-Ray Fixer (Temperature Same As Developer) and Automatic X-Ray Fixer (Fix and Wash 5° Below Developer Temperature)**

| General Function | Chemical                     | Special Function                                                        |
|------------------|------------------------------|-------------------------------------------------------------------------|
| Fixing agent     | Ammonium thiosulfate         | Clears away the unexposed silver halide crystals.                       |
| Acidifier        | Acetic or sulfuric acid      | Stops development by neutralizing developer. Provides required acidity. |
| Hardener         | Aluminum chloride or sulfide | Shrinks and hardens the emulsion.                                       |
| Preservative     | Sodium sulfite               | Maintains chemical balance of the fixer chemicals.                      |
| Solvent          | Water                        | Liquid for dissolving chemicals.                                        |

**Wash the Film.** After completion of fixation, the film hanger should be placed into the water tank between the developer and fixer tanks. Excess fixer should be drained back into the fixer tank before moving it to the water tank. Films are washed in the water tank for 15 minutes in clean running water. A temperature of approximately 70°F is recommended. Prolonged washing tends to make the emulsion soft, especially if left in the wash overnight. The object of washing is to remove residual processing chemicals and silver salts from the radiograph. If these residues are not removed, the radiograph will turn brown with time, impairing its value as a permanent record.



**Dry the Film.** Films should be dried in a dust-free area at room temperature or in a suitable drying oven. In most offices, films are dried by merely placing the film hanger on a rack in the darkroom above a drip tray designed to catch the runoff excess water. Some offices use an ordinary fan to dry films. However, the fan should not blow directly on the films. Cabinet dryers are available and are equipped with a fan and heating elements. The temperature should not exceed 120°F (49°C). Usually, this type of dryer should be vented to the outside to prevent moisture condensation in the darkroom.

**Mount the Films.** The dry radiographs are removed from the hanger by opening the clips. The films should not be pulled from the clips, as it may damage the edges of the films. The hanger clips should be washed after processing because chemical residues on the clips will cause marks on the next films developed. Films should be placed into special film mounts (see section on mounting.)

## AUTOMATIC PROCESSING

Manual film processing is gradually being replaced by automatic processing. Although there are many advantages to using automatic processors, they are complex mechanisms that must be maintained on a strict basis exactly as recommended by the manufacturer. Without an exacting maintenance schedule, automatic processors are worthless. However, with proper care they eliminate one of the most time-consuming, messy, and cost-ineffective procedures ever known to dentistry—manual processing.

### Advantages of Automatic Processors

1. Processing time is shortened from 60 to 90 minutes to 1.5 to 5 minutes.
2. Constant film quality, due to fixed processing cycles.
3. Less floor space or counter top space is required.
4. The darkroom can be eliminated when the automatic processor is equipped with a daylight loader.
5. Less equipment is required, such as film racks, film hangers, film dryers, timer, and thermometer.
6. Wet reading of films is eliminated. Wet reading of films drips solutions all over the office; in addition, dry films are much more diagnostic.

### How Automatic Processor Rollers Work

The basic mechanism design of automatic processors, as recommended by the authors, usually consists of a series of rollers that transport the films through the various solution sections, beginning with the developer, then directly into the fixer, and then the wash and dryer (Fig. 6-2). Note that the film does not go into a wash bath between developing and fixing as in manual processing. The explanation of this is based on the functions of rollers, as shown in the next paragraph.

### Functions of Automatic Processor Rollers

1. The rollers transport the film through each section of the processor.
2. The rollers provide a massaging action that contributes to the uniform distribution of chemicals on the film emulsion in the developer and fixer sections.
3. Special squeegee rollers remove processing solutions from the film surfaces, reducing the amount of solution carry-over from one tank to the next.
4. Squeegee rollers in the wash section remove most of the water from the emulsion before transport of the film to the drying section, allowing the film to dry uniformly and rapidly.
5. Because the tanks are small, the motion of the rollers in the developer and fixer tanks helps stir the solutions. Therefore, replenishment must automatically occur frequently.

### Automatic Processing Solutions and Replenishment

When using automatic developer solutions, a hardening chemical, glutaraldehyde, is added to the conventional manual processing developer to prevent the emulsion from softening and sticking to the rollers. Sulfate compounds are also added to the manual processing developer to minimize the swelling of the emulsion so the films can be transported by the rollers uniformly. If manual processing developer solution is used in an automatic processor, the film emulsion will most likely stick to the rollers and damage the radiographic image. With automatic processors, a rigid schedule of chemical replenishment is necessary to maintain the proper concentrations of the solutions and to neutralize the unwanted by-products of each reaction. To maintain the alkalinity of the developer, the acidity of the fixer, and the chemical strength of both solutions, a replenisher must be added at a constant rate for each film processed. In the drying section, the film is quickly dried by jets of heated air before the film drops into the discharge receptacle.

Because the total processing time is reduced in automatic processing, the chemical concentration and temperature of the solutions must be increased. Phenidone is substituted for metol (Elon) as a developing agent because, when combined with hydroquinone, it provides a rapid synergistic chemical reaction necessary for automatic processing. In the larger extraoral or medical 90-second automatic processors, the temperature is kept at 90 to 94°F in the developer, fixer, and wash sections and 135°F in the dryer section. The dental automatic units regularly process at temperatures of approximately 83°F for a 4.5-minute cycle; however, in some processor models, the processing time can be adjusted to a faster cycle of 1.5 to 2.5 minutes if required (e.g., endodontic and surgical procedures).

Most dental automatic processors now have automatic replenisher systems that are based on the amount and size

of film being processed. The replenisher solution is injected into the bottom of the tank while the excess overflows from the top of the tank. Usually 6 ounces must be added to the developer and 3 ounces to the fixer after processing four full-mouth surveys or four panoramic films. If continued satisfactory results are expected, automatic processors must be cleaned routinely (weekly in a busy office), and preventive maintenance procedures must be followed. Experience has shown that the greatest cause of automatic processor problems is failure to keep the rollers clean. A schedule should be established for cleaning the rollers and replenishing and changing solutions. Procedures or products should never be substituted or changed unless recommended by the automatic processor manufacturer.

#### Automatic Processor Preventive Maintenance Procedures

1. Transport sections should be checked each day to see if they are aligned properly. The films will fall through to the bottom of the tanks if the transport sections are not aligned.
2. Moving parts should be lubricated monthly. Gears, sprockets, idlers, bearings, drive mechanisms, and ring points must be lubricated. Failure to do so will cause excessive wear of moving parts, eventually slow the speed of the rollers, and in turn affect film quality. No oil should get on the rollers. Manufacturer's instructions must always be followed.
3. The solutions should be replenished on a regular basis according to the rate of films processed. After four panoramic films or full-mouth surveys, approximately 6 ounces of replenisher should be added. Failure to do so will result in low levels of exhausted developer and fixer. This will cause smudgy, low-density (light) films. This is why an automatic replenisher system is recommended.
4. The temperature of the processing solutions should be checked regularly. Changes in the temperature of the developer will cause changes in the density of the processed film. (It takes a change in temperature of only a few degrees to affect the density. It is important to be sure that the thermostat on the processor is accurate.)
5. The cover should be kept open slightly when the processor is not in use. After each day's operation, the cover should be left open slightly so the chemical fumes can escape. Failure to do so could lead to fogging (blackening) of films.
6. Solutions should be changed every 1 to 4 weeks, depending on the rate of use of the processor. Processing solutions especially made for automatic processors should be used. Processing solutions designed for manual processing should never be used.
7. The manufacturer's instructions should always be followed. The manual should be referred to as often as needed to assure proper maintenance and to assist in troubleshooting.

#### How to Feed Films Into the Automatic Processor

1. Films should be fed slowly and carefully. Panoramic films should be fed into the processor in a straight line with the roller system. Failure to do so could cause a jam-up in the processor.
2. If film is bent, the unbent side of the film should be inserted into the machine first; the bent edge should then be unbent and trail.
3. Damp or wet films should not be fed into the machine because they will contaminate the rollers and cause streaking of subsequent films.
4. Films should not be fed too quickly in succession. They may stick to each other and jam the machine (allow 5 seconds between films fed into the same slot). Some machines come with a feed light, which comes on when it is okay to feed the next film.

#### Which Automatic Processor to Purchase?

Several brands of automatic processors are available. Because they are competitive in performance and price, the decision of which brand to purchase usually rests on the quality and performance of the processor and on the availability of competent repair service (Figs. 6-10 and 6-11). Other factors to consider include the availability and convenience of use of a daylight loader and counter top space required. The basic features of any automatic processor are



**Figure 6.10 A/T 2000 Automatic X-Ray Film Processor.** The A/T 2000 Automatic X-ray Film Processor automatically controls time, temperature, chemistry agitation, and chemistry replenishment. It shuts itself off as soon as the last film exits the processor and returns to a stand-by status, which saves water, electricity, and general wear and tear. Normal speed is a 5.5-minute processing cycle for archival quality dental films of all sizes up to 8 × 10 inches. Endo speed is a 2.5-minute processing cycle that provides a "quick look" for nonarchival quality periapical films used in endodontic procedures. (Courtesy of Air Techniques Inc., Hicksville, NY 11801).





**Figure 6.11 DENT-X 9000 Automatic X-Ray Film Processor.** Dent-X 9000 with a daylight loader. It features a unique replenishing system that controls all processing chemistry. Infrared sensors measure film size on input and replenish (refresher) developing and fixing solutions based on the amount of film being processed. Develops all sizes of film up to  $8 \times 10$ -inch size. Dry films in 4.5 minutes, and endo wet readings in 1 minute. (Courtesy of Dent-X Co., Elmsford, NY 10523).

cycle time shorter than 5 minutes, a roller transport system, thermostatically controlled solution temperature with digital display, an automatic solution replenishment system, simple-to-follow maintenance instructions and procedures, inexpensive and readily available processing solutions, and reliability of the automatic processor system. No automatic processor is reliable without maintenance.

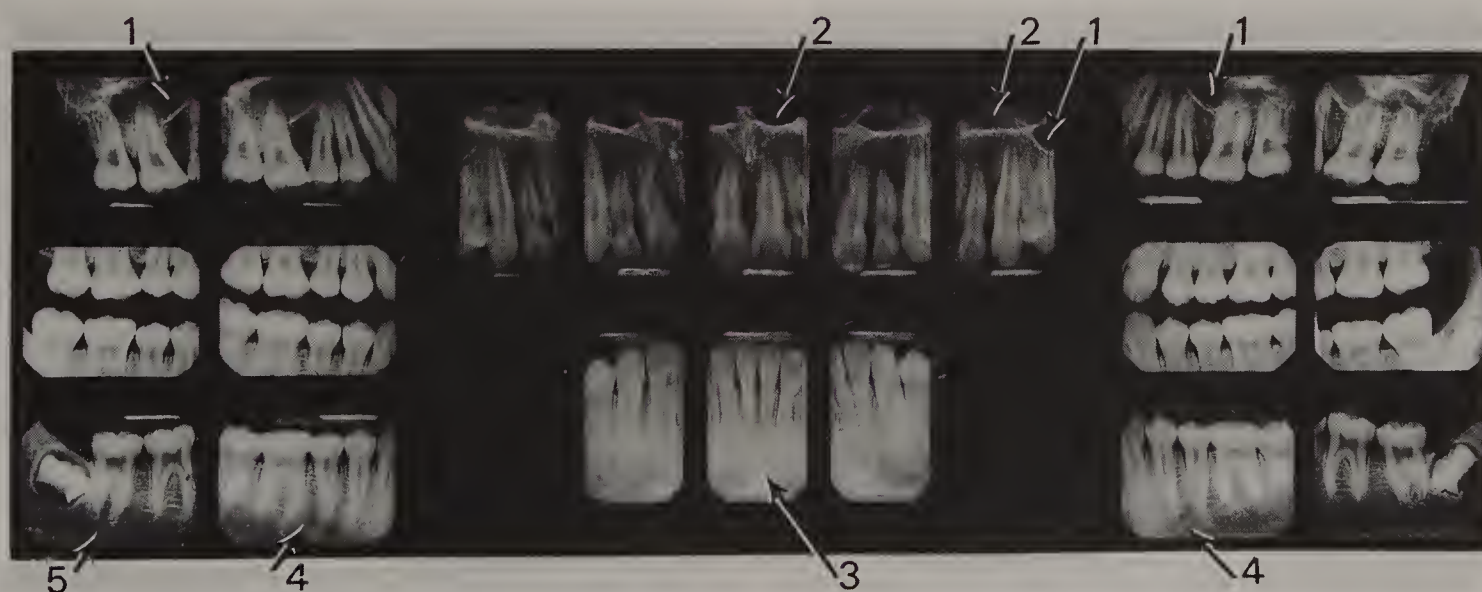
## MOUNTING DENTAL RADIOGRAPHS

### Reasons for Mounting Radiographs

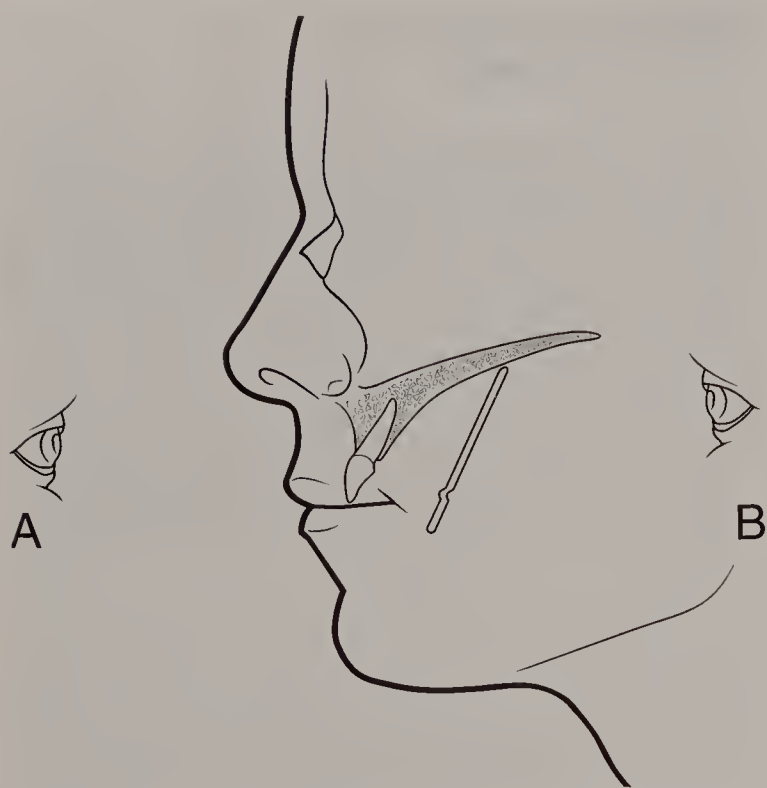
1. There is less chance for an error in interpretation because films are mounted in normal anatomical relation to one another.
2. It prevents finger marks, scratches, and abrasions because radiographs are not handled as much.
3. To avoid inefficiency and confusion, repeated study and comparison of single radiographs with one another is time-consuming. It results in inefficiency and confusion.
4. Mounts exclude illumination around the individual radiographs. This is an aid in interpretation because it prevents glare to the interpreter's eyes.
5. Radiographs in mounts are easy to file. Therefore, they are instantly available for studying during an operative procedure and consultation.
6. It has a psychological effect on patients. The impression and educational value that mounted radiographs have on the patient is in itself sufficient reason for mounting them.

### RADIOGRAPH MOUNTING PROCEDURES

Mounting intraoral radiographs is a relatively simple procedure when the individual responsible has some knowledge of the normal radiographic anatomical landmarks for each region of the mouth and can recognize tooth morphology (shape and form). Each anatomical region of the jaws has identifying anatomical landmarks (Fig. 6-12). These landmarks are further described in detail in



**Figure 6.12 Normal Anatomic Landmarks for Mounting.** Full mouth radiographic survey (FMX): (1) maxillary sinus, (2) nasal cavities, (3) genial tubercles, (4) mental foramen, and (5) mandibular canal.



**Figure 6.13 Mounting Films As If Viewer Is Looking Directly At The Patient.** The intraoral radiograph is positioned in the mouth with the raised portion of the raised dot positioned toward the x-ray tubehead. (A) If film is mounted in this manner, it is as though the viewer is looking directly at the patient. (B) If mounted with raised dot away from the viewer, it is as if the viewer is in the patient's mouth looking out (mounting procedure not used very often).

Chapter 14. Before initiation of the mounting procedure, it is important to know from what aspect the radiographs will be viewed (Fig. 6-13).

### Two Ways of Mounting Radiographs

1. In the first method of mounting, the radiographs are mounted with the depressed or concave sides of the embossed dots toward the viewer. The viewer is then observing the radiographs from the lingual aspect, with the tube side of the film toward the back of the mount, as if he or she was inside the patient's mouth looking out. Although still used by many older dentists, this method is less commonly used and is not a recommended method of mounting radiographs.
2. In the second method of mounting, the radiographs are mounted with all the raised or convex sides of the embossed dots toward the viewer. The viewer is then observing the radiographs from the facial aspect, with the tube side of the film toward the viewer, as if he or she was looking directly at the patient (Fig. 6-13). This is the preferred method because the films are mounted in the same relationship as the teeth are recorded on the examination chart. This makes for less chance of error.

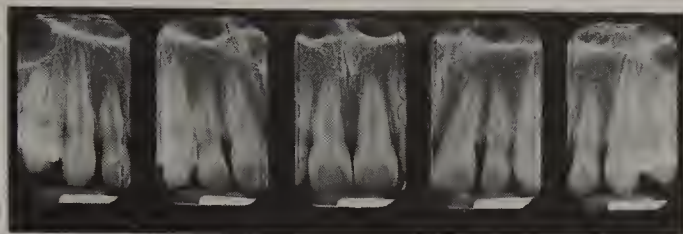
Once the processed radiographs are dry, care must be taken to avoid fingerprinting the radiographs. Consequently, radiographs should be handled by their edges only, with clean, dry fingers or by using white cotton cloth gloves (used by photographers) to mount films.

## Procedure for Mounting Radiographs

### Procedure for Mounting Radiographs in Which the Radiographs Are Mounted As Though the Viewer Is Looking Directly at the Patient (Recommended Procedure)

- Step 1. Arrange all radiographs of the full-mouth radiographic survey (FMX) on a flat viewbox with the embossed dot or bump upward.
- Step 2. Arrange the radiographs on the viewbox in order of anatomical site (e.g., select and arrange in [redacted] anterior or anterior regions).
- Step 3. Take all maxillary posterior radiographs and arrange them with the crowns of the teeth toward the bottom of the viewbox. With all embossed dots convex side toward you and the crowns of the teeth oriented downward, it will be necessary only to identify mesial or distal anatomical landmarks of teeth to distinguish right from left. Posterior radiographs with the more mesial anatomical structures of jaws and teeth are mounted in the premolar position; those with more distal landmarks are mounted in the molar positions (Fig. 6-12).
- Step 4. Identify the maxillary anterior radiographs and rotate the incisal edges of each film down toward the bottom of the viewbox (Fig. 6-14).
- Step 5. Identify the maxillary central incisor radiograph and mount it in the center of the anterior section of the mount. Next, identify the right (R) and left (L) lateral and canine radiographs and mount them with mesial anatomical structures always directed toward the middle of the mount.
- Step 6. Identify the four posterior mandibular radiographs. Rotate these radiographs until the coronal (crown) portions of the teeth are directed toward the top of the viewbox. Identify mesial and distal structures and arrange in appropriate areas of the mount (Fig. 6-12).
- Step 7. Rotate the three mandibular anterior radiographs until their incisal edges are positioned toward the top of the viewbox. Identify the central incisor radiograph and mount it in the center window of the mount. Next, mount the left and right canine radiographs (Fig. 6-15).
- Step 8. The remaining four films are interproximal (bitewing) radiographs. Orient these radiographs with the curve of Spee (occlusal plane between maxillary and mandibular teeth) directed upward toward the distal. If the occlusal plane is flat, attempt to identify characteristics of the respective crowns; frequently, the bifurcation of the mandibular molar is distinguishable and may serve as a valuable aid in distinguishing mandibular molars from three-rooted maxillary molar teeth. Once the appropriate arch is identified, the radiograph can be oriented properly. The direction of the most mesial structures is used to identify right from left and premolar from molar regions (Fig. 6-16).





**Figure 6.14 Mounting Radiographs of Maxillary Anterior Teeth.**

The radiographs of maxillary teeth are mounted with their incisal edges downward toward the center of radiographic mount. The maxillary centrals are mounted in the center of the maxillary anterior section. The practitioner should identify the right and left lateral and canine radiographs and mount them with mesial portion of each tooth toward the middle of the mouth.

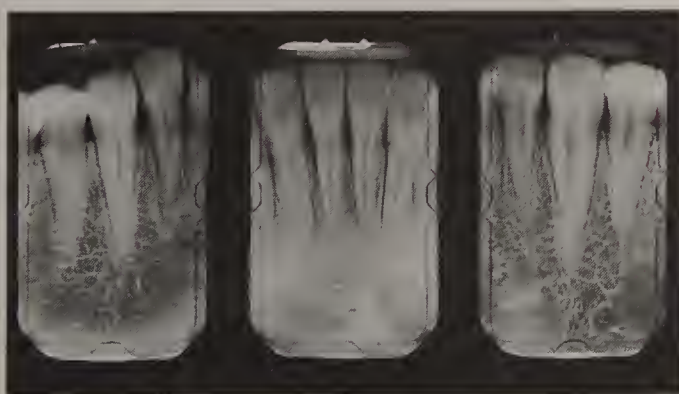
## RADIOGRAPHS

Since the discovery of x-rays, persons have been trying to reproduce radiographs. A single radiographic series may seem sufficient at the time taken; however, it may become necessary to refer or transfer a patient to another dentist while keeping the original radiographs. Also, as third-party payments increasingly become a part of every practice, it becomes necessary to find a simple and inexpensive

method of duplicating radiographs when lawsuits are initiated.

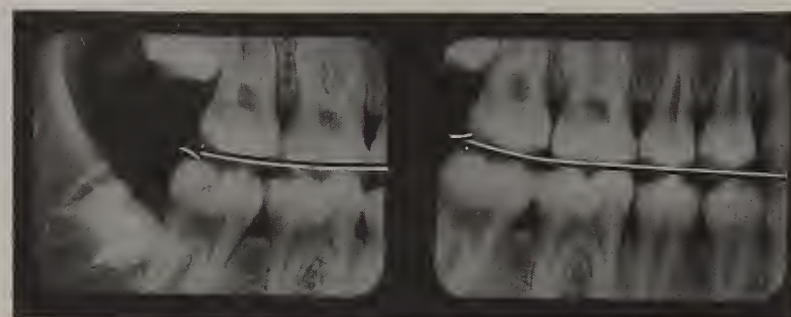
### DUPLICATING FILMS

Films can be duplicated by the use of a special **duplicating film** called **direct-reversal films**, which have been solarized by a chemical treatment of the emulsion. **Solarization of a film** is exposing the film (chemically or by light) beyond that which produces maximum density until a decrease in density occurs. This coats the latent-image cen-



**Figure 6.15 Mounting Radiographs of Mandibular Anterior Teeth.**

The practitioner should mount the three anterior radiographs until their incisal edges are positioned toward the top of the middle of the mount. He or she should identify the central incisor region and mount the radiograph in the center window of the mount. Next, the left and right canine radiographs should be mounted.



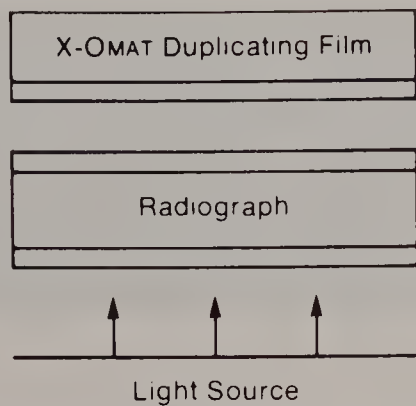
**Figure 6.16 Mounting Bitewing Radiographs.** The practitioner should orient radiographs with "curve of Spee" directed upward toward the distal. It should be remembered that the mandibular molars have two roots and that the maxillary molars have three roots. Once the maxillary and mandibular arches can be identified, the radiographs can be properly oriented as to whether they are radiographs of the left side or right side of the patient.

ters with a layer of silver bromide and prevents the action of the developing agent on the emulsion grains. **The important thing to remember about solarized film is that more light exposure produces less density**, which is the opposite of standard radiographic film exposures. Because duplicating film is a direct positive or reversal film, increasing exposure reduces the density produced on a duplicating film. Therefore, a duplicate that is too low in density can be corrected by decreasing the exposure. If the

duplicate is too high in density, it can be corrected by increasing the exposure. Radiographic duplicating film has a solarized emulsion side (purple side) on a blue-tinted polyester film base and an antihalation coating (shiny side) on the opposite side. **Halation** is light reflected back from air after it has passed through the duplicating film. This reflected light causes unsharp edges at the boundaries of the duplicated image. Halation (reflected light) can be prevented by an antihalation layer on the back side of the duplication film, which contains a dye that absorbs the reflected light before it reaches the light-sensitive emulsion layer. The important thing to remember is that duplicating film has emulsion only on the purple side of the film.

### DUPLICATION PROCEDURE

The basis for the duplicating technique is to expose a special duplicating film to a light that has passed through the original film. The duplicating film is designed to be exposed with an ultraviolet light source, such as a BLB ultraviolet fluorescent lamp (Fig. 6-17). The radiograph to be duplicated must be held in close contact with the emulsion side of the single-coated duplicating film during exposure to prevent blurring. This may be accomplished by use of one of the commercially available contact printers (Fig. 6-18). Kodak X-Omat duplicating film is available in seven sizes, including the

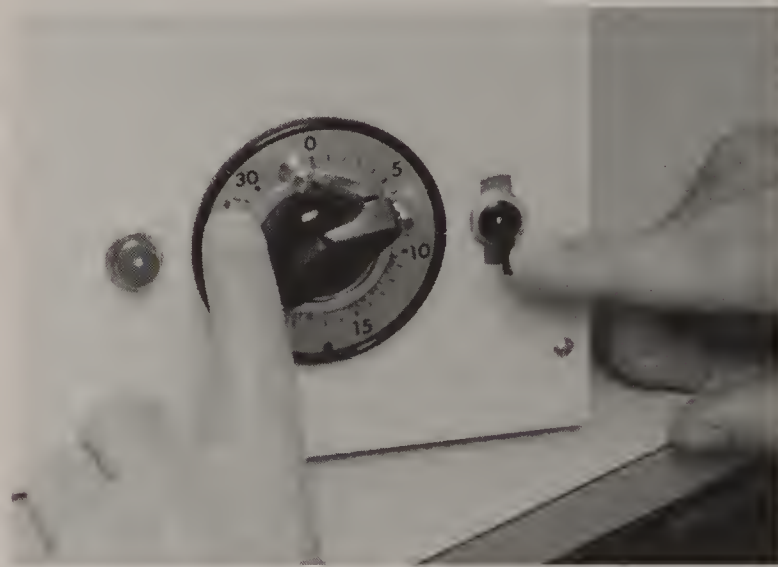


**Figure 6.17 Diagram of Technique of Duplicating Film.** The duplicating film has emulsion on one side; original radiograph has emulsion on both sides of the film.

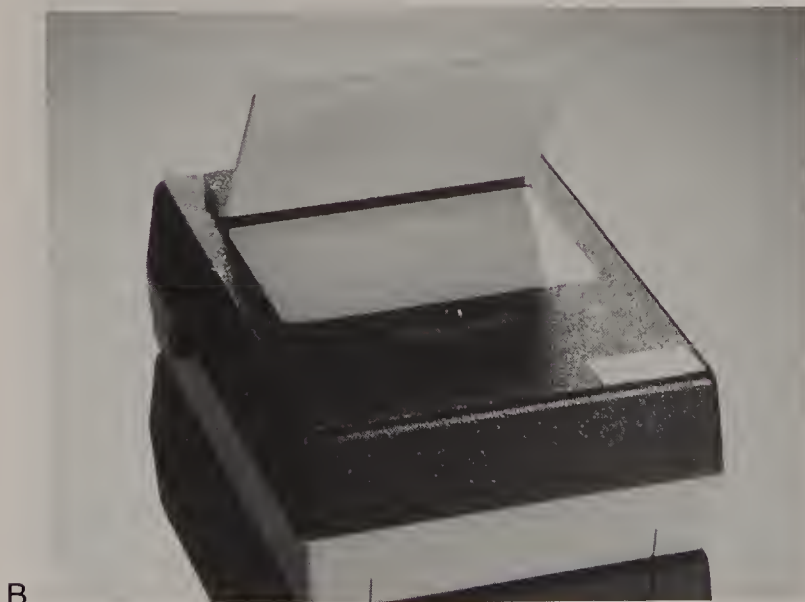
periapical size. Radiographs are duplicated in the dark-room under safelight conditions. The radiographs are placed in full contact with the duplicator top. Film mounts are usually not recommended unless they allow the radiographs to contact the duplicator top. The duplicating film is then placed on top of the radiograph to be duplicated with the emulsion side (usually the lavender or purple side) contacting the radiographs. The lid of the duplicator is closed over the radiographs and duplicating film. The duplicator is then activated for the time specified in the manufacturer's directions. The duplicating film is removed, and the film is processed in the normal way.



A1



A2



B

**Figure 6.18 Technique of Duplicating Film By Commercial Duplicator.** (A) Duplication procedure using a Lester Dine Duplicator. (A1) First, the panoramic or intraoral film to be duplicated is placed on the illuminator surface. Second, the duplicating film with purple side (solarized emulsion side) down is placed on top of the panoramic film. (A2) Exposure time is set to expose films, and the lid is closed. (After exposure, the duplicating film is developed as usual.) (B) Rinn Mini-Ray Duplicator. This cigarette-pack-sized duplicator can be used to duplicate single No. 1, 2, and 0 intraoral films using Kodak precut and packaged duplicating film.



## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 6.1. FILM PROCESSING AND MOUNTING

#### Materials and Equipment Needed

1. Exposed full-mouth survey (FMX) or half-mouth survey from previous laboratory exercise.
2. FMX film mount.
3. Darkroom and processing equipment.
4. Viewbox.

#### Instructions

- Step 1:** Following the instructions for either manual processing or automatic processing, process all radiographs. Collect the dried films.
- Step 2:** Using the viewbox, sort the films and mount them in the film mount.

### CASE-BASED QUESTIONS FOR LABORATORY EXERCISE

1. Identify any technique errors in the FMX; try to name the error and its cause.
2. Explain how to correct the above errors.
3. Identify any improperly mounted films.
4. What mistake(s) did you make resulting in incorrect mounting?

### OPTIONAL EXERCISE 6.2. X-RAY FILM DUPLICATION

#### Materials and Equipment Needed

1. Film duplicator or contact printer.
2. Original film.
3. Kodak duplicating film.
4. Darkroom.
5. Processing facility.
6. Timer.

#### Instructions

- Step 1:** In the darkroom, open the top of the film duplicator and place the film to be copied on the plastic surface.
- Step 2:** Place the duplicating film emulsion side (purple side) down on top of the original film.
- Step 3:** Close the top tightly so there is good contact between the original film and duplicating film.
- Step 4:** Set the timer (usually from 5 to 10 seconds, depending on duplicator brand).
- Step 5:** Remove duplicating film and process.

### CASE-BASED QUESTIONS FOR LABORATORY EXERCISE

1. If your original film was too dark, how could you make the duplicate lighter?
2. Explain why it is important to get the correct side of the duplicating film in contact with the original film.

**Note to Instructors:** An inexpensive, small-sized intraoral film duplicator is available from Dentsply/Rinn (Elgin, IL), and prepackaged intraoral-sized duplicating film is available from Kodak (Rochester, NY).

### CASE-BASED PROBLEM-SOLVING

You do not have a film duplicator, but somebody mentioned you can use a simple photographic contact printer (available in photography shops) or even a glass picture frame to duplicate radiographs. How would you do this? Materials available are a darkroom, duplicating film, film to be duplicated, a contact printer or picture frame, and a viewbox.

### REVIEW QUESTIONS

1. Which of the following is the clearing agent in the fixer?
  - A. Potassium alum.
  - B. Ammonium thiosulfate.
  - C. Acetic acid.
  - D. Potassium bromide.
  - E. Hydroquinone.
2. What determines the time an exposed radiograph remains in the developing solution?
  - A. The temperature of the solution.
  - B. When the unexposed silver bromide is removed.
  - C. When the image of the film becomes stabilized.
  - D. The time it takes for the image to appear.
3. Which of the following best describes a desirable film mount?
  - A. It should be translucent to allow more light to reach the film.
  - B. It should be gray and opaque to light transmission.
  - C. It should be black to block light transmission and prevent glare.
  - D. It should be purplish because this is the color of the retina of the eye.

4. In correctly mounted radiographs, the curve of Spee:
  - A. Should curve downward toward the distal.
  - B. Should curve upward toward the distal.
  - C. Should curve downward or upward toward the distal, depending on whether the concave or convex side of the embossed dot is used.
  - D. Indicates correct mounting of the anterior teeth.
5. Placing the film in the fixer first results in:
  - A. A black film.
  - B. A clear film.
  - C. A mottled film.
  - D. No change.
6. In manual processing, films should be washed in running water for at least:
  - A. 10 minutes.
  - B. 15 minutes.
  - C. 30 minutes.
  - D. 40 minutes.
7. In manual processing, the optimum time and temperature for developing film is:
  - A. 3 to 4 minutes at 70°F.
  - B. 4.5 to 5 minutes at 75°F.
  - C. 4.5 to 5 minutes at 65°F.
  - D. 4.5 to 5 minutes at 68 to 70°F.
8. What is the cause of yellow or brown stains appearing on film some months after processing?
  - A. Aged film.
  - B. Improper exposure technique.
  - C. Films stored in a hot place.
  - D. Incomplete fixing and washing.
9. Radiographs are rinsed in clean running water to:
  - A. Rid the film of chemicals.
  - B. Dissolve metallic silver.
  - C. Shrink the emulsion.
  - D. Get rid of the latent image.
10. Which of the following safelight filters is recommended for developing screen-type films such as panoramic films?
  - A. Kodak Morlite filter.
  - B. Rinn Extra Lite filter.
  - C. Wratten series 6B filter.
  - D. None of the above.
11. The safety of a darkroom safelight depends on the:
  - A. Distance of the safelight from the work bench.
  - B. Time the films are exposed to the safelight.
  - C. Wattage of the bulb in the safelight.
  - D. Speed of the film.
  - E. All of the above.
12. The many differences between automatic and manual processing include which of the following?
  - A. Processing solutions.
  - B. Solution chemistry.
  - C. Solution concentration.
  - D. Transport mechanism.
  - E. All of the above.
13. Which of the following factors contribute to fog with a resultant degradation of film quality?
  1. Unsafe safelight.
  2. Unsafe storage following exposure.
  3. Overdevelopment.
  4. High temperature development with no change in processing time.
  5. Outdated emulsion.
  6. White light leaks in the darkroom.
  - A. 1, 2, 3, and 4.
  - B. 1, 3, 5, and 6.
  - C. 1, 2, 3, 5, and 6.
  - D. 1, 3, 4, 5, and 6.
  - E. All of the above.
14. During the processing of Ultraspeed film in a private dental office, which of the following is the most important source of film fog?
  - A. Secondary radiation to the dental operator.
  - B. Unsafe safelight.
  - C. Developing solutions that are too cold.
  - D. Excessive fixation.
15. What is the most common cause of automatic processor jamming?
  - A. Using depleted solutions in the processor.
  - B. Using high solution temperatures in the processor.
  - C. Feeding bent films into the processor.
  - D. Feeding large films into the processor.

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# Analysis of Errors and Artifacts

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *List the three basic film quality evaluation criteria and the factors that control them.*
2. *List the five bitewing radiograph evaluation criteria.*
3. *Identify the five basic radiographic quality control tests.*
4. *Recognize and correct technique errors.*
5. *Recognize and correct exposure and processing errors.*
6. *Recognize and correct film-handling errors.*
7. *Purposefully create errors and recognize the errors in the processed images using the Workshop/Laboratory Exercises format.*
8. *Compare and contrast manual versus automatic processing using the Case-Based Problem-Solving format.*
9. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                          |                           |                        |                         |
|--------------------------|---------------------------|------------------------|-------------------------|
| apices cut-off           | definition                | finger artifact        | pressure marks          |
| automatic processor film | density                   | foreshortening         | radiopaque artifacts    |
| feeding                  | deposits on film          | high-density image     | region not covered      |
| backward film            | detail                    | horizontal angulation  | scratched film emulsion |
| bend marks               | dimensional distortion    | low-density image      | stains                  |
| black artifacts          | dot artifact              | mean tangent           | static electricity      |
| black streaks            | double image              | moisture contamination | technique errors        |
| blank (clear) image      | dust and powder artifacts | movement               | tongue artifact         |
| cone-cut                 | elongation                | overlapped contacts    | torn emulsion           |
| contrast                 | film distortion           | partial image          | vertical angulation     |
| dark density film        | film fog                  | "phalangioma"          | white artifacts         |

## INTRODUCTION

All dental radiation workers in a dental office or clinic have the responsibility to produce high-quality diagnostic radiographs. These workers must be competent in their techniques and be aware of what constitutes proper handling and correct processing of the film. Strict adherence

to the principles of patient management, technique, film handling, film storage, and darkroom procedures will eliminate needless additional radiation exposure to the patient by minimizing the necessity for retaking nondiagnostic radiographs. Each retake doubles the dose of radiation to the patient and doubles the cost of obtaining the image.

## EVALUATION CRITERIA

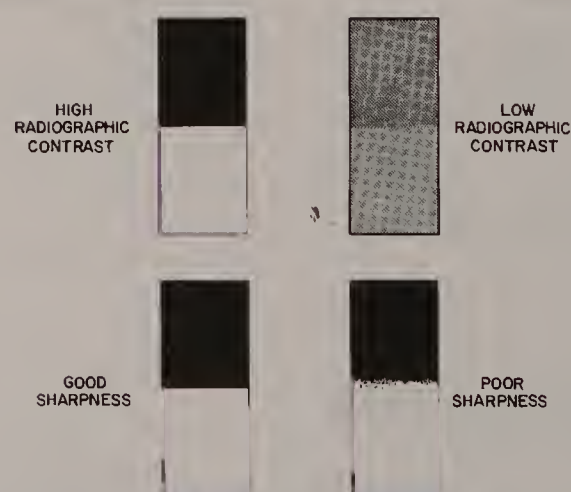
### QUALITY EVALUATION CRITERIA

1. All radiographs must have acceptable image characteristics of detail, definition, density, and contrast. The operator must control these image characteristics by using the most appropriate techniques available with a minimum of deviations, which will degrade the image. The illumination provided by the viewbox permits differentiation among the various structures of the teeth, the periodontal ligament spaces, the supporting bone, and the normal anatomical landmarks.
  - a. **Detail** refers to the point-by-point delineation of the minute elements of the objects in the radiographic images formed on the dental film. Detail is responsible for maximizing the information in an image. Detail is controlled by kVp and the developing process.
  - b. **Definition** refers to the distinctness and sharp demarcation of all the detail that makes up the radiographic images of the objects and their structural elements in the dental film. Definition is controlled by distance factors, focal spot size, type of film, and motion factors. Adequate definition is present when the apical lamina dura, periodontal ligament space, and individual trabeculae can be clearly demarcated around a healthy tooth.
  - c. **Density** is the general tendency of the film toward a lighter or darker overall appearance. Reasonable density will allow the dental health-care worker to visualize a faint outline of the soft tissue in the edentulous regions on the radiograph. Density is controlled primarily by the exposure time, mA, kVp, developer solution freshness, and temperature.
  - d. **Contrast** refers to the differences in density between adjacent areas in the dental film (Fig. 7-1). When the contrast is too high (short-gray-scale contrast), minute details in the bone are obliterated; when the contrast is too low (long-gray-scale contrast), small carious lesions in the interproximal enamel are difficult to read; however, bone lesions are easier to read. Contrast is controlled primarily by kVp. It is also affected by the type of film (D, E+, or F), processing solutions, and absorption differences in the subject (subject contrast). Each patient has a built-in step-wedge consisting of soft tissue, alveolar bone, enamel, dentin, and pulp. When all these can be clearly seen, optimal contrast is present.
  - e. The radiograph is free from film handling and processing errors and is not severely creased or stained.
2. All crowns and roots, including apices, are fully depicted together with interproximal alveolar crests, tooth contact areas, and surrounding apical bone regions.
  - a. All apices of all teeth, together with approximately 1/8 inch of surrounding apical bone, must be seen clearly at least once in a complete radiographic survey.

- b. Film covers all interproximal, periradicular, and/or retromolar regions of the anatomical region of interest. This includes distal of the canine on premolar radiographs and the third molar region in molar radiographs.
- c. The radiographs should not exhibit "cone-cutting" or "partial images."
- d. The embossed (raised) dot should appear at the incisal or the occlusal edge of the radiograph.
3. Images of all teeth and other structures are shown in proper relative size and contour with minimal distortion and without overlapping images, where anatomically possible.
  - a. The interproximal contacts of the two posterior bitewing radiographs should not overlap.
  - b. Images of the teeth and other structures should not be distorted to the extent that radiographic interpretation is impossible. Buccal and lingual cusp tips in posterior periapical radiographs should be superimposed at least to the same degree as is seen in the bitewings.

### BITEWING RADIOGRAPH EVALUATION CRITERIA

1. The interproximal contacts should not be overlapped from the distal surface of the canine to the mesial surface of the third molar, to the extent that interpretation is impossible.
2. The crowns of the maxillary and mandibular teeth should be centered in the image from top to bottom.
3. The crest of the alveolar bone should be visible with no superimposition of the crowns of the adjacent teeth.
4. The occlusal plane should be as horizontal as possible.
5. The buccal and lingual cusps should not be excessively separated. Slight separation of individual buccal and lingual cusp tips is permissible, as well as in individual teeth, due to malpositioning of a tooth. In general, the cusp tips should be nearly superimposed.



**Figure 7.1 Radiographic Contrast.** (Top) Radiographic contrast is the combination of subject contrast and film contrast that results in density differences between adjacent areas on the radiograph. (Bottom) Sharpness is the abrupt change in going from one density to another on a radiograph.



## RETAKES

Radiographs that are nondiagnostic are almost always retaken. Retakes should be avoided for the following reasons:

1. Retakes expose the patient to unnecessary radiation.
2. Retakes waste the time of the dental health-care worker and/or his or her coworkers.
3. Retakes waste film, which is costly.
4. Retakes waste infection control items, supplies, and procedures.

## TYPES OF ERRORS

The majority of errors produced can be categorized into

1. Technique errors.
2. Exposure and processing errors.
3. Film-handling errors.

When errors are made, the dental radiation worker must take the necessary time to troubleshoot the problem and correct it. An error can often be produced in more than one way. Therefore, all possibilities must be taken into account, and the cause identified. For instance, a **blank (clear) image** may be caused by nonexposure or by placing the film into the fixer solution first. The dental radiation worker needs to check both the exposure technique and the darkroom processing solution sequence. Errors are often the direct result of “shortcuts.” Improper attention to technique, film exposure, film processing, and storage procedures almost always compromises film quality and often leads to retakes. Radiographs that are of poor quality also

interfere with interpretation of the dental images that, in turn, may influence the diagnosis and treatment planning procedures. In a court of law, radiographs often play a vital role. Poor radiographs may be inadmissible or may be further evidence of sloppiness, negligence, or a lower-than-acceptable standard of dental care.

## TECHNIQUE ERRORS

### Patient Preparation Errors

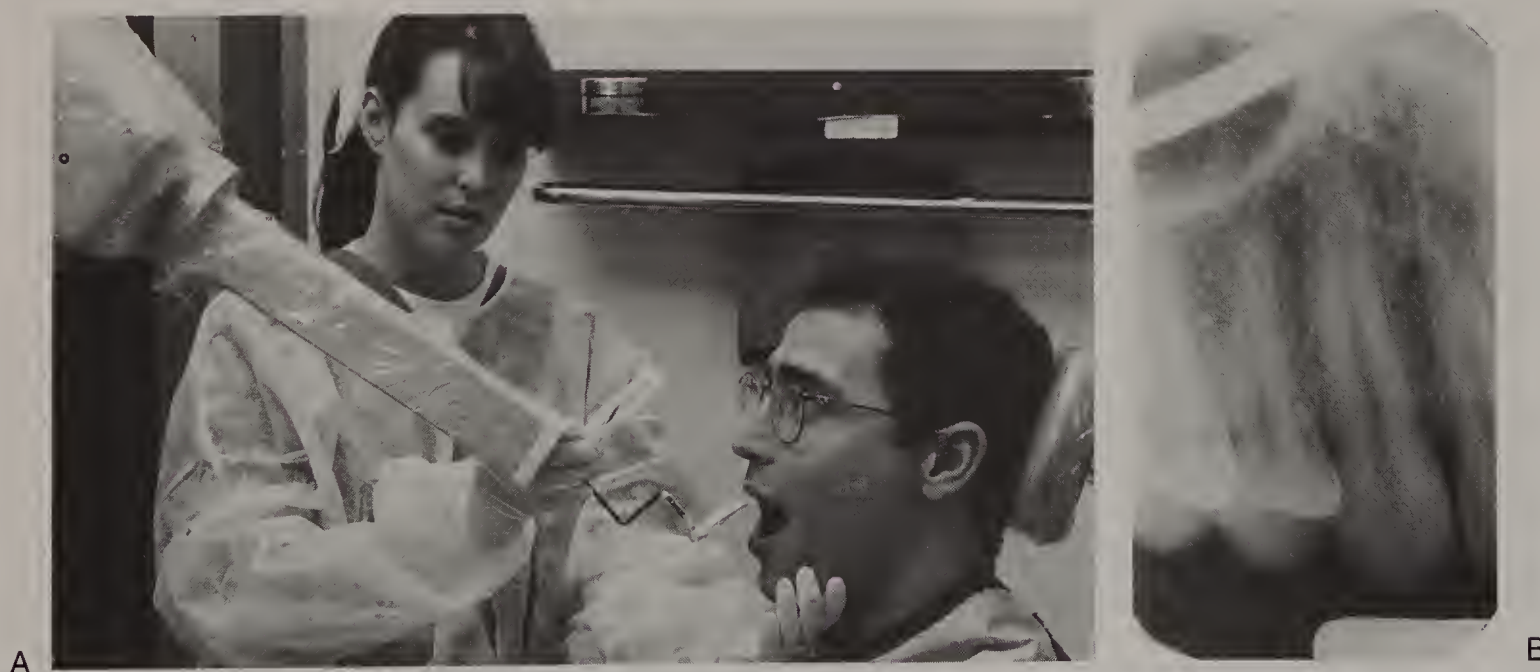
**Radiopaque Artifacts.** Dental appliances, body piercings, jewelry, and eyeglasses left in place will be recorded and appear superimposed over the dental images on the finished radiograph (Figs. 7-2 and 7-3). These areas appear white (radiopaque).

Before placing any films in the patient’s mouth, the operator should ask the patient to remove dental appliances, such as partial and complete dentures. Sometimes acrylic prostheses may be left in to help with film placement and retention. For extraoral images (such as panoramic radiographs) other items, such as wigs, hairpieces, eyebrow jewelry, necklaces, and napkin chains, must be removed.

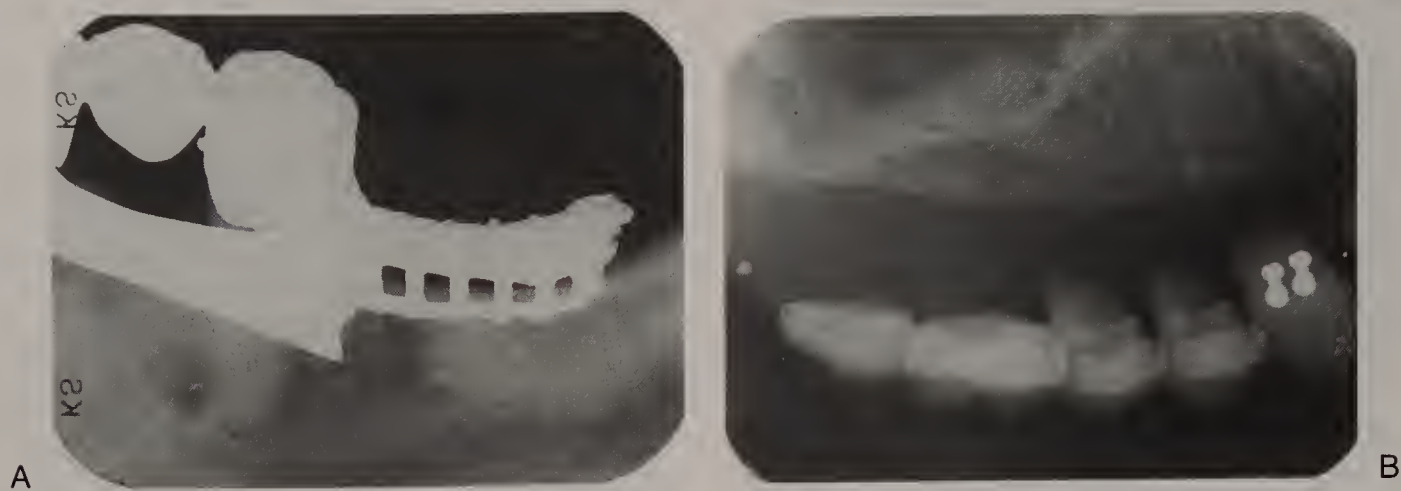
**Movement.** Movement of the film, patient, or x-ray tubehead will result in a **blurred image** (Fig. 7-4). Most movement errors are caused by patient (object) movement (Fig. 7-4). The operator, in explaining the procedure to the patient, needs to emphasize and later remind the patient to remain motionless during exposures and to **keep biting** on the biteblock until after the exposure. If the tubehead shakes, it must be stabilized before making the exposure.

### Film Placement Errors

**Apices Cut-Off.** This error occurs when the film is not positioned apically enough to record the entire tooth,



**Figure 7.2 Eyeglasses and Radiographs.** (A) Eyeglasses left on patient. (Patient should be instructed to remove eyeglasses before exposure of film.) (B) Radiograph resulting from patient still wearing eyeglasses.



**Figure 7.3 Removable Appliance and Complete Denture Remaining.** (A) Lower removable appliance remaining. (Patient should be instructed to remove removable appliance [partial denture] before exposure of film.) (B) Complete upper denture left in place.

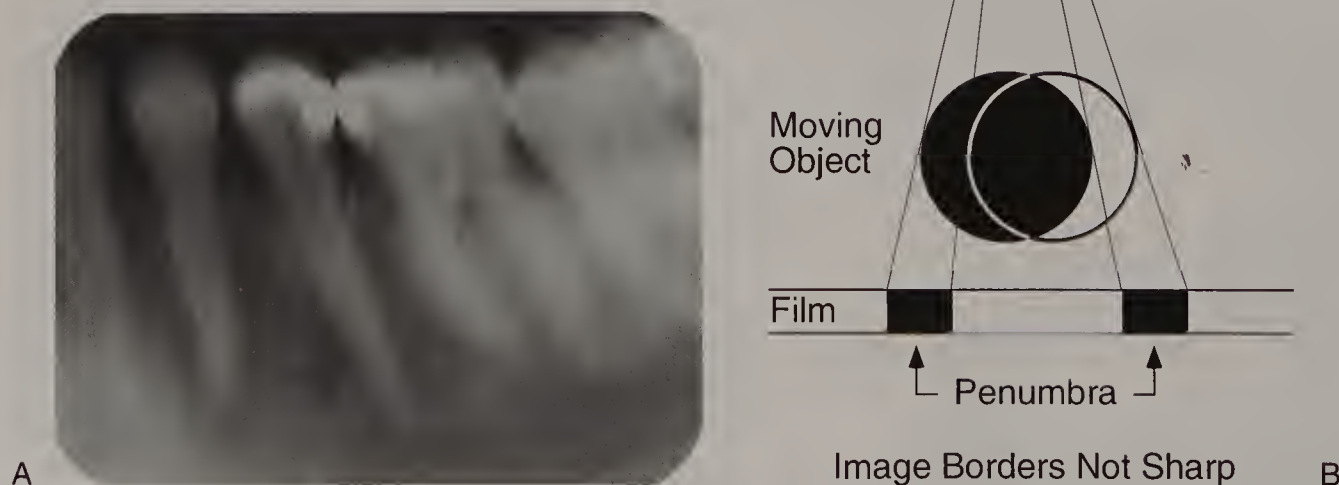
leaving too much film extending beyond the crowns. The operator can correct this in the paralleling technique by moving the film farther away lingually from the teeth in the maxillary arch and positioning the film more apically in the mandibular arch. At least 1/8 inch of film should be seen above or below the apices of the teeth (Fig. 7-5). Insufficient vertical angulation can project the apices of the teeth off the film.

**Specific Region not Covered.** This is the result of not placing the film to cover all the teeth in the area of interest (Fig. 7-6). Close inspection of the teeth or area in question, as well as adherence to specified film placement guidelines, will aid the operator in avoiding this error. Each film is positioned in the mouth to include specific ar-

eas of the teeth and related structures. To minimize this positioning error, three guidelines should be followed:

- The distal surfaces of the canine should be visible in the premolar views.
- The third molars or retromolar/tuberosity areas of the teeth should be seen in the molar views.
- The tooth/teeth of specific interest should be centered on the film.

**Backward Film.** A low-density “herringbone,” “tire-track,” or “geometric pattern” appearance of a film is the result of directing the x-rays through the lead foil side of the film packet (Fig. 7-7). Current E+ lead foil is embossed with a geometric pattern resembling tightly

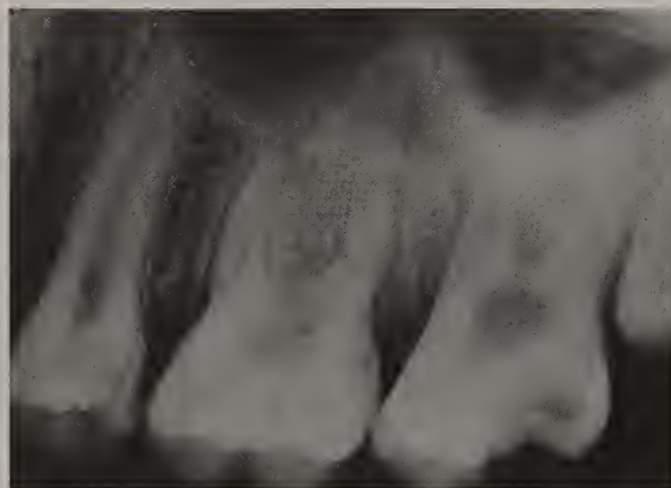


**Figure 7.4 Movement of Patient Error.** (A) Radiograph of patient who moved during exposure. (Patient should be properly instructed not to move.) (B) Diagram demonstrates how object movement increases penumbra, producing an unsharp image.





**Figure 7.5 Mandibular Molar and Premolar Apices Cut Off.** This usually happens when the patient fails to bite down on the biteblock because of discomfort.



**Figure 7.6 Specific Region Not Covered.** In this maxillary molar projection, the third molar is not covered properly. The film should be positioned farther back in the mouth.

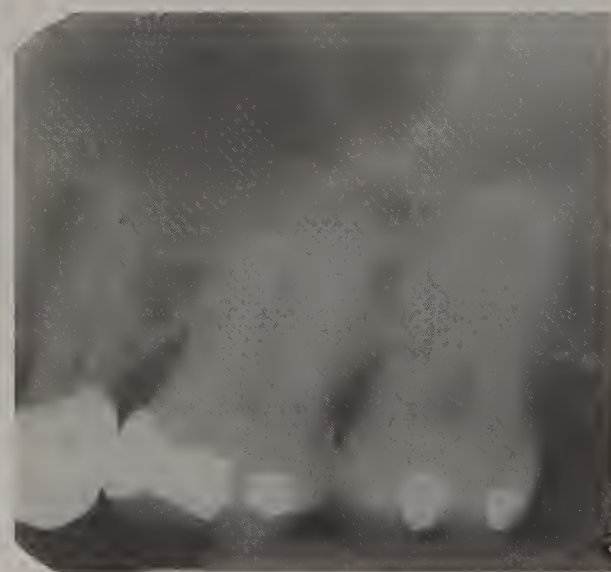


A

C



B



D

**Figure 7.7 Film Placed Backward.** (A) Photograph of anterior No. 1 size film being placed backward in the mouth. Note that the printed side of the film packet has been placed toward the beam of radiation. (B) Ping-pong ball pattern of the lead foil as seen in image when film is placed backward. (C) Note tire track pattern of the lead foil used in some film packets. (D) Maxillary molar of radiograph of film packet placed backward in the mouth. Note the light density of the radiograph and faint tire track pattern produced by the x-ray "blocking effect" of the lead foil, which is now in front of the film.



**Figure 7.8 Dot in the Apical Region.** (A) Photo of film placed with “dot not in the slot.” (B) Note the dot at the apex of the central incisor; it may often be superimposed on the apex and thus interfere with the visualization of pathology.

packed ping-pong balls. When the film is placed backward, the lead foil absorbs much of the radiation, the embossed lead foil pattern superimposes over the dental structures, and the structural orientation is reversed. The raised dot is now reversed! When this happens, the tab or backside of the film packet has been placed toward the source of radiation. Failure to retake this image can result in unneeded procedures on the wrong side of the patient.

**Dot Artifact.** The film identification dot produces a circular radiolucent (dark) artifact on the finished radiograph. This dark dot artifact may interfere with interpretation of the apical areas of the teeth (Fig. 7-8). Therefore, the film identification dot should be placed toward the coronal (occlusal) aspect of the teeth when taking periapical radiographs. Place the dot in the slot.

**Double Image.** When an exposed film is placed in another region and reexposed, the resulting film will have two superimposed images (Fig. 7-9). Use of a film organizer or film receptacle for exposed film will help the operator keep track of the film exposures made and prevent this error, which results in two retakes. Minimizing interruptions helps to avoid this error. Usually a blank, unexposed film is also found when this error occurs.

**Tongue or Finger Artifacts.** Films must be positioned behind the teeth without interference by the tongue (Fig. 7-10). Otherwise, this structure will be superimposed over the dental images and interfere with interpretation of the radiograph. Digital retention of the film by the patient is

sometimes used by older practitioners using the bisecting angle technique and for some endodontic procedures. This may result in a finger superimposed over the radiographic image (Fig. 7-11). This error has been referred to as the “phalangioma” error. Digital retention of the film



**Figure 7.9 Double Images on Radiograph.** Caused by two exposures made on one radiograph before processing. This double exposure was made when two radiographic exposures were made at right angles to each other.





**Figure 7.10 Tongue Artifact.** Tongue image (arrows). Film was improperly placed on top of the tongue.

by the patient is not recommended and should be avoided by using film-holding devices.

### Overlapping Errors

Overlapping is caused by either improper film placement and/or BID angulation.

#### Film Placement Error (Overlapping)

To prevent overlapping, the flat plane of the surface of the film should be positioned parallel to the mean tangent of the teeth to be radiographed. The **mean tangent** is defined as the plane joining the most exterior points of the curved

or molars). If this is not done, the contacts and embrasures between the teeth will be overlapped (Fig. 7-12).

#### BID Horizontal Angulation Error (Overlapping)

Overlapped contacts of interproximal surfaces of teeth will superimpose over each other if the direction of the x-rays is misdirected in the horizontal plane (Fig. 7-13). The



**Figure 7.11 Phalangioma or Finger Artifact.** Caused by the patient's finger (arrow) being placed between the film and the beam of radiation. This has been jokingly called "phalangioma" (tumor of the finger); in reality, it is only a finger.



**Figure 7.12 Overlapping (Improper Horizontal Placement of Film).** Film is **not** positioned horizontally parallel to the mean tangent of the teeth to be radiographed. This will result in the contacts and embrasures of the teeth being overlapped.

horizontal angle of the BID controls the x-ray entry through the interproximal surfaces of the teeth. The BID should be positioned horizontally, so the flat plane at the end of the BID is parallel to the film positioned in the mouth. This should direct the x-rays in a proper **horizontal angulation** to open the interproximal embrasures. Incorrect horizontal angulation not only overlaps contact surfaces, but also affects the definition of the total periapi-



**Figure 7.13 Overlapping (Horizontal Angulation Error).** Incorrect horizontal angulation of the BID that will cause overlapping of contacts of teeth in this posterior bitewing film.



**Figure 7.14 Overlapping.** Bitewing radiograph showing overlapping of the contacts of upper and lower teeth.

cal image. By directing the x-rays in an oblique fashion rather than a perpendicular one, the resulting tooth images appear widened and less defined (Fig. 7-14). The overall film density is also reduced because structures are thicker in an oblique plane; consequently, fewer x-rays reach the film. Correction of this error is the same as the correction for overlapped contacts. The x-rays are directed perpendicular to the mean tangent of the teeth being radiographed or to the properly placed film. This is most easily accomplished with the use of an instrument such as the Dentsply/Rinn XCP positioning device (Elgin, IL).

#### Shape Distortion Error

This error is caused by improper vertical angulation of the BID and/or placement of the film.

**Foreshortening.** When too much vertical angulation is used, the image appears shortened on the radiograph (Fig. 7-15).

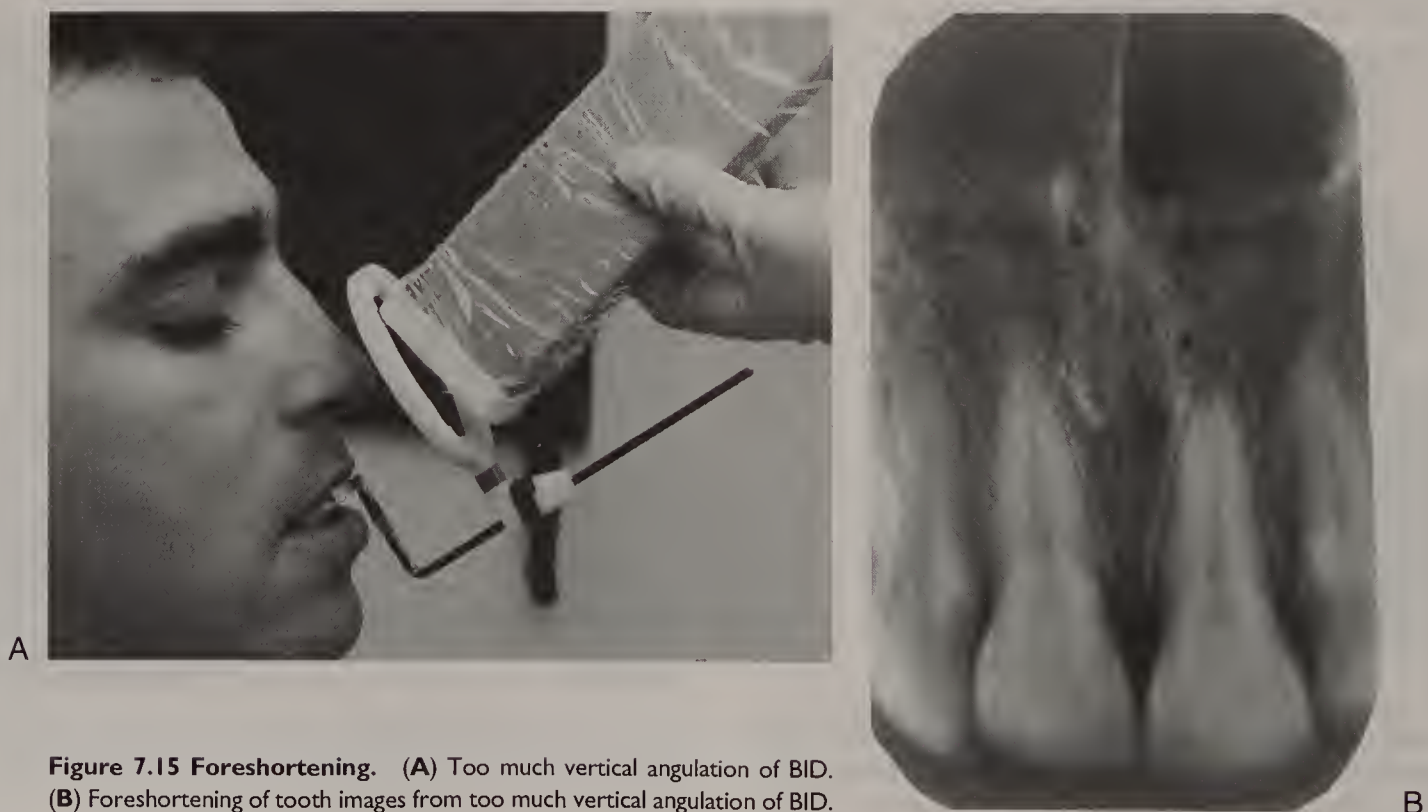
**Elongation.** Elongation of tooth lengths occurs when not enough vertical angulation is used, thus lengthening the teeth images (Fig. 7-16).

**Film Distortion.** Image lengthening and distortion, as shown in Figure 7-17, may occur if the patient exerts too much biting pressure on the biteblock or if the film backing portion of the biteblock is trimmed or removed. This causes the film packet to bulge in the center. The image conforms to the distorted shape of the film surface. This error can be avoided by keeping the film in contact with the biteblock backing for support or instructing the patient to reduce the biting or pressure they are exerting on the biteblock.

**Dimensional Distortion.** This type of image distortion is inherent in the bisecting-angle technique and is especially seen as length distortion of roots of maxillary molars. It results in elongation of the palatal root and foreshortening of the two buccal roots. Neither of the roots lies in the bisecting-angle plane (Fig. 7-18). Correction of this distortion necessitates use of a paralleling technique for more accurate recording of the root lengths of the maxillary molars.

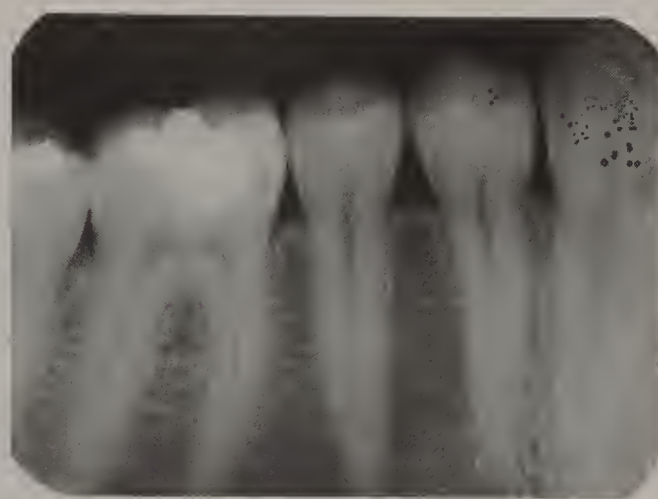
#### Cone-Cutting Errors

A cone-cut is the result of partial coverage of the film by the x-ray BID (Fig. 7-19). The term “cone-cutting” is a phrase that has stuck with us since the time dentists used a “pointed plastic cone” to direct the x-rays to the film. The plastic cone we speak of today is a beam indicating



**Figure 7.15 Foreshortening.** (A) Too much vertical angulation of BID. (B) Foreshortening of tooth images from too much vertical angulation of BID.



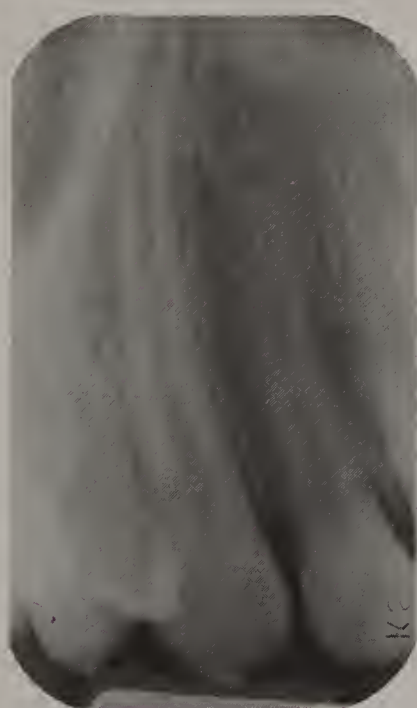


B



C

**Figure 7.16 Elongation and Apical Ends of Teeth Cut Off.** (A) Photograph showing “too flat” a vertical angulation of the BID that results in the apices of the teeth being projected off the film. (Teeth images are longer than their actual lengths and the apices are cut off.) (B) Radiograph of elongation of lower premolar teeth with apices cut off. (C) Radiograph of elongation of maxillary anterior centrals with apices cut off.



**Figure 7.17 Film Distortion and Tooth Lengthening From Film Bending.** Improper film placement and film retention causing the film to bend. Note elongation of teeth and “fuzzing-out” of tooth images in the upper left corner where the film has been bent or curved.

device (BID), which is an open-ended, lead-lined, circular or rectangular cylinder that helps to position and collimate the beam of radiation.

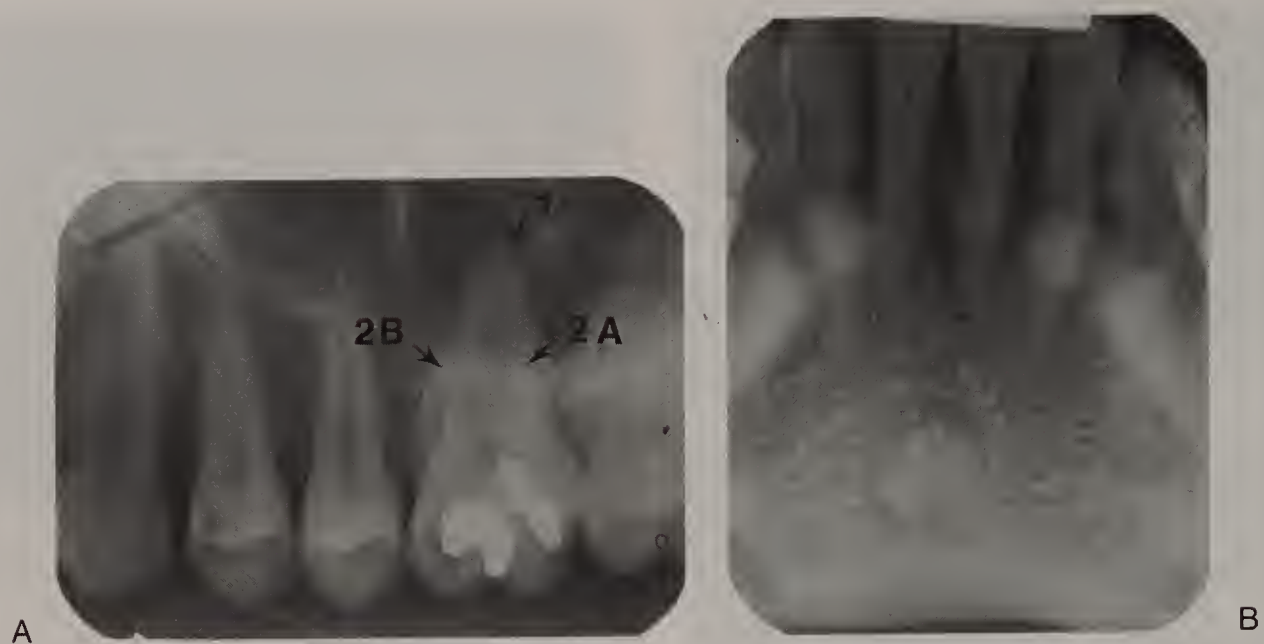
#### **Crowns of Teeth Not Showing**

The cause is not enough film extending below the maxillary teeth or above the crowns of the mandibular teeth. Another cause is that the vertical angulation of the BID was too steep (Fig. 7-18B). Table 7-1 shows a summary of intraoral and projection technique errors.

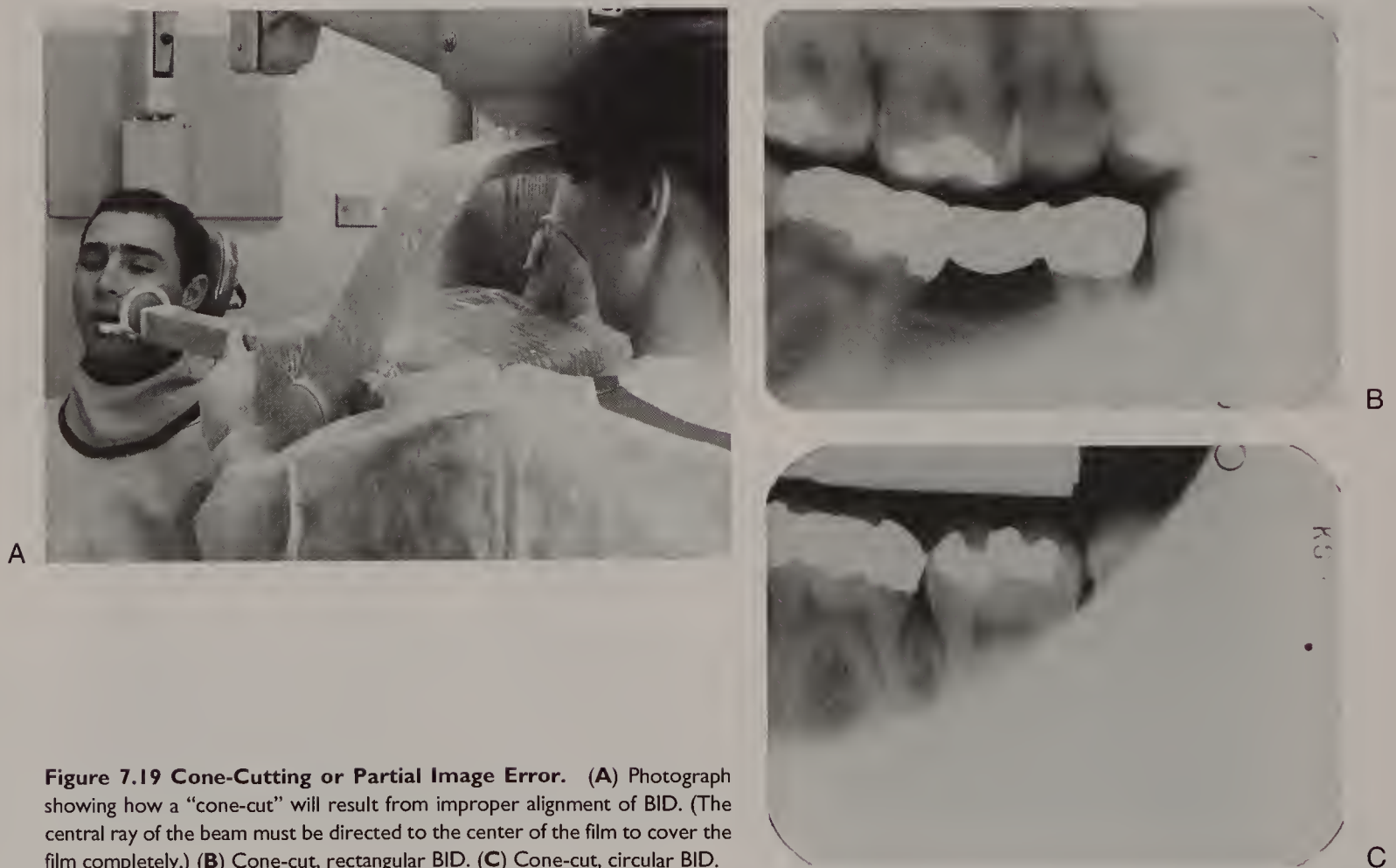
### **EXPOSURE AND MANUAL PROCESSING ERRORS**

#### **Blank Film, No Image**

A film that has received no radiation will have no image and will reveal a clear, blue-tinted film. This may occur in several ways: (1) the x-ray machine was not “turned on” or the control panel was set for another tubehead, (2) the operator had completely failed to align the x-ray BID with the film, or (3) the operator may not have depressed the timer button properly to activate the exposure, or (4) the film was not exposed at all, while another was used twice and produced a double exposure.



**Figure 7.18 Dimensional Distortion and Crowns Cut Off.** (A) Dimensional distortion on the maxillary first molar (1) elongated palatal (lingual) root, (2A) foreshortened distal buccal root, and (2B) foreshortened mesial buccal root. This is usually caused by using bisecting technique, which is inherent in the technique. (B) Crowns cut off due to excessive vertical angulation. Note the mandibular tori and use of #2 film that could have caused interference with film placement.



**Figure 7.19 Cone-Cutting or Partial Image Error.** (A) Photograph showing how a "cone-cut" will result from improper alignment of BID. (The central ray of the beam must be directed to the center of the film to cover the film completely.) (B) Cone-cut, rectangular BID. (C) Cone-cut, circular BID.



**TABLE 7-1. Summary of Intraoral Projection and Technique Errors**

| Error                                                  | Cause                                                                                                                                                                                                                      |
|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Radiopaque artifacts on radiograph                     | Leaving dental appliance in mouth and/or eyeglasses or jewelry on the patient                                                                                                                                              |
| Blurred image on radiograph                            | Movement of film, patient, or tubehead during exposure                                                                                                                                                                     |
| Apical ends of teeth cut off                           | A. Film placed too close to the teeth in the maxillary arch in paralleling technique<br>B. Too flat a vertical angulation, which causes elongation                                                                         |
| All of specific region not showing                     | Faulty film placement (center the film over the area of interest)                                                                                                                                                          |
| Herringbone effect or ping-pong ball and light density | Printed back side of film placed toward beam of radiation (film reversed)                                                                                                                                                  |
| Black dot in apical area                               | Manufacturer's identifying depression on film placed toward apical area of the teeth (place "dot in slot"—XCP instrument)                                                                                                  |
| Double images of radiographs                           | Film exposed twice to radiation; "use film cup"                                                                                                                                                                            |
| "Phalangioma" (patient's finger in image)              | In holding the film (bisecting angle technique), the finger is placed between the film and the teeth                                                                                                                       |
| Tongue image                                           | Placing the film on top of the tongue                                                                                                                                                                                      |
| Overlapping of teeth                                   | A. Plane of the film is not parallel to the lingual surface of the teeth<br>B. Incorrect horizontal angulation of the cone (BID)                                                                                           |
| Foreshortening of image                                | Bisecting technique: vertical angulation of cone (BID) too steep<br>Paralleling technique: film not parallel with long axes of the teeth<br>Paralleling technique: long cone (BID) is not positioned correctly             |
| Elongation of image                                    | Bisecting technique: vertical angulation of cone (BID) too flat<br>Paralleling technique: film is not positioned parallel to the long axes of the teeth<br>Paralleling technique: long cone (BID) not positioned correctly |
| Dimensional distortion of image                        | Inherent error in bisecting angle technique produces elongation of palatal roots and foreshortening of buccal roots of molars in the same view                                                                             |
| Image distorted severely                               | Film is bent as patient bites on the film-holder or biteblock                                                                                                                                                              |
| Partial image "cone-cut"                               | Cone (BID) of radiation not covering the area of interest                                                                                                                                                                  |
| Crowns of teeth not showing                            | Not enough film ( $\frac{1}{8}$ " ) showing below or above the crowns of the teeth<br>Vertical angulation too steep                                                                                                        |

### Low-Density Film Image

A light or low-density image may be the result of insufficient radiation exposure or a processing error (underdevelopment) (Fig. 7-20). Exposure factors must be checked to make sure the proper kilovoltage, milliamperage, source-film distance (locator ring placed close to skin), and correct timer setting were used. The exposure settings may have been too low or the source-film distance too long for the exposure settings. A common error is not aligning the BID properly or not placing the locator ring close to the patient's cheek. If the exposure settings are correct, the timer button exposure technique should be used properly. The timer button has a "dead man" switch and must be held down constantly until the audible sound stops, indicating the exposure has been completed. Light-density films may also be the result of a drop in line voltage or insufficient power at the time of exposure, although this is rare. A separate circuit may be necessary for optimal performance of the x-ray machine. A correctly exposed film may be light or low in density if darkroom factors are not optimal. Low developer solution, low tem-

perature, insufficient developing time, exhausted or contaminated developer chemicals, and overfixation can be responsible for this problem. Each factor must be thoroughly examined. The most frequent of these is depleted



**Figure 7.20 Low-Density Film.** Low-density film may be the result of insufficient radiation exposure or underdevelopment of the film.



**Figure 7.21 High-Density Film.** This may be the result of overexposure or overdevelopment of the film.

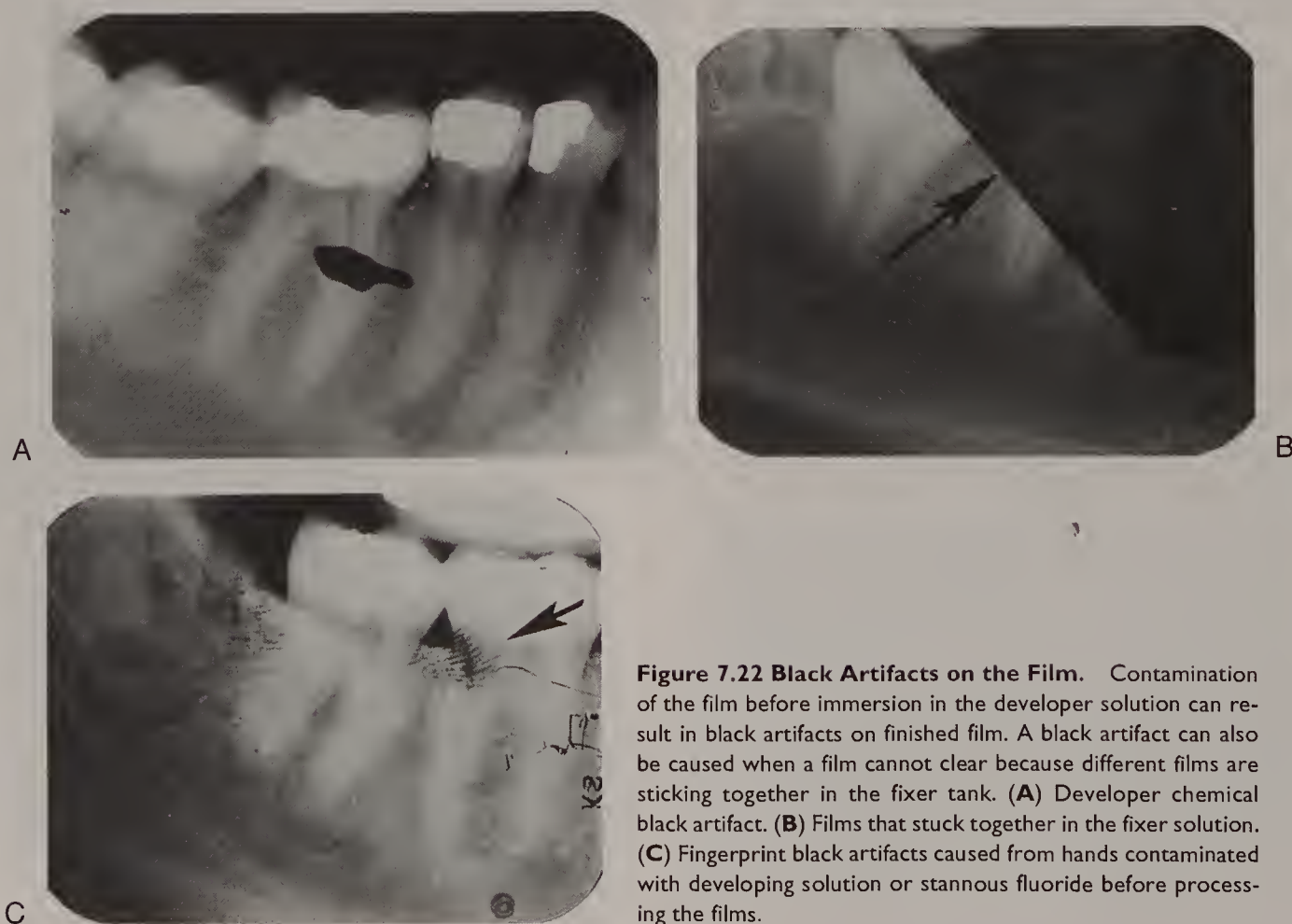
developer solution in the automatic processor. Eventually (2 to 4 weeks), the chemicals will need complete replacement. All processing solutions exhibit reduced chemical activity after a period, no matter how often they are replenished.

### High-Density (Dark) Image

A dark or **high-density image** may be the result of too high a radiation exposure, overdevelopment of film, or an unsafe darkroom (Fig. 7-21). Exposure factors such as milliamperage, kilovoltage, source-film distance, and exposure time must be checked for accuracy. These settings may have been too high or the source-film distance too short for the exposure settings. The film speed should also be checked—whether D, E+, or F speed film is being used? D speed settings for E+ or F speed film will result in dark or overexposed images. However, a correctly exposed film may appear dark in density, when darkroom factors are not optimal. High developer solution temperatures, prolonged developing time for the temperature of the solution, or overstrength developing solutions are all potential causes of overdevelopment of the film. Each factor should be checked thoroughly. Darkroom problems are rarely the cause of dark films. The films are usually overexposed.

### Partial Image (Processing Error)

A technically accurate and properly exposed film with a **partial image** can be due to partial immersion of the film in the developer chemicals in hand processing. Over time, the level of developer solution drops due to evaporation and carry over of the solution into the water bath by the film hangers and films. Replenishment is necessary to maintain proper solution strength and level.



**Figure 7.22 Black Artifacts on the Film.** Contamination of the film before immersion in the developer solution can result in black artifacts on finished film. A black artifact can also be caused when a film cannot clear because different films are sticking together in the fixer tank. (A) Developer chemical black artifact. (B) Films that stuck together in the fixer solution. (C) Fingerprint black artifacts caused from hands contaminated with developing solution or stannous fluoride before processing the films.





**Figure 7.23 Black Streaks on the Film.** Black streaks can be caused by many things, such as overinspection during development, lack of agitation of films in the developer, fixer-contaminated hanger clips, and dirty rollers in the automatic processors. (A) Developer chemical reaction with fixer residue left on the hanger clips, causing black streaking. (B) Black streaking marks caused by dirty rollers in the automatic processor.

### Black Artifacts

Contamination of the radiographic film surface before immersion into the developer solution can result in artifacts on the finished radiograph (Fig. 7-22A). Contaminants that cause black artifacts include developer chemicals, moisture (saliva), stannous fluoride, light leaks in the film packet, and overlapping of films during processing (Fig. 7-22B). The darkroom working surfaces, operator's hands, and film packets must be clean and dry. Careful handling of the film by the edges will prevent unnecessary artifacts such as fingerprints (Fig. 7-22C).

### Black Streaks

Streaking of the film emulsion may be the result of overinspection of the films during development, lack of proper film agitation when first immersed in processing solutions, fixer-contaminated processing hanger clips, insuffi-

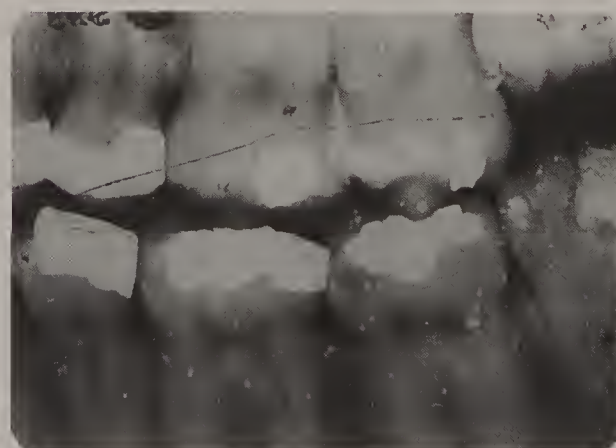
cient fixing, or improper rinsing (Fig. 7-23A). Streaks may also be caused by dirty rollers in automatic processors (Fig. 7-23B). Processing "shortcuts" such as those cited cause black streaks, which detract from film quality and often result in needless retakes.

### White Artifacts

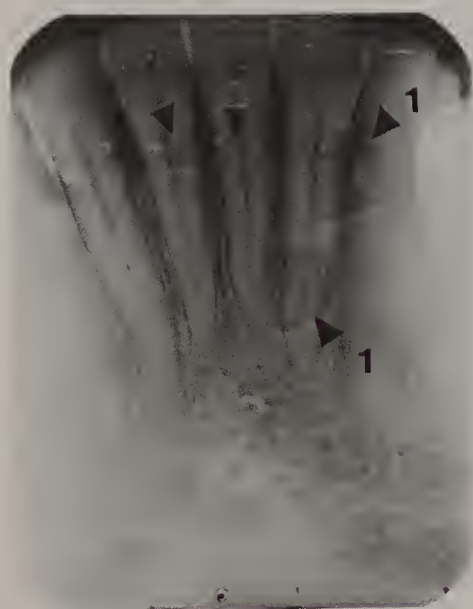
Precontamination of the film surface with droplets of fixer solution, as well as air bubbles that form on the film surface during initial immersion of the film in the developing solution, can cause white teardrop artifacts on the finished radiograph (Fig. 7-24). Also, fixer solutions on the fingers can cause white fingerprints in the image. Clean and dry working surfaces are essential for proper processing. Gentle agitation of the films when first placed in the processing solution will remove air bubbles (Fig. 7-25) and allow complete development of the latent image.



**Figure 7.24 White Artifacts on the Film.** Contamination of the film emulsion surface with droplets of fixer solution before development. The fixer droplets will clear the film of silver halide in the emulsion during the development phase, forming white artifacts.



**Figure 7.25 Air Bubbles on the Film.** Air bubbles (white round areas) forming on the film as the film is first placed into the developer solution can be removed by agitation of the films. The black line running across the film is caused by rough handling of the film during processing.



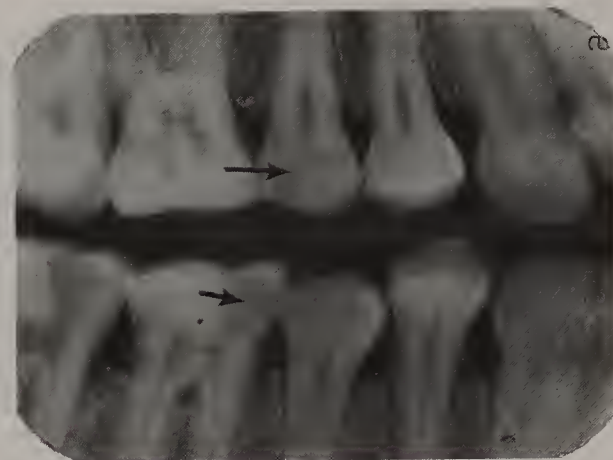
**Figure 7.26 Developer Stain.** (1) Darker areas are watery developer stains. (2) White areas are deposits of zirconium prophylaxis paste on teeth.

### Deposits on Film

Chemical precipitants that adhere to the film and mar its surface are most often due to contaminated, improperly prepared, or exhausted solutions. Unclean film hanger clips may also carry chemical deposits that may be the source of solution contamination. When changing solutions, the operator must thoroughly clean the tanks, not interchange the tanks between the two solutions (the same tanks should always be used for developer and fixer), mix the new chemicals according to manufacturer's instructions, and use separate stirring rods to mix the solutions.

### Stains

Most stains that appear on finished radiographs are the result of exhausted solutions or insufficient rinsing (Fig. 7-26). Manual and automatic processing solutions need replenishment and have a limited life span. The maximum life for manual processing solutions is usually 15 to 30 days, depending mainly on the number of films processed. A thorough rinsing of the processed radiographs is necessary not only to remove any remaining chemicals from the film, but also to rinse the film hangers free of chemicals. Films should be rinsed in a running water bath for 15 minutes. The most common stain is brown due to insufficient removal of the fixer solution from the manually processed film (Fig. 7-27). The brown stain occurs with age and is due to the retained hypo (thiosulfate) from the fixer reacting with the metallic silver image to form brown silver sulfide—just as silverware acquires a brown tarnish when exposed to hydrogen sulfide produced by cooking gas.



**Figure 7.27 Brown Stain on the Film.** This is caused by not washing film properly after fixing. If the film is not washed long enough after fixing, the hypo (thiosulfate) retained in the film emulsion will in time react with the metallic silver grains in the radiograph to form a brown-silver sulfide stain (arrows).

## AUTOMATIC FILM PROCESSING ERRORS

There are several errors in automatic processing that can be made to render the film unreadable. An automatic film processing troubleshooting chart is shown in Table 7-2.

### Feeding Film in Automatic Processors

The following are a few important recommendations for feeding the film into the automatic processor to prevent errors.

#### How to Feed Films

1. Films should be fed slowly and carefully. Panoramic films should be inserted into the processor in a straight line with the roller system. Failure to do so could cause a jam-up in the processor.
2. If film is bent, the unbent side of the film should be inserted into the machine first; the bent corner or edge should be manually unbent.
3. Damp or wet films should not be fed into the machine because they will contaminate rollers and cause streaking of subsequent films.
4. Films should not be fed too quickly in succession. They may stick to each other and could jam the machine (allow 5 seconds between films fed into the same slot). There will be a dark density area on the film where the films stuck together.

## FILM-HANDLING ERRORS (TABLE 7-3)

### Pressure Marks

Writing on the film packet with a ballpoint pen or pressure from the cusps and incisal edges of the teeth (occurring mostly in pediatric occlusal radiography) will produce marks on the finished radiographs (Fig. 7-28).



**TABLE 7-2. Automatic Film Processing Trouble Chart**

| <b>Condition</b>                     | <b>Cause</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Low-density (light) films            | <ul style="list-style-type: none"> <li>A. Solution temperature too low</li> <li>B. Exhausted developer (underreplenishment)</li> <li>C. Improper agitation or massaging action of rollers</li> <li>D. Processing too fast (higher temperature and/or faster roller speed)</li> </ul>                                                                                                                                                                                                                                                                                                                                                          |
| High-density (dark) films            | <ul style="list-style-type: none"> <li>A. Solutions overheated</li> <li>B. Light leaks in the processor cover</li> <li>C. Too much replenishment</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Wet or tacky films                   | <ul style="list-style-type: none"> <li>A. Dryer and developer temperatures too low</li> <li>B. Dryer thermostatic control or heater inoperative</li> <li>C. Dryer air circulation inadequate (high humidity in dryer section)</li> <li>D. Wrong chemistry and/or film</li> <li>E. Processing too fast (higher temperature and/or faster roller speed)</li> </ul>                                                                                                                                                                                                                                                                              |
| Film discoloration (brown)           | <ul style="list-style-type: none"> <li>A. Contamination of fixer by the developer solution</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Film discoloration (greenish yellow) | <ul style="list-style-type: none"> <li>A. Fixer solution exhausted (underreplenishment)</li> <li>B. Processing too fast (higher temperature and/or faster roller speed)</li> <li>C. Wrong type of film for the processor solution</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                  |
| Fogged films (unwanted density)      | <ul style="list-style-type: none"> <li>A. Incorrect or defective safelight filter or bulb</li> <li>B. Light leaks in the darkroom</li> <li>C. Developer temperature too high</li> <li>D. Improper storage of films</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Streaking (uneven density)           | <ul style="list-style-type: none"> <li>A. Underreplenishment</li> <li>B. Rollers encrusted with chemical deposits</li> <li>C. Dirty wash water</li> <li>D. Film not hardened properly by chemicals</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Surface marks                        | <ul style="list-style-type: none"> <li>A. Foreign materials or irregularities on the surface of the rollers</li> <li>B. Rough handling of the film before processing</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Films chalky or dirty                | <ul style="list-style-type: none"> <li>A. No wash water or dirty wash water</li> <li>B. Fixer contaminated</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Jams or failure of film to transport | <ul style="list-style-type: none"> <li>A. Chemicals contaminated or diluted</li> <li>B. Chemical temperature too high</li> <li>C. Films excessively soft and not adequately hardened; when enough gelatin lubricates the rollers, films will jam up with one another</li> <li>D. Dirty rollers</li> <li>E. Racks not seated properly</li> <li>F. Dirty wash water</li> <li>G. Incorrect dryer temperature</li> <li>H. Hesitation in drive assembly, causing film to pause in transit</li> <li>I. Film not tracking though the processor in straight line (improper feeding of films)</li> <li>J. Bent film corners as leading edge</li> </ul> |

TABLE 7-3. Summary of Film Handling Errors

| Error                                         | Cause                                                                                                                                                                                                                 |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Black pressure marks on film                  | Teeth marks on film (especially pediatric occlusal film)                                                                                                                                                              |
| Black bend lines on film                      | From bending film to reduce patient discomfort                                                                                                                                                                        |
| Black marks on film                           | Saliva contamination of black protective paper covering film; caused by failure to blot film packet with paper towel                                                                                                  |
| Black “lightning- or tree-like” marks on film | Static electricity; removing film too rapidly from packet or box in air with dry humidity                                                                                                                             |
| Torn emulsion and scratches on film           | Careless handling of film during processing when emulsion is soft and swollen                                                                                                                                         |
| Dust and powder artifacts                     | Film contact with dust, grit, or glove powder before processing                                                                                                                                                       |
| Fogged film (unwanted density)                |                                                                                                                                                                                                                       |
| A. Light fog                                  | 1. Light leaks in the darkroom<br>2. Improper safelight; check bulb wattage, distance, and filter-film compatibility<br>3. Turning overhead (white) light on too soon; (be certain films have cleared in fixer first) |
| B. Radiation fog                              | Improper storage; insufficient protection of film next to x-ray machine                                                                                                                                               |
| C. Processing (chemical fog)                  | 1. Developer temperatures too high<br>2. Overstrength developer (check manufacturer’s instructions)<br>3. Prolonged development for temperature<br>4. Contaminated developer (clean tank routinely)                   |
| D. Deterioration of film                      | 1. Temperature of storage area too high (store in refrigerator)<br>2. Humidity of storage area too high (store in refrigerator)<br>3. Strong fumes (ammonia, paint)                                                   |
| White ball-point pen marks                    | Writing on front of film packet with ball-point pen                                                                                                                                                                   |



Figure 7.28 Marks From Ballpoint Pen. Writing on the film with a ballpoint pen produces white marks. The name “Bob” can be seen clearly.

**Bend Marks**

Black linear artifacts (Fig. 7-29) on finished radiographs are the result of purposeful bending of the film to reduce patient discomfort. Film bends must be kept to a minimum and be strategically located so that the bends do not interfere with the major images on the film. Black crescent creases (Fig. 7-30) are the result of incidental crimping of the film, usually produced by excessive bending and not the fingernail. Films should be handled with care to avoid distracting artifacts.

**Moisture Contamination**

Saliva contamination of the film packet may cause the inner black paper wrapping to adhere to the film emulsion, producing a black artifact (Fig. 7-31). Film packets (especially paper packets) should be wiped off with a paper towel before inserting them into a film receptacle. Moisture present on the fingers can also produce artifacts on



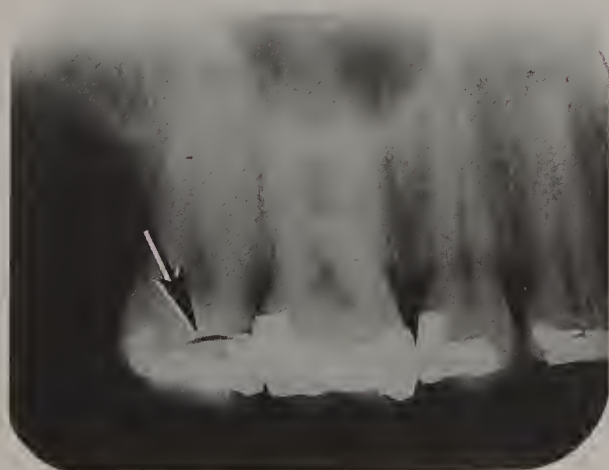


**Figure 7.29 Bend Marks (Purposeful Bending).** (A) Photograph showing purposeful bending in an anterior No. 1 film packet. (B) Black bend marks at the corners of a posterior periapical No. 2 bitewing radiograph.

the film. When handling films out of the film packet, hands should be clean, dry, and free from contamination from processing chemicals. Film should be handled only by the edges, without touching the surface.

### Static Electricity

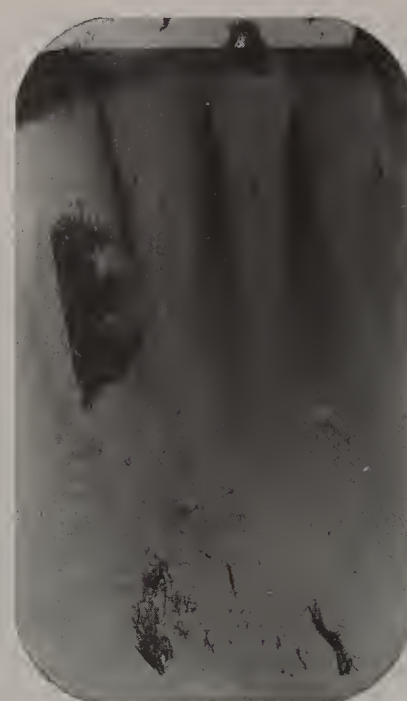
A dry indoor environment, such as occurs in winter, combined with rough unwrapping of films or rapid sliding of panoramic films out of the film box or soft cassette may produce a small charge of static electricity that exposes the film at the point of origin. Also, synthetic uniform materials and rubber-soled shoes rubbing against carpet contribute to static electricity production by the film-handler (Fig. 7-32). This can be reduced by placing a humidifier or container of water in the darkroom during cold months when the heating system is working.



**Figure 7.30 Black Crescent Mark (Incidental Crimping).** Black crescent artifact caused by excessive crimping and bending of the film packet to make it more comfortable for the patient.

### Torn Emulsion and Scratches

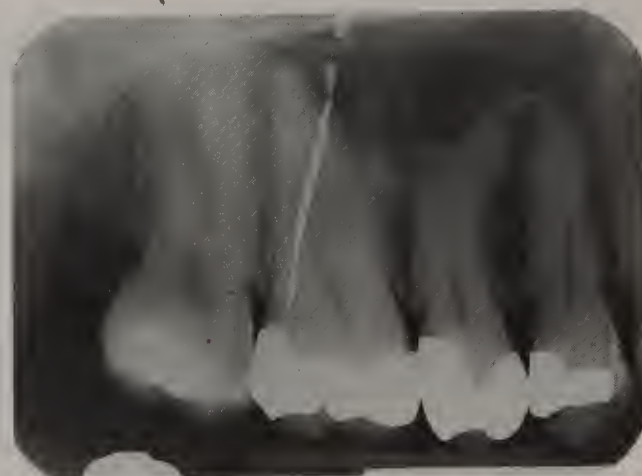
Careless handling of the film, especially during film processing when the emulsion is soft and swollen, often results in a removal of the emulsion and a visible scratch when the surface of the film is examined in reflected light. If the film surface is scraped against the processing tank, another film hanger, or the operator's fingernail, the emulsion can be easily peeled off (Fig. 7-33).



**Figure 7.31 Moisture (Saliva) Contamination.** Saliva from the patient soaking through the film packet (especially paper packets) and causing the black protective paper to stick to the wet emulsion of the film, causing black areas on the film.



**Figure 7.32 Static Electricity Error.** Linear form of static electricity marks with lightning-like streaks. This may take several forms, such as small dots or a tree-like configuration.



**Figure 7.33 Torn Emulsion Error.** Emulsion torn due to rough handling in the processing cycle when emulsion was soft.

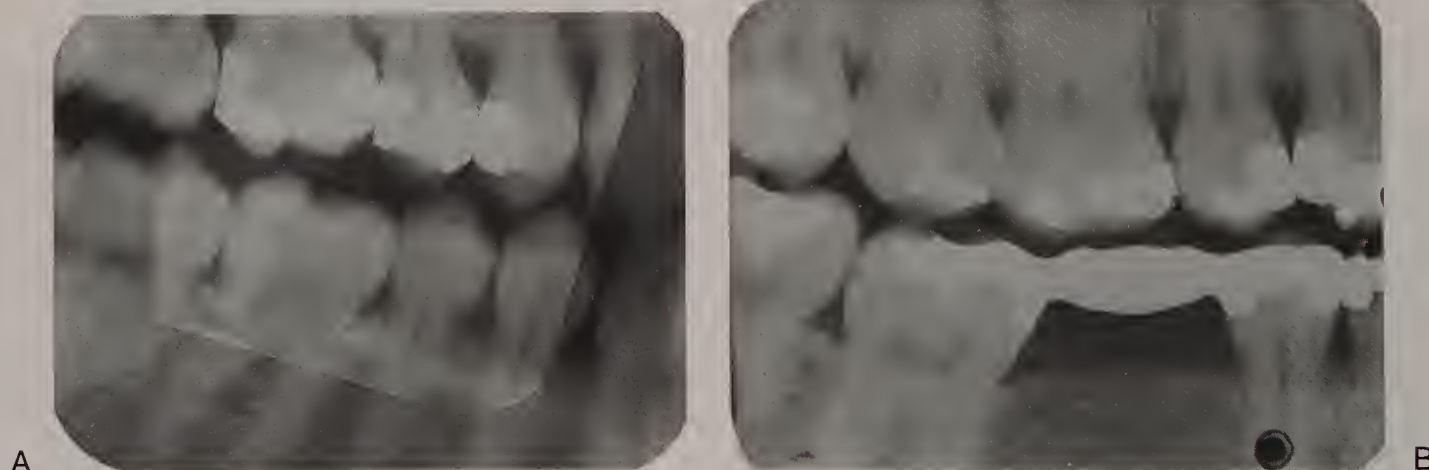
### Dust and Powder Artifacts

Film contact with dust, grit, dirt, or glove powder before film processing can result in pinpoint black artifacts on the film emulsion. It is recommended that nonpowdered gloves be used during radiology infection control procedures. After processing, when films are dry and ready to mount, contact with the above contaminants should be avoided. These contaminants cause the particles to cling to the film surface.

### Film Fog

Film fog, evidenced by a dull-gray low-contrast image, has several possible causes (Fig. 7-34). Films can be fogged by use of outdated film, improper film storage, radiation before and after exposure, improper safelight conditions, higher-than-optimum developing solution temperatures, and white light leaks in the darkroom.

Radiographic film must be stored according to expiration date in a cool, dry environment (preferably a refrigerator) and away from radiation and strong chemicals. Radiographic film is also sensitive to white light. Because of this, the darkroom should be white-light-tight, with proper safelight lamp distance (4 feet of the working surface), red filter (GBX-2), and bulb (15 watt) to guard against fog. When opening film packets and feeding film in the slots of the automatic processor in the daylight loader, the operator's hands should not be removed from the sleeves until the films placed into the slots have moved completely within the machine. Chemical film fog may be due to excessive developing temperature, overdevelopment, and use of poorly mixed, contaminated, or exhausted developer solution. Lead lined film storage containers must have a non-lead inner lining to prevent contact between the film and lead lining.



**Figure 7.34 Fogged Film.** (A) Film was superimposed over another film. Note the difference between the fogged portion of the film and the portion of the film under the superimposed film that is not fogged. (B) Overall gray appearance of film fog (unwanted density) from various causes such as unsafe safelight, light leaks, outdated film, overheated film, and film exposed to scatter radiation.



## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 7.1. INTRAORAL TECHNIQUE ERRORS

#### Materials and Equipment Needed

1. X-ray machine and processing facility.
2. Film-holding device.
3. Eight No. 2 films (intraoral).
4. Manikin or skull.

#### Instructions

Using the x-ray machine and manikin, **improperly** place each film and expose it to obtain the following errors:

1. Backward or “reversed” image.
2. Dot artifact error.
3. Double image.
4. Overlapped bitewing contacts.
5. Foreshortening of maxillary centrals.
6. Elongation of maxillary centrals.
7. Dimensional distortion of maxillary first molar.
8. Cone-cut.

After processing, mount the films and label each error.

### EXERCISE 7.2. INTRAORAL EXPOSURE AND/OR PROCESSING ERRORS

#### Materials and Equipment Needed

1. All equipment items in Exercise 7.1.
2. Seven No. 2 films (intraoral).

#### Instructions

Using the x-ray machine and manikin, **improperly** expose and/or process a film to obtain the following errors:

1. Blank image.
2. Light image.
3. Dark image.
4. Black fingerprint in image.
5. Fixer stain in image.
6. Fogged film with an image of teeth.
7. Bent corner of film.

After processing, mount the films and label each error.

### CASE-BASED PROBLEM-SOLVING

You are trying to figure out if you prefer manual processing to automatic processing. Make a chart listing the comparative advantages and disadvantages of each and report what you would do if you had your choice.

**Hint:** Do not forget potential for errors, cost, maintenance, time for obtaining a dry processed film, infection control, and so forth. You may want to give some factors more weight or importance than others.

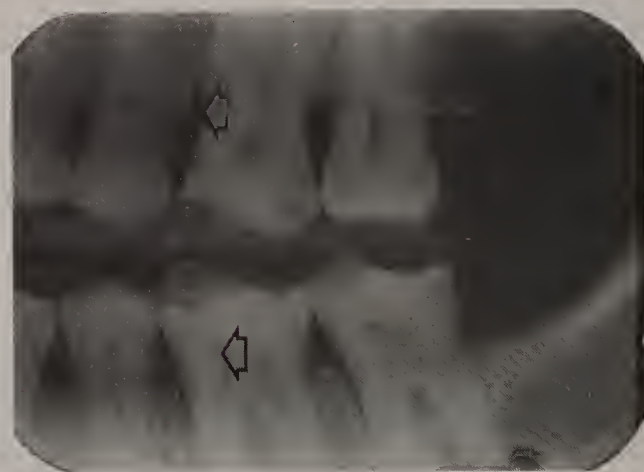
## REVIEW QUESTIONS

1. Which of the following could explain why your films are coming out too dark?
  - A. Unsafe safelight.
  - B. Light leaks in the darkroom.
  - C. Overexposure.
  - D. Overdevelopment.
  - E. All of the above.
2. A very light density radiograph may be caused by:
  - A. Too long an exposure time.
  - B. The leaded side of the film placed toward the tube.
  - C. Developing solution that is too warm.
  - D. Removing the film from the fixing bath too soon.
  - E. Leakage of white light in the darkroom.
3. Tree-like or lightning-like black streaks on a processed film are caused by:
  - A. Bending the film packet.
  - B. Static electricity.
  - C. Films overlapping in the processor.
  - D. Automatic processing roller marks.
  - E. Scratching the emulsion.
4. Radiographic films that are not properly fixed:
  1. May turn orange-brown.
  2. Emerge wet from the processor.
  3. Lose archival quality.
  4. Show an increase in contrast.
  - A. 1, 2, and 3 only.
  - B. 1, 2, and 4 only.
  - C. 2 and 4.
  - D. 1 and 3.
5. “Cone-cutting” or partial image on a radiograph is caused by:
  - A. Underexposure.
  - B. Improper exposure technique.
  - C. A damaged BID.
  - D. Improper coverage of film with BID.
  - E. Movement of BID.
6. A “herringbone,” “tire track,” or “geometric pattern” appears in an image if it is:
  - A. Not processed properly.
  - B. Exposed by too much radiation.
  - C. Exposed to insufficient radiation.
  - D. Placed in oral cavity backward.
  - E. Exposed to static electricity.

7. What is the function of the raised dot on the film?
  - A. It identifies the side of the film toward the line of occlusion.
  - B. It identifies the side of the film toward the tongue.
  - C. It identifies the side of the film toward the beam of radiation.
  - D. It identifies the maxillary or mandibular teeth, depending on how the film is placed in the mouth.
  - E. It identifies E+ type of film.
8. If an unexposed film is stripped from its film packet, exposed to light, and then processed, it will:
  - A. Be unaffected.
  - B. Turn white.
  - C. Turn black.
  - D. Be translucent.
  - E. Be streaked.
9. If an exposed film is stripped from its packet, processed properly in dark conditions, and then exposed to light, it will:
  - A. Be unaffected.
  - B. Turn white.
  - C. Turn black.
  - D. Be translucent.
  - E. Be streaked.
10. Which of the following will not produce fog?
  - A. Films left unprotected in the operatory where x-rays are taken.
  - B. Films stored for many years.
  - C. Light leaks in the dark room.
  - D. Films stored in lead containers.
  - E. Films stored near source of heat.
11. Which of the following will produce fog?
  - A. Light leaks in the darkroom.
  - B. Films stored for many years in an unsafe place.
  - C. Films left unprotected where x-rays are taken.
  - D. Unsafe safelight.
  - E. All of the above.
12. In the paralleling technique, what is the cause of foreshortening of the image?
  - A. "Too much" vertical angulation of BID.
  - B. "Too flat" a vertical angulation of BID.
  - C. Improper horizontal angulation of BID.
  - D. Movement of BID.
  - E. Placing film parallel to long axis of the teeth.
13. In the paralleling technique, what is the cause of elongation of the image?
  - A. "Too much" vertical angulation of BID.
  - B. "Too flat" a vertical angulation of BID.
  - C. Improper horizontal angulation of BID.
  - D. Movement of BID.
  - E. Placing film parallel to long axis of the teeth.
14. In the paralleling technique, what is the cause of overlapping of images?
  - A. "Too much" vertical angulation of BID.
  - B. "Too flat" a vertical angulation of BID.
  - C. Improper horizontal angulation of BID.
  - D. Movement of BID.
  - E. Placing film parallel to long axis of the teeth.
15. Black marks or streaks in the image of a processed film are caused by:
  - A. Bending of corners of film.
  - B. Incidental crimping of film.
  - C. Saliva contamination.
  - D. Static electricity.
  - E. All of the above.

## CASE-BASED QUESTIONS

### CASE 7.1



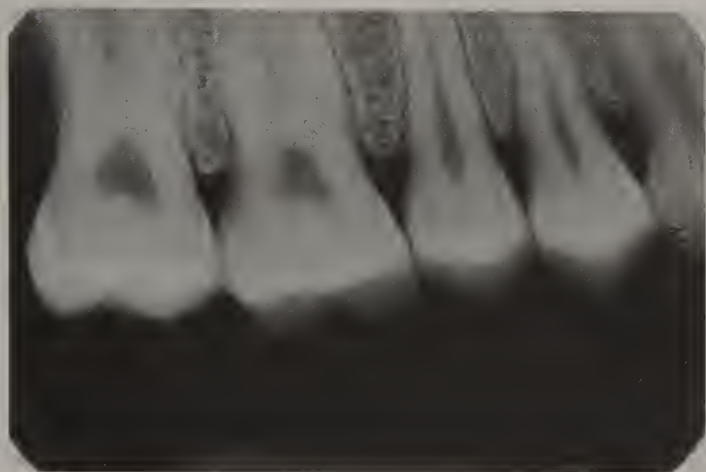
### QUESTION

1. Identify the error in this radiograph: (Disregard arrows)
  - A. Film contaminated by fixer before development.
  - B. The film packet was reversed.
  - C. Excessive exposure to thermal changes before development.
  - D. Improper use of Styrofoam biteblock.
  - E. Use of outdated film.



**CASE 7.2**

A 16-year-old girl with a very sensitive palate had this maxillary premolar radiograph taken. The radiograph has to be retaken.

**QUESTION**

1. What is the most likely cause of this common radiographic error?
  - A. The film was placed too far from the teeth.
  - B. The patient did not bite on the biteblock.
  - C. BID was misaligned with the film.
  - D. Film bending.
  - E. Film placed too far forward in the mouth.

**CASE 7.3**

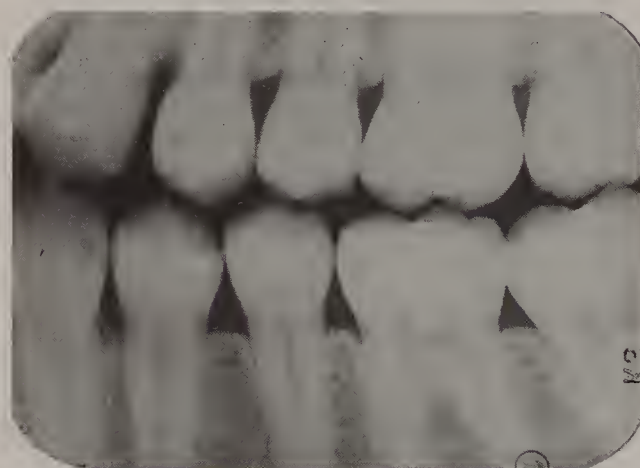
A dental hygiene student was required to take a premolar bitewing of her first patient. She knew it was very important to get the distal of the canines on this projection. This is the resultant bitewing radiograph.

**QUESTION**

1. What are the causes of this common error?
  1. Improper film placement.
  2. Improper exposure time.
  3. Improper processing.
  4. Improper horizontal angulation of BID.
  5. Malposed teeth.
  6. Improper vertical angulation of BID.
  - A. 1 and 6.
  - B. 2, 3, and 5.
  - C. 2, 5, and 6.
  - D. 1 and 4.
  - E. 3, 4, and 5.

**CASE 7.4**

A premolar bitewing is taken of an 18-year-old female in your office. Technically the radiograph is excellent, but it is undiagnostic. The bitewing radiograph is placed on an illuminator in a darkened room, and the light of the illuminator is turned down low. The radiograph is still not satisfactory for your diagnostic needs, and a retake is ordered. The processing solutions are fresh and have been stirred.

**QUESTION**

1. What is the best method to correct for this radiographic error?
  - A. Decrease kilovoltage.
  - B. Do not place film backward in the mouth.
  - C. Decrease developing time.
  - D. Increase exposure time.
  - E. Use a slower-speed film.

**CASE 7.5**

After taking a maxillary premolar radiograph using the Dentsply/Rinn instruments and manual processing, a fellow worker tells you that there were common errors on the radiograph, and you agree.

**QUESTION**

1. How would you correct for these errors?
  1. Leave film in the water bath longer after fixation.
  2. Leave film in the developer longer.
  3. Decrease vertical angulation.
  4. Place dot in the slot of the film-holder.
  5. Position the film more mesially.
  6. Position the film more distally.
  - A. 1, 3, and 6.
  - B. 1, 4, and 5.
  - C. 3, 4, and 5.
  - D. 2 and 4.
  - E. 1, 2, and 6.

**CASE 7.6**

A loyal patient of your dental clinic comes to you for her 1-year check up and this radiograph was taken.

**QUESTION**

1. What caused the common errors in this radiograph?
  1. Too flat a vertical angulation of the BID.
  2. Too steep a vertical angulation of the BID.
  3. Fixer artifact.
  4. Developer stain.
  5. Air on emulsion
  6. Rough handling of film.
  - A. 1 and 3.
  - B. 2 and 4.
  - C. 2 and 6.
  - D. 3 and 6.
  - E. 1 and 5.

**CASE 7.7**

Your office has purchased a new automatic processor. The first time you use it, two films come out stuck to each other, with the resultant film.

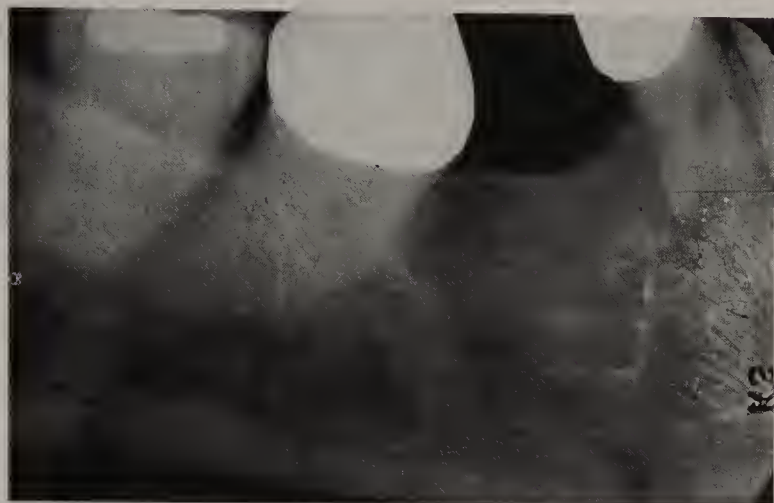
**QUESTION**

1. What causes this error?
  - A. Processing temperatures are too high.
  - B. The rollers are set too slow.
  - C. Films were inserted too fast in the same slot.
  - D. Films have bent edges.
  - E. Dryer not working properly.



**CASE 7.8**

This radiograph has a white fingerprint at the right-hand edge near the KS marking of the manufacturer.

**QUESTIONS**

1. What is the cause of this?
  - A. Oily finger.
  - B. Glove powder on finger.
  - C. Developer on finger.
  - D. Fixer on finger
  - E. Propy paste on finger
2. What speed is this film?
  - A. D.
  - B. E+.
  - C. F.
  - D. Agfa Light Speed.
  - E. Speed cannot be determined.

**CASE 7.9****QUESTIONS**

1. What is wrong with this radiograph?
  - A. Cone-cut using a round BID.
  - B. Cone-cut using a rectangular BID.
  - C. Two films stuck in the processor.
  - D. White light leak.
  - E. Improper film placement.
2. What type of film is this?
  - A. Speed D or Ultra-speed.
  - B. Speed E or EKTASPEED.
  - C. Speed E+ or EKTASPEED Plus.
  - D. Speed F or INSIGHT.
  - E. None of the above; it is the new Agfa film.

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# Quality Assurance and Legal Aspects

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *Define quality assurance.*
2. *State the two major categories of quality assurance.*
3. *State the three stages of dental radiology facilities.*
4. *Discuss the components of each stage.*
5. *List the two areas of routine testing of the x-ray system.*
6. *Describe the ways to test the x-ray machine.*
7. *Describe the ways to test the darkroom.*
8. *Identify the other areas of quality assurance with regard to radiographic procedures.*
9. *Identify the ownership of dental radiographs.*
10. *Explain the process of billing and loaning of radiographs.*
11. *Discuss the liability for failing to use radiographs and the impact of radiographs as evidence.*
12. *Demonstrate how to make a step-wedge using x-ray packet lead foil through the Workshop/Laboratory Exercises format.*
13. *Simulate and troubleshoot timer failure, darkroom fog, and developer solution failure using the Workshop/Laboratory Exercises format.*
14. *List all possible causes of low-density films using the Case-Based Problem-Solving format.*
15. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

aluminum filters  
coin test  
collimation test  
densitometer  
error log  
evidence

focal spot checker  
fog test  
half-value layer (HVL)  
liability  
mAs reciprocity test

measuring output  
ownership of radiographs  
pocket dosimeter  
quality administration  
quality assurance

quality control  
resolution  
retake log  
sensitometer  
spinning top

## INTRODUCTION

As applied to dental radiology, **quality assurance** refers to those steps that are taken to make sure that a dental office or radiologic facility will produce consistently high-quality radiographs with minimum cost in patient exposure. The common causes of unsatisfactory radiographs were discussed in Chapter 7. Many of these, such as improper angulation and film positioning, result primarily from human error. Others, such as exposure and processing problems, may result from equipment failure. The term **quality assurance** has come into general use to describe the administrative and technical efforts that are made to identify and correct equipment problems before they have become so severe as to affect the diagnostic quality of the radiographs being produced. For instance, if quality assurance principles concerning periodic changes of the developing solutions are not followed in a dental office, the films will begin to be of light or low density because the developer solution has weakened with time. The tendency in this situation is to increase the exposure time when taking radiographs to increase the darkness of the radiograph. This procedure unnecessarily increases the radiation dose to the patient. This one example shows why quality assurance principles are important.

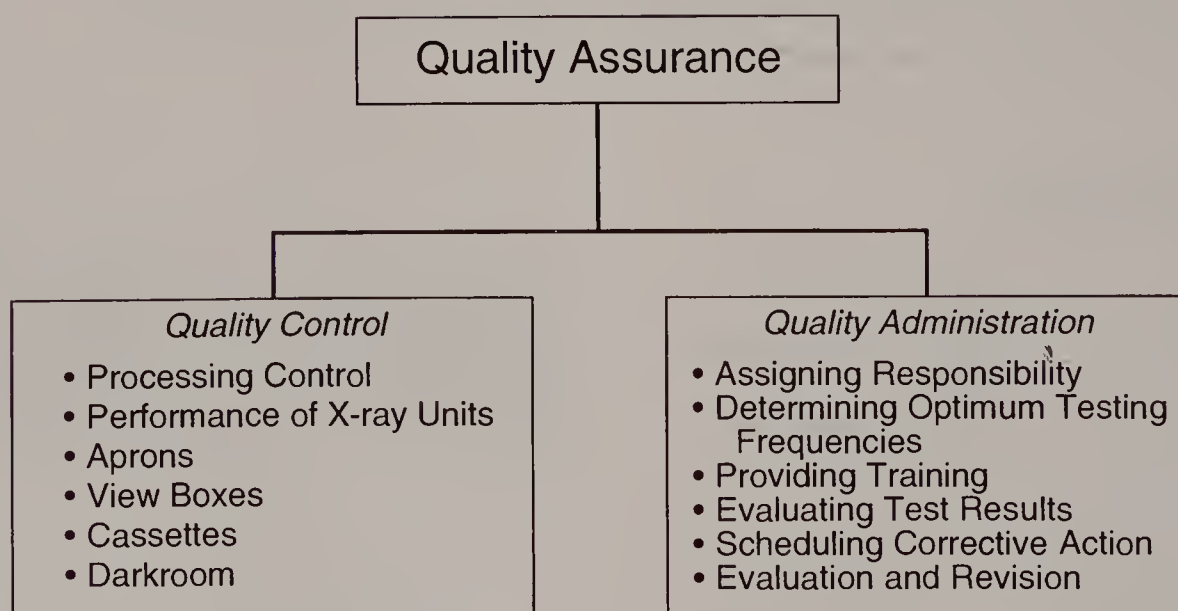
Quality assurance may be divided into two major cat-

egories: **quality administration** and **quality control** (Fig. 8-1). Quality administration refers to the management aspect. It includes those organizational steps taken to make sure that testing techniques are properly performed and that the results of tests are used to effectively maintain a consistently high level of image quality. Quality control can be summarized in two ways. First, it comprises the procedures used for the routine physical testing of the x-ray. Second, each testing procedure can be viewed as a method of demonstrating one or several basic principles of dental radiography, thus further clarifying our understanding of the subject.

## QUALITY ADMINISTRATION

### WHAT IS QUALITY ASSURANCE?

A dental radiology quality assurance program involves periodic evaluation of the x-ray equipment. This includes the entire chain of components from the x-ray machine, through processing, to the viewing of the radiographs. Currently, some states require dental offices to establish written guidelines. Each dental office should establish maintenance and monitoring procedures as summarized on the next page:



**Figure 8.1 Quality Assurance.** Quality assurance is divided into two major categories: quality administration and quality control.



**Summary of Quality Maintenance and Monitoring Procedures**

|                      |                                                                                                                                                                                                                               |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| General              | Use reference films<br>Fill out a retake log book<br>Check thyroid shields and lead aprons for cracks<br>Use exposure and technique charts<br>Use rectangular collimation<br>Use the fastest film speed and screens available |
| Daily <sup>a</sup>   | Clean the darkroom<br>Perform processor quality control                                                                                                                                                                       |
| Monthly <sup>a</sup> | Clean screens and cassettes<br>Check viewing conditions and viewboxes<br>Perform safelight test                                                                                                                               |
| Yearly <sup>a</sup>  | Check stability of tubehead/arm<br>Check kVp accuracy<br>Check mA accuracy<br>Check timer accuracy<br>Check half-value layer<br>Check focal spot degradation<br>Check collimator efficacy                                     |

<sup>a</sup>The frequency of these inspections will vary according to state regulations and manufacturers' directions.

**Point System Used to Stage A Dental Facility for Needed Quality Assurance Procedures**

|                                                                                                       | Points     |
|-------------------------------------------------------------------------------------------------------|------------|
| A. Evaluation of facility, film processing, and workload                                              |            |
| 1. Radiology facilities: equipment and techniques                                                     |            |
| Intraoral radiography only (periapical, bitewing, occlusal)                                           | 1          |
| Intraoral and panoramic radiography only                                                              | 3          |
| Intraoral, panoramic, and extraoral skull/cephalometric radiography                                   | 7          |
| 2. Film processing method                                                                             |            |
| Manual (time—temperature tanks)                                                                       | 1          |
| Automatic (processing machine)                                                                        | 3          |
| 3. Radiograph workload (average)                                                                      |            |
| Less than 100 films <sup>a</sup> per week                                                             | 1          |
| 100–300 films <sup>a</sup> per week                                                                   | 3          |
| More than 300 films <sup>a</sup> per week                                                             | 6          |
| B. Recommended monitoring level of quality assurance program (total point value of 1, 2, and 3 above) |            |
| Stage I dental practice                                                                               | <8         |
| Stage II dental practice                                                                              | 8–11       |
| Stage III dental practice                                                                             | 12 or more |

<sup>a</sup>One panoramic or cephalometric film equals 20 periapicals.

In 1983 at the request of the American Dental Association, the American Academy of Dental Radiology, now

the American Academy of Oral and Maxillofacial Radiology (AAOMR), made recommendations for quality assurance in dental radiology. The AAOMR recommendations were based on facilities' size and workload, as determined using the point system shown above. Once a facility has been staged, different levels of recommendations apply, as listed in the following outline:

**Staging Dental Practice****Stage I Dental Practice**

It is recommended that facilities qualifying as Stage I use the following program:

1. Reference films.
2. Retake log.
3. Daily visual monitoring of radiographs produced.
4. Monthly check of viewboxes.
5. Monthly darkroom assessment.
6. Annual test of the x-ray machine.

**Stage II Dental Practice**

It is recommended that facilities qualifying as Stage II use all Stage I recommendations plus the following:

1. Daily assessment of automatic processor/manual processing solutions.
2. Monthly check of cassettes and intensifying screens.

**Stage III Dental Practice**

It is recommended that facilities qualifying as Stage III use Stage II recommendations plus a sensitometer, a densitometer, and an increased level of effort in administration. A sensitometer is a simple device that exposes an x-ray film to a highly reproducible step pattern of light intensity. After development, the film is studied with a densitometer. A densitometer is a device for measuring density, the degree of darkening of exposed and processed x-ray or photographic film.

**SETTING UP A QUALITY ASSURANCE PROGRAM**

The personnel identified to perform the testing procedures can adapt them to the special requirements of a given facility. For example, a facility is staged to determine the level of quality assurance needed, and specific procedures are then put into place according to the time schedule previously described.

**Quality Control Kits**

The components of the kit will depend first on the stage of the facility, which identifies what quality control procedures are needed and at what intervals. Second, personnel at each facility will decide which procedures will be used in-house and which ones will be carried out by an outside expert. For the purpose of this chapter, we assume all procedures will be performed by personnel within the dental facility. A list of qualified outside experts is generally available from state agencies overseeing the use of ionizing radiation.

The quality control kit usually contains the following:

1. Pocket dosimeter and charger (ionization chamber).
2. kVp test device (kVp meter).
3. Aluminum filters in 0.1- and 0.5-mm thicknesses.
4. Brass spinning top or electronic timer meter.
5. Aluminum or lead foil step-wedge.
6. Lead numbers to mark films.
7. Sensitometer and densitometer (optional).
8. Processing solution thermometer.
9. Resolution test object (focal spot checker).
10. Piece of rare earth screen (collimator checker).

The use of the suggested quality control kit as listed above will be explained by the manufacturer of each product when it is purchased. These radiation testing products can be purchased through Keystone X-Ray (Neptune, NY), Picker X-Ray (Charlotte, NC), Radiation Measurements (Middleton, WI), and Nuclear Associates (Carle Place, NY).

## QUALITY CONTROL PROCEDURES IN DENTAL RADIOLOGY (USING QUALITY CONTROL KIT DEVICES)

The routine procedures used for assessing of the x-ray system can be divided into two major parts: the x-ray machine and the darkroom film processing.

### TESTING THE X-RAY MACHINE

The x-ray machine is tested for the following three factors relating to the x-ray beam: quantity, quality, and collimation. These three factors can be compared to gasoline at the gas pump. The quantity is measured in gallons, the quality is expressed in octane, and the collimation is the rubber collar that prevents the escape of fumes at the pump nozzle that are harmful if inhaled. Although the x-ray beam can be checked for quantity, quality, and collimation by office personnel, most states send inspectors at intervals to inspect and certify the dental x-ray equipment for the above parameters.

#### Checking the Quantity of the X-Ray Beam (Output)

The purpose of checking the quantity of an x-ray beam is to verify that the output of the x-ray machine has not changed since the last procedure. The quantity of x-ray photons, sometimes referred to as the exposure or output, is affected by the mA circuit (especially if an adjustable mA setting is present) and mainly by the exposure time. The kVp also affects the amount of radiation but is not tested here. To measure for quantity, one needs to set the x-ray machine at a standardized set of exposures (for ex-

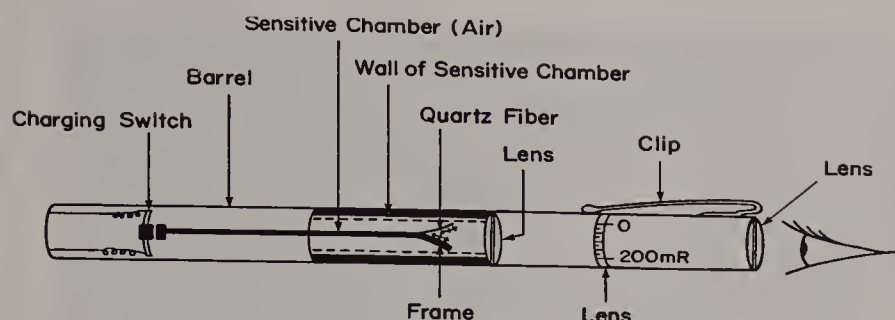
ample, 15 impulses [0.25 seconds], 7 or 10 mA, and 65 or 70 kVp) and measure the quantity of radiation being generated. A pocket dosimeter or another type of dosimeter (ionization chamber) is used to take this measurement (Fig. 8-2). If the first (baseline) reading has always been 180 milliroentgen (mR) and the current (second) measurement is the same, then no further testing of beam quantity is necessary. This could also be done by using an inexpensive aluminum or lead foil step-wedge (Fig. 8-3) and comparing a baseline step-wedge image (taken when machine was new or calibrated) with a current step-wedge image processed with fresh solutions. Each step in the image of the current step-wedge should be exactly the same shade of gray as in the baseline image (taken when machine was new or calibrated). This test is usually done yearly or as required by local regulations.

**Trouble With Quantity.** If the above dosimeter reading is different (usually less) or if the step-wedge image is different from the reference image (usually lower density), then the timer and the mA circuit are investigated.

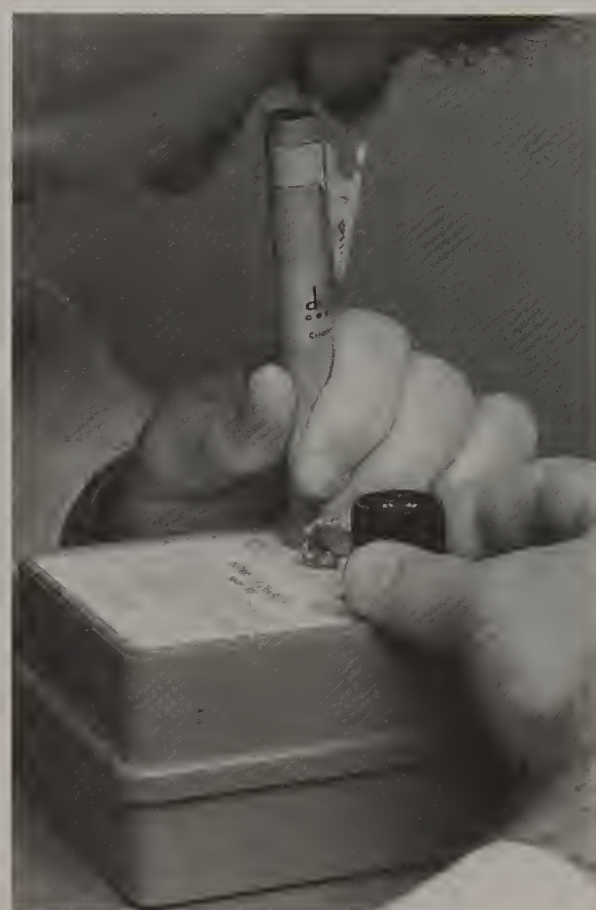
**Checking the Timer.** The purpose of checking the timer is to see if it is functioning accurately. This procedure can also be used to visibly demonstrate the principle that x-rays are generated in impulses in self-rectified dental x-ray machines. Remember, there are 60 impulses in 1 second; therefore, 1/10 second equals 6 impulses. A simple brass spinning top can be used. It is placed on top of an occlusal film or a panoramic film in a cassette (Fig. 8-4). The regular self-rectifying dental x-ray machine is set at, for example, 15 impulses or 0.25 seconds. The central ray is directed perpendicular to the spinning top, which is in motion. When the timer is activated, one small black dot will be seen on the processed film for each impulse. These dots should be counted and compared with the timer setting. Using this example, one should see 15 dots. Alternately, a more expensive electronic timer meter is recommended for convenience or to check the timer of a high-frequency, constant potential dental x-ray machine; an instant readout is obtained. Remember, constant potential x-ray machines do not put out impulses; the radiation is constant for the selected exposure time interval. If the timer is inaccurate, the x-ray machine will require servicing.

**Checking the mA Circuit.** The purpose of checking the mA circuit (filament circuit) is to ensure the proper functioning of the 10 and 15 mA settings on some machines. This procedure can also be used to visibly demonstrate the principle of mAs reciprocity. That is to say, "exposure or mAs equals mA times exposure time in seconds." If the x-ray machine has only one mA setting (usually 7 mA), the mA circuit can only be checked by a technician using an ammeter. If 10 and 15 mA circuits are available, the "mAs reciprocity" principle is used to test these two circuits. As long as the mAs factor is the same (when using 10 and 15 mA settings) and the output or quantity of radiation mea-





**Pocket Dosimeter (Fully Charged)**



**B**

**Figure 8.2 Pocket Dosimeter.** (A) Diagram of a pocket dosimeter for measuring radiation output. (B) A pocket dosimeter must be charged before use. (C) The pocket dosimeter being read after exposure.

sured with the pocket dosimeter remains the same for 10 and 15 mA settings, the mA circuits are said to be operating properly. The other variable in mAs reciprocity is the timer, which regulates exposure time and is checked first to ensure it is accurate. First, the operator sets the machine at 15 mA and 1 second or 60 impulses (i) ( $15 \text{ mA} \times$

$1 \text{ sec} = 15 \text{ mAs}$  or  $15 \text{ mA} \times 60 \text{ imp.} = 900 \text{ mAi}$ ; 15 mAs is the same as 900 mAi). For example, at 75 kVp, the operator then measures the output in mR with a pocket dosimeter or with a step-wedge film. The x-ray machine should then be set at 10 mA and 1.5 seconds or 90 impulses (15 mAs or 900 mAi) at 75 kVp, and the output is measured again with a dosimeter or step-wedge film. While the mA was varied, the mAs remained the same between the two exposures. Given that the timer is accurate, then the output in mR should be the same for the two exposures, if the two mA circuits are operating correctly. This only works because of the principle of mAs reciprocity. If the two readings are different, the x-ray machine will require servicing.

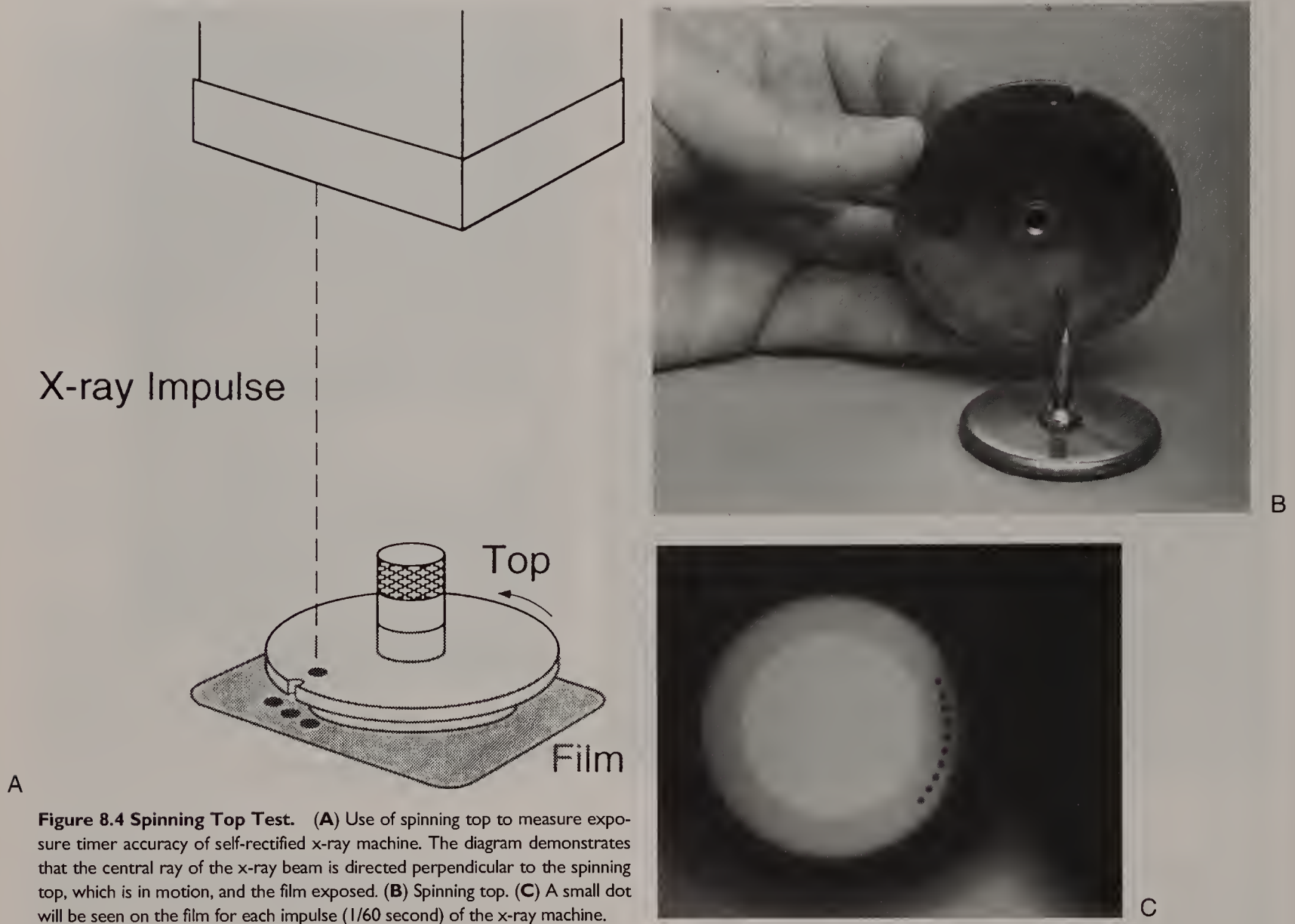
### Checking the Quality of the X-Ray Beam

The quality of the x-ray photons is a function of kVp that determines the wavelength or penetrating power of the x-ray beam. However, two other factors control quality of the x-ray beam. They are the accuracy of the kVp setting and the focal spot size. Focal spot size change will usually indicate focal spot degradation that decreases detail and sharpness in the image. X-ray beam quality should be checked yearly or as required by local regulations.

**Checking the Penetrating Power of the Beam.** The purpose of checking the penetrating power of the x-ray beam



**Figure 8.3 Checking Output.** If the steps in the baseline image (top) match the densities of the steps in today's image (bottom), then the radiation output reading (top) has not changed between the baseline and today's reading (bottom).



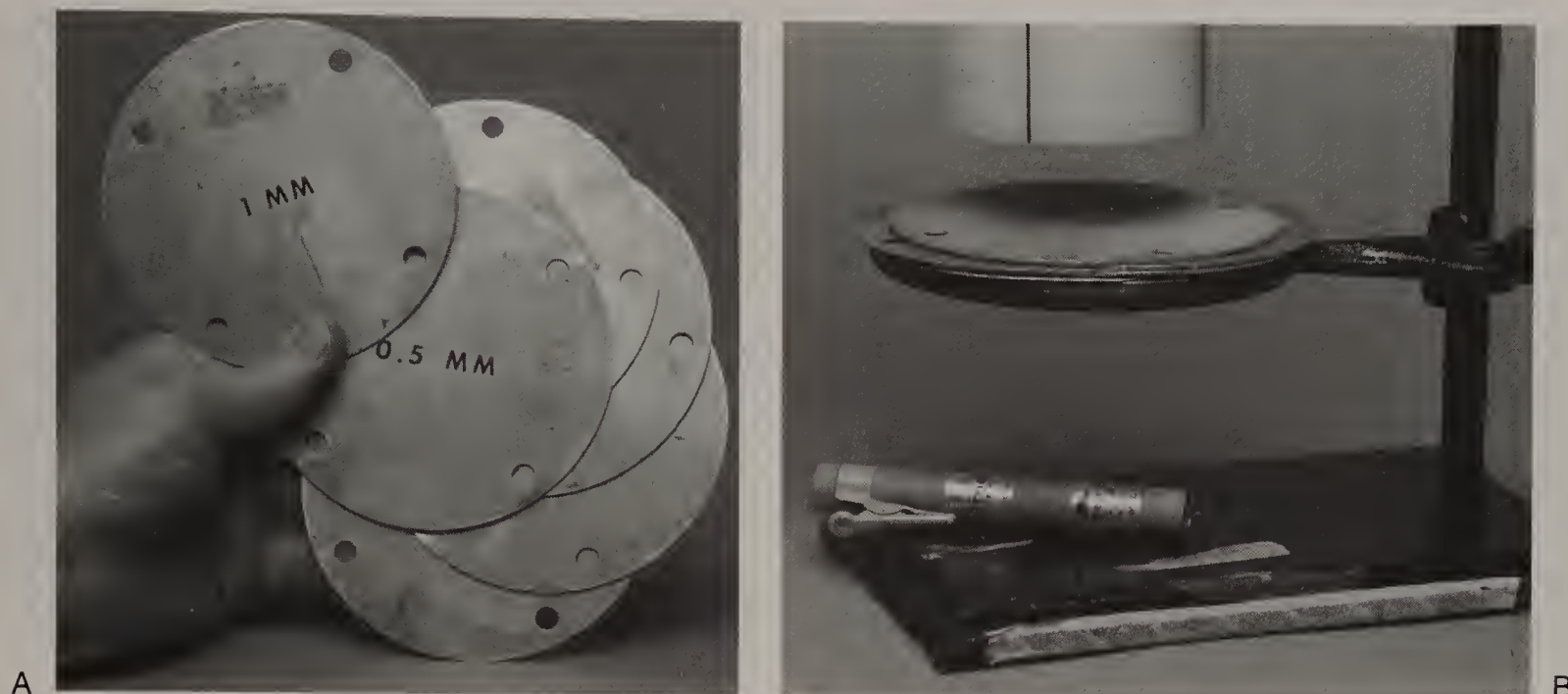
**Figure 8.4 Spinning Top Test.** (A) Use of spinning top to measure exposure timer accuracy of self-rectified x-ray machine. The diagram demonstrates that the central ray of the x-ray beam is directed perpendicular to the spinning top, which is in motion, and the film exposed. (B) Spinning top. (C) A small dot will be seen on the film for each impulse (1/60 second) of the x-ray machine.

is to ensure in a general way that the kVp circuit is functioning within safe limits. Also, this procedure can be used to visibly demonstrate the half-value layer (HVL) principle that states: “50% of the x-ray photons should penetrate through a standardized thickness of a given material (usually aluminum) depending on kVp.” The quality or penetrating power of the x-ray beam is measured by its half-value layer. The standard that is set by the federal government states that if the x-ray machine has a maximum of 69 or less kVp, 50% of the x-ray output must pass through at least 1.5 mm of aluminum; if the machine delivers 70 or more kVp, then 50% of the output must pass through at least 2.5 mm of aluminum. The HVL specification is indicated on the label of every x-ray machine. To test HVL, the operator simply places discs of 1.5 or 2.5 mm of aluminum above a pocket dosimeter (Fig. 8-5). The x-ray machine is set at its maximum kVp setting. The operator then compares output readings in mR with and without the aluminum discs in place. The position of the BID, dosimeter, or any machine settings

should not be varied. The readings should be checked to see if the penetrating power of the x-ray machine meets the federal standard. For example, if the machine is set at 65 kVp and the reading without the aluminum is 200 mR, then at least 100 mR of x-radiation must penetrate through the aluminum when 1.5 mm of aluminum is placed between the end of the BID and dosimeter. If the machine fails this test, it must be serviced.

**Checking the Accuracy of the kVp Setting.** The purpose of checking the kVp is to determine the accuracy of the kVp setting on the machine. This procedure of checking the kVp can also be used to visibly demonstrate kVp measurement. It should be remembered that kVp is responsible for wavelength and frequency. If the x-ray machine fails the HVL test, it will require servicing. This is because the quality of the radiation beam is below the federal standard, and the kVp or high-voltage circuit must be checked; kVp inaccuracy and a disturbance in the kVp circuit is the usual cause. A kVp meter (Fig. 8-6) is used to check the kVp or high-voltage circuit. Some machines





**Figure 8.5 Checking the Half-Value Layer of the Beam.** (A) Various thicknesses of aluminum sheets. (B) Aluminum sheets placed between the beam indicating device (BID) and pocket dosimeter.

have a single preset kVp indicated on the machine label; others have a kVp selector dial, and kVp settings can be adjusted or changed. The machine is set at any kVp setting or the maximum kVp setting and aimed at the target area on the kVp meter. The exposure time should be long enough for the kVp meter to obtain a reading (1 second or 60 impulses). The kVp meter measures the wavelength and frequency of the beam of radiation and gives an ac-

curate read-out of the actual kVp, regardless of the setting of the machine. The measured kVp should be the same as the machine setting. If it is different, the problem is identified as being associated with the machine itself, not the external power supply to the dental office.

**Checking the Focal Spot.** The purpose of checking the focal spot is to evaluate the surface area of the focal spot (target) that becomes pitted over time and enlarges. This procedure can also be used to visibly demonstrate differences in image quality relating to focal spot size. How can a focal spot enlarge over time? One can think of the following example to answer this question. When the focal spot is new, its surface is smooth like a newly paved roadway. Over time, the focal spot is bombarded by electrons at high speed that results in pitting on its surface, much like a roadway develops potholes. A newly paved road will hold only a thin film of water when wet; a roadway full of potholes will hold much more water. This is because the road's surface area has increased by virtue of all the potholes. So it is with the pits on the surface of the focal spot.

An enlarged focal spot decreases definition (sharpness) and increases magnification. Focal spot size can be checked with relative ease by using a test object containing a number of bar patterns to test the resolution of the image. A small focal spot size provides sharpness that is measured by resolution. **Resolution** is the ability to visibly separate (or resolve) images of small objects placed close together. It was previously stated that one should be able to distinctly see the periodontal ligament space, lamina dura, and individual trabeculae in the image. When an x-ray machine is new, the target is relatively small, and the



**Figure 8.6 Checking the Accuracy of the kVp Setting.** The kVp meter used to check kVp setting accuracy; the BID is aimed at the target area on top of the device. This kVp meter also measures exposure time to check the timer switch.

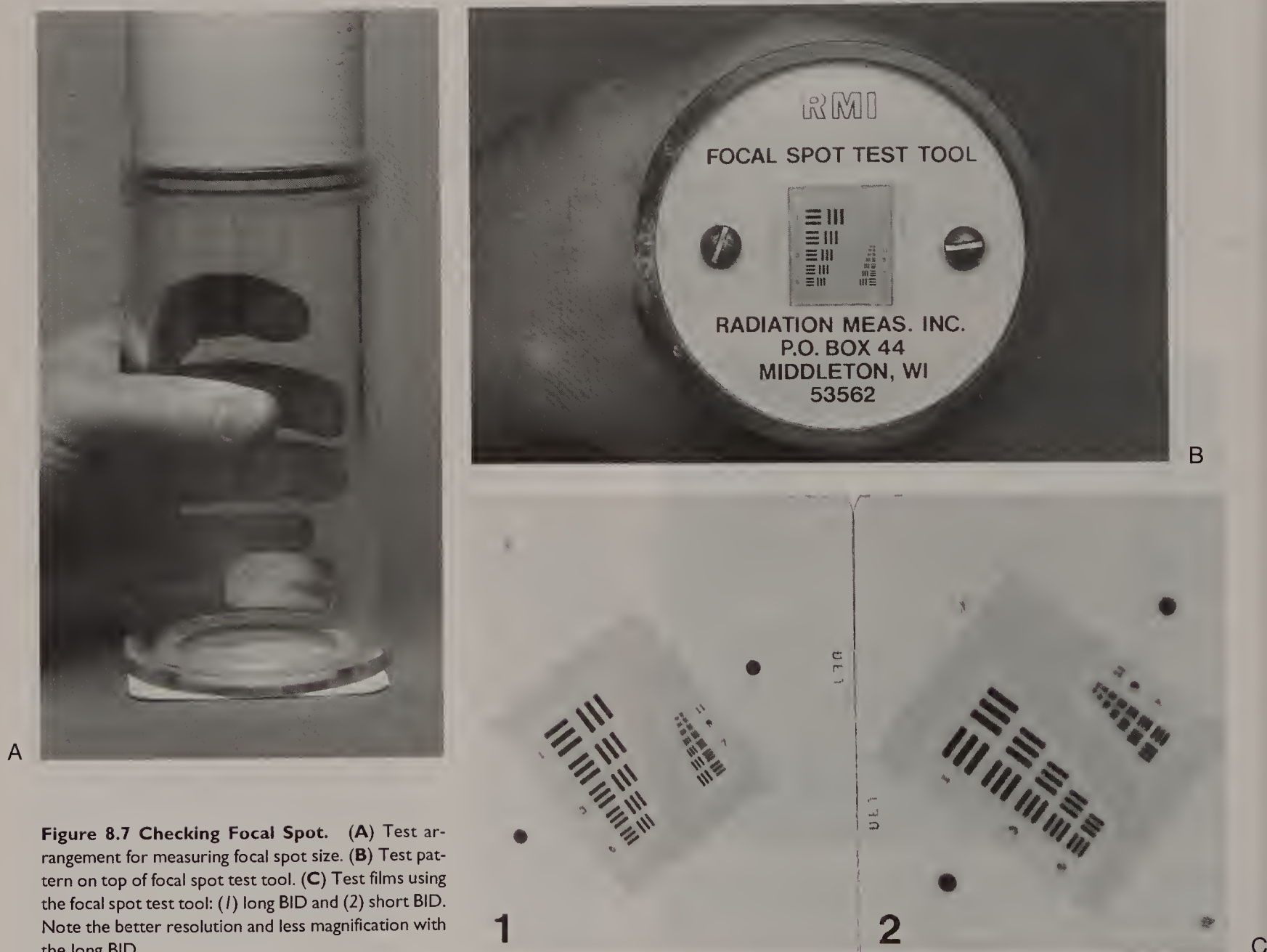
eye can separate or resolve about 11 or 12 line pairs per millimeter. However, as the focal spot degrades, the resolution gets down to seven or less line pairs per millimeter, and the image gets fuzzy or unsharp.

**Focal Spot Checker.** The focal spot checker is a relatively simple, inexpensive device consisting of a 6-inch plastic cylinder, which has paired slots in a wafer of lead that are closer and closer together on one end; the other end is open (Fig. 8-7). The slots allow radiation to pass through and expose a film. The open end of this cylinder is centered on a piece of occlusal film, and an exposure is made by placing the end of the BID against the closed end of the cylinder. Because the object (lead wafer test object) is so far (6 inches) from the film, any degradation of the focal spot will show up in the processed radiograph. Excellent resolution is 11 or 12 line pairs; poor resolution is 7 or less line pairs. When the resolution is poor, the focal

spot will need to be replaced by rebuilding the tubehead or purchasing a new machine.

### Checking the Collimation of the X-Ray Beam

The purpose of checking the collimator is to ensure proper collimation (reduction of size) of the beam. This procedure can also be used to visibly demonstrate the divergent nature of the x-ray beam. The collimator eliminates the peripheral (more divergent) portion of the x-ray beam. What is the function of the collimator? The following example can be used to answer this question. Some better-quality metal flashlights have a focusing ring near the lens of the light. When the ring is turned one way, the beam of light spreads out; when the ring is turned in the opposite way, the beam of light becomes smaller or more focused. According to federal standards, the beam of radiation must be collimated (focused) to 2.75 inches at the tip of the BID. Any machine failing to comply is considered illegal.

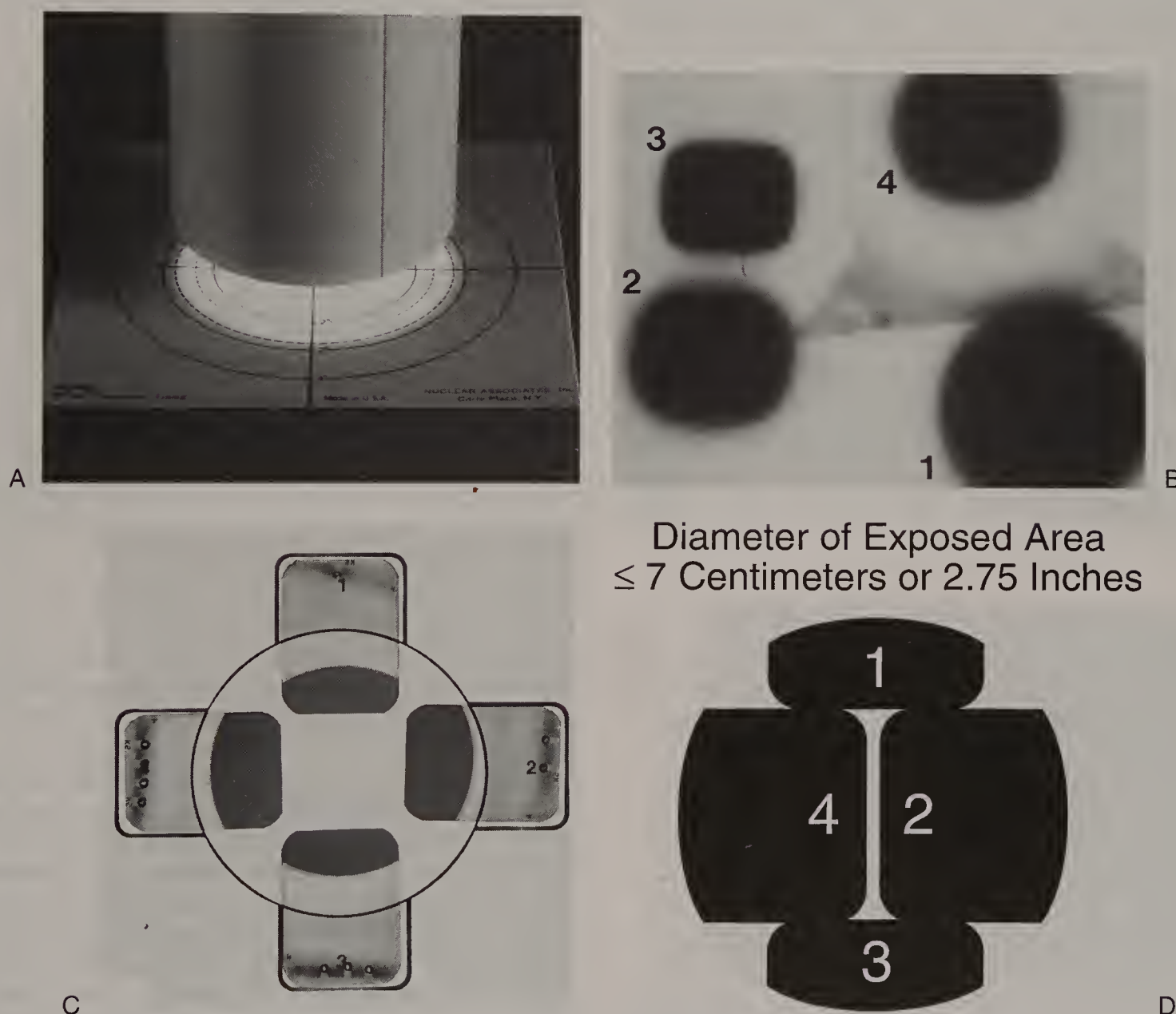


**Figure 8.7 Checking Focal Spot.** (A) Test arrangement for measuring focal spot size. (B) Test pattern on top of focal spot test tool. (C) Test films using the focal spot test tool: (1) long BID and (2) short BID. Note the better resolution and less magnification with the long BID.



**Collimation Test.** To test collimation, the operator simply places the end of the BID of the x-ray machine against a rare earth fluorescent screen or a loaded panoramic cassette (Fig. 8-8). The exposure time is set at about 1 or 2 seconds. The lights in the room are then turned off. The operator looks through the leaded barrier window to see if the fluorescence is limited to the diameter of the BID; he or she could also process the panoramic film to see if the exposed area of the film is limited to the diameter of the BID. Collimation may also be verified by radiographing four No. 2 dental films placed on a piece of paper in the form of a cross-shaped template. The BID and the location of each film should be traced on the paper, and the films should be identified with lead numbers or small puncture holes in

the film packet made with a pin, so each can be returned to its proper place after exposure. The BID is positioned to cover approximately half of each film packet and to touch the packets. The films are exposed using half the maximum anterior exposure, are processed, and are returned to the proper order (Fig. 8-8). If the exposed area is greater than 2.75 inches in diameter, the lead collimator opening is too large. In some machines, radiation escapes to expose more tissue than the diameter of the BID. Rarely, the beam of radiation will not be centered on the open end of the BID due to faulty positioning of the collimator. When this is the case, unavoidable cone-cuts will be the consistent, frustrating problem. Adjusting the collimator by tapping it into place or replacing the BID solves the problem.



**Figure 8.8 Verification of Collimation.** (A) Collimator checker using a rare earth fluorescent screen. (B) Four different collimators checked by exposing a single panoramic film: (1) short round BID; (2) long round BID; (3) long rectangular BID; (4) leakage of radiation from tubehead. (C) Arrangement of film for testing collimator. (D) The measured diameter of the exposed films should be 7.0 cm, or 2.75 inches, or less.

## TESTING THE DARKROOM

The darkroom is tested for the following two factors: fog and processing quality. Fog can be checked monthly, whereas processing quality is checked daily.

### Detecting Fog in the Darkroom

Fog consists of unwanted exposed silver halide crystals. This is usually caused by excessive light that degrades the diagnostic value of the image. A fog check procedure can be used to visibly demonstrate fog (unwanted density) on film and the sources of fog in the darkroom. What does fog look like in an image? The following example can be used to answer this question. On a clear day, one can see for miles; on a foggy day, one may be able to see only a few feet ahead. When driving, fog can obscure a road hazard and endanger lives. Fog from excessive white light in the darkroom obscures the image created by the x-rays. However, unlike a foggy day, film fog is sometimes difficult to see on the radiograph without a proper viewing procedure. First, the darkroom should be inspected for visible white light leaks. The operator can do this by standing in the darkroom with all the lights off, including the safelight(s), for several minutes until his or her eyes become accustomed to the dark. The operator can then look around doors, windows, and at the edges of ceiling tiles. Any white light leaks should be marked and blocked. Processing equipment, radios, or similar devices may be emitting unsafe and unwanted light; these should be checked for glowing lights. Second, the safelight should be tested for causing fog.

**Safelight Test.** One of the tests for a safelight is the coin test (Fig. 8-9). The operator takes the fastest intraoral film in the office (see Chapter 6) and exposes it to approximately 3 impulses of radiation, or 1/20 of a second, or he



**Figure 8.9 Safelight Coin Test.** Several preexposed films should be unwrapped and placed on the counter top under the safelight. A coin is placed on top of the unwrapped films. A film is processed every 2 minutes. The interval of time required for the outline of the coin to be seen is the time the safelight is safe.

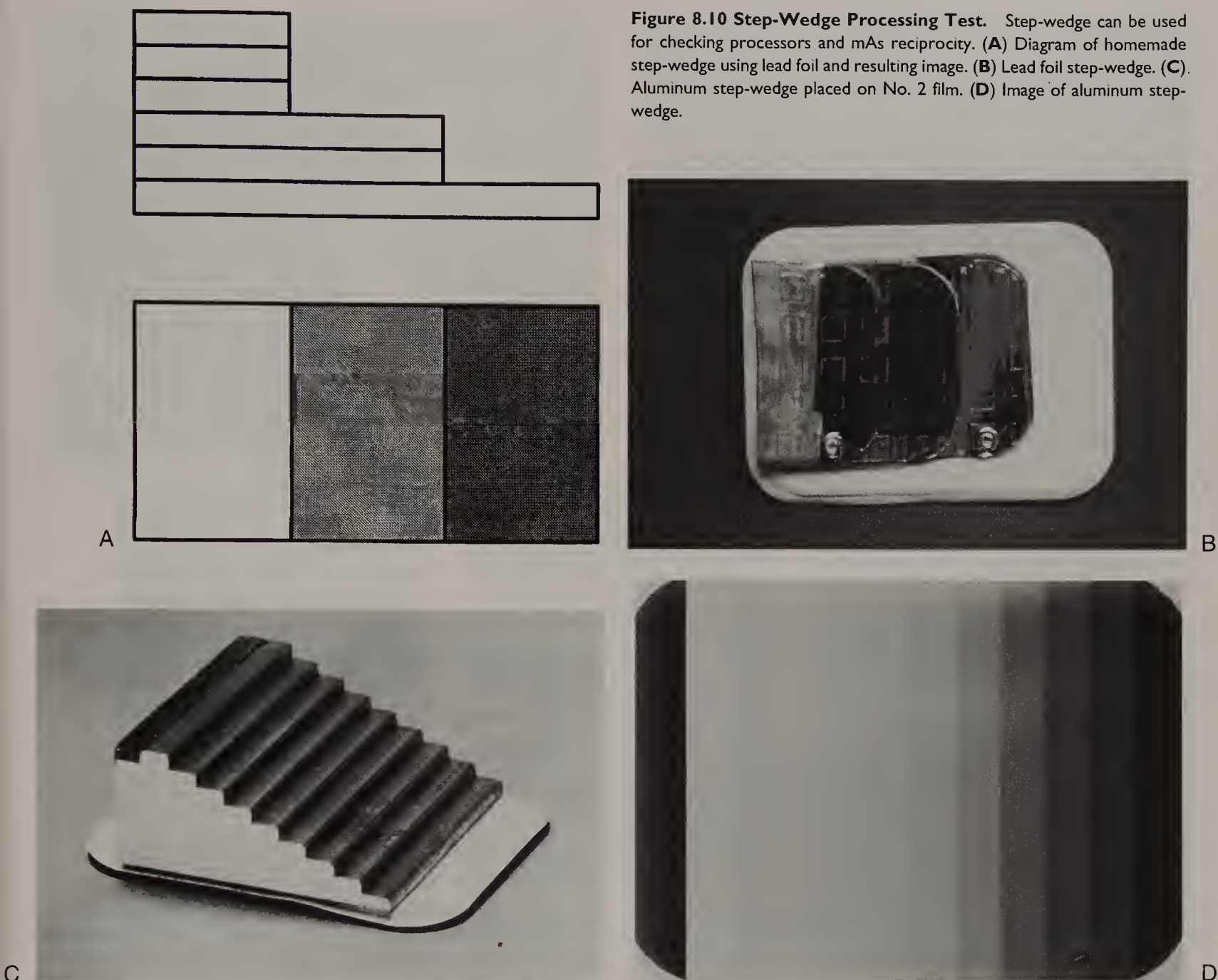
or she makes an image of a test object like a skull. An exposed radiograph is more sensitive to fog than an unexposed film. The operator then enters the darkroom. On the workbench near the safelight, he or she removes the film from the film packet and places a coin over the center of the film. The film and coin should be left beneath the safelight for varying periods up to about 15 minutes; each film is then processed. As soon as an outline of the coin becomes visible, this is the time beyond which the safelight will not be safe. Most safelights are safe for 5 to 8 minutes. If panoramic or cephalometric film is used in the office, it must be remembered that screen film is faster than intraoral (nonscreen) film and is more subject to fog. A box of panoramic or cephalometric film should be placed on the counter top under the safelight. A film is removed from the box, which is then closed. The panoramic film is then placed under the box. The operator should then pull out approximately 1 inch of film every minute. After 5 to 8 minutes, a line of darker density will be seen for every minute. The number of inches from the edge of the film to where the first line of density appears is the number of minutes the safelight is safe. Most GBX-2 safelight filters designed for use with panoramic or cephalometric films are safe for 5 to 8 minutes if the wattage of the bulb is 15 or 7.5, the distance from the counter top is no less than 4 feet, and the safelight filter is not cracked or damaged.

### Checking the Automatic X-Ray Processor/Manual Processing Solutions

The purpose of checking processing solutions is to determine the proper freshness of developer solution and developer temperature. This procedure can also be used to visibly demonstrate how a depleted and/or a cold developer solution can result in unacceptable low density (light) films. This is a very common problem. The automatic x-ray processor should be checked daily. The usual problem, more than all others, is depleted developer or cold developer solution due to failure of the heating element or its control. In manual processing, the developer solution becomes depleted with use or by contamination with fixer during wet reading, or there is a failure of the water temperature regulator valve.

**Step-Wedge Test.** The simplest way to check processing is to take a supply of reference films using a step-wedge under the best conditions of exposure and processing. An inexpensive aluminum step-wedge can be purchased or one can be made with varying thicknesses (1, 3, and 6 pieces) of lead foil from the film packets (Fig. 8-10). The properly exposed and processed reference films should be stored in the refrigerator. All reference films should be taken from the same box of film using the same x-ray machine and exposure factors. When the solutions are fresh, a baseline film is processed and placed on an illuminator for future daily comparisons. Every day, one of the pre-



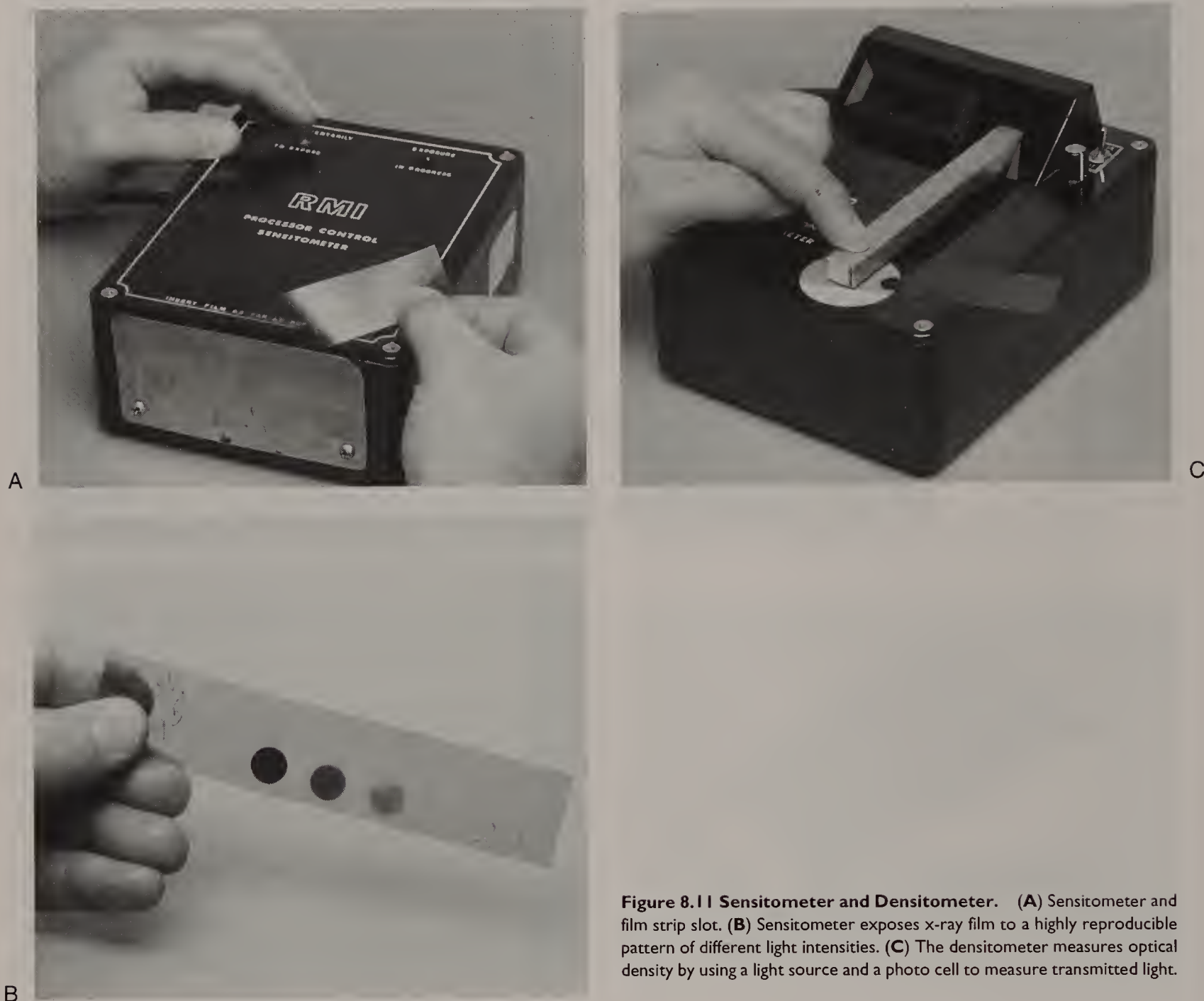


**Figure 8.10 Step-Wedge Processing Test.** Step-wedge can be used for checking processors and mAs reciprocity. (A) Diagram of homemade step-wedge using lead foil and resulting image. (B) Lead foil step-wedge. (C) Aluminum step-wedge placed on No. 2 film. (D) Image of aluminum step-wedge.

exposed reference films is run through the processor or processed manually to see if the density (overall darkness of the image) and contrast (number of visible steps of the wedge) remain constant compared with the baseline film on the illuminator. If not, the solutions should be replenished or changed. The developer solution should be replenished after 4 full-mouth surveys, 4 panoramic films, or 80 intraoral films. Four to six ounces of fresh developer should be added, depending on the size of the tanks or the manufacturer's instructions. Fixer can be replenished at the same time; however, only 2 to 3 ounces of fixer will be needed, as fixer lasts twice as long as developer. If the problem persists, the temperature of the developer solution should be checked. All manual processors require temperature-controlled solutions, usually at 70°F; in automatic processors, the developer should be approxi-

mately 83°F. Therefore, daily temperature readings of the developer solution should be taken in the morning after the solutions have had a chance to heat up (usually 30 minutes). In manual processing, this can be done with a special floating thermometer that is easily obtainable from a dental supply house or aquarium store. For automatic processors, an inexpensive thermometer for checking automobile air conditioning can be obtained.

**Sensitometer and Densitometer Test.** The purpose of checking processing with the sensitometer and densitometer is to more accurately identify and quantify fog, density changes, and contrast changes. This procedure can also be used to visibly demonstrate fog and the difference between density and contrast. The goal is to detect processing problems early, before the image is visibly affected. The sensitometer and densitometer (Fig. 8-11) are



**Figure 8.11 Sensitometer and Densitometer.** (A) Sensitometer and film strip slot. (B) Sensitometer exposes x-ray film to a highly reproducible pattern of different light intensities. (C) The densitometer measures optical density by using a light source and a photo cell to measure transmitted light.

devices recommended for use in Stage III dental practices. The sensitometer produces three standardized exposures on an x-ray film by light, and then the film is processed. The densitometer measures one of the exposed areas for density, the difference between the lightest and darkest exposures for contrast, and any other area of the film emulsion (not exposed by the sensitometer) for fog.

#### **SIMPLE QUALITY CONTROL DEVICE TO TEST THE X-RAY UNIT AND PROCESSING IN STAGES I AND II DENTAL PRACTICES**

A simple and inexpensive method of testing both the x-ray equipment and processing is to use a special reference film produced under ideal conditions of exposure and pro-

cessing. To achieve this, a dental quality control device called the Dental Radiographic Normalizing and Monitoring Device (Dental Radiographic Devices, Silver Spring, MD) (Fig. 8-12) or the Dental Quality Control Test Tool (Nuclear Associates) can be used to expose reference films that are stored in the refrigerator. The exposure instructions are on the devices. One of the preexposed reference films should be developed as a baseline. The density of this baseline film should be compared against one of the numbered film densities provided on a sliding strip in the quality control device (Fig. 8-12). The density step number (each step is numbered) on the sliding strip that matches the baseline reference film density will now be the standard density number for future comparison. The quality control device (Fig. 8-12) should be





**Figure 8.12 Dental Radiographic Normalizing and Monitoring Device.** (A) Front of device gives instructions for exposing the monitor film. (B) The back of the device contains a slot into which the processed film is inserted and matched with the density strip. (C) Baseline monitor film measures 11 on the density strip. (D) Several days later, a newly exposed monitor film does not match the baseline reading (11). (E) By moving the density strip, a new match is found. A problem exists if the density of the monitor film changes by two or more units.

used to periodically expose monitor films to check radiographic technique. If after processing the monitor film there is a difference of two or more steps between the current monitor film density and the baseline film standard density number previously determined, there is a problem with either the processing technique or the x-ray equipment/exposure technique. At this point, a previously exposed reference film should be taken from the refrigerator and developed. If the reference film is also off the same number of steps from the standard density number, the problem is in the processing technique. Such a problem is probably in the processing chemistry, because the refer-

ence films were previously exposed correctly using the quality control device. If the reference film matches within two steps, the problem is most likely with the x-ray equipment or the exposure technique. However, at this point more specific tests, as previously discussed, will be necessary to troubleshoot the x-ray equipment and/or the exposure technique for the specific problem.

### OTHER QUALITY CONTROL ITEMS

The office should maintain a common retake and error log so that personnel can be retrained with reference to

correcting actual problems. Lead aprons and thyroid shields, cassettes, and viewboxes should be inspected periodically to ensure proper functioning. Exposure charts should be posted in the vicinity of the x-ray control panel. Proper settings for varying anatomical areas, bitewings, and film speed (D, E+, and F) should be displayed, and stored film should be checked to see if the expiration date has passed. A quality assurance log should be maintained. This log should record the frequency of procedures, results, and any necessary corrective actions.

### Benefits of Quality Assurance

The implementation of a quality assurance program will lead to improved diagnostic performance and a substantial savings in cost. Every retake doubles the radiation exposure to the patient, is an additional expense, and wastes valuable time. Quality assurance procedures have been shown to lower the level of radiation to which the patient is exposed by decreasing the number of retakes and by preventing overexposure of the patient in an attempt to compensate for processing deficiencies (increasing exposure time due to low-density films). A well-run quality assurance program also serves to enhance our understanding of many of the concepts in quality image production. Remember the old adage, "What the mind does not know, the eye cannot see."

## DECISIONS FOR SELECTION OF RADIOGRAPHS

The ultimate decision to use or not to use diagnostic radiography must be based on the nature and extent of the diagnostic information required for providing high-quality oral health care and must be consistent with good and acceptable clinical practices. In making such professional decisions, the underlying assumption is that every exposure carries some potential risk, but that risk is difficult to quantify. The only basis for determining the need, the extent, or the frequency of radiographic examinations must be professional judgment. This process must include a determination of the minimum amount of radiation exposure that will produce the optimal diagnostic information with maximal radiographic quality. The need for or the extent of a radiographic examination should be based on selection criteria and clinical findings examination.

A Food and Drug Administration (FDA) panel has published a set of radiographic selection criteria—which include patient signs, symptoms, developmental stage, and historical features—that help with the decision about which radiographs to take and when to take them (U.S. Department of Health and Human Services, 1987) (Table 8-1).

"Routine radiographs," which are radiographs taken without considering the patient's clinical findings and history, should not be taken. An example of routine radio-

graphs would be to take a full-mouth series or a panoramic radiograph on every new patient without a prior clinical examination or bitewing radiographs on every patient at 6-month intervals. If it is believed that a radiograph would not change the diagnosis or treatment and such a radiograph is unlikely to provide additional helpful information, it should probably not be taken. Postoperative radiographs should be taken only when there is a clinical indication and not as verification for third-party payment plans. It is always prudent to select the type of radiographic examination that minimizes exposure, such as a panoramic radiograph rather than the full-mouth survey.

## LEGAL ASPECTS OF DENTAL RADIOGRAPHY OWNERSHIP OF THE X-RAYS

When the patient pays for a set of radiographs, he or she is paying for the dentist's ability to interpret the radiographs and arrive at a diagnostic opinion based on radiographic and clinical findings. X-rays are a part of the dentist's records and do not rightfully belong to the patient. One of the most important decisions by a higher court concerning ownership of radiographs was handed down by the Supreme Court of Michigan in 1935 (*McGarry v J. A. Mercier Co.*). In this case, the plaintiff was a physician who was employed by a construction company (J. A. Mercier Co.) to treat their employees in case of injury on the job. J. A. Mercier had refused to pay the physician for services rendered to one of their employees, because the physician failed to deliver to them radiographs taken of the employee during treatment. The court ruled in favor of the physician, stating that the radiographs were the legal property of the physician. The court further declared that, "It is a matter of common knowledge that x-ray negatives are practically meaningless to the ordinary layman. But the retention by the physician or surgeon constitutes an important part of the clinical record in the particular case, and in the aggregate these films may embody and preserve much of value incident to a physician's or surgeon's experience."

### CARE IN BILLING

If the radiographs are billed separately from the diagnosis and treatment, the dentist may run the risk that the court may render a verdict in favor of the patient, saying the patient owns the radiographs because they were paid for separately. Thus, radiographs should always be included in services rendered for diagnosis and treatment when billing a patient. A separate charge for radiographs should not be itemized.



**TABLE 8-1. Guidelines for Prescribing Dental Radiographs**

| <b>Patient Category</b>                                                                                 | <b>Child</b>                                                                                                                                                                                                 | <b>Adolescent</b>                                                                                                                                                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                         | Primary Dentition (eruption of first permanent tooth)                                                                                                                                                        | Transitional Dentition (following eruption of first permanent tooth)                                                                                                                                                                                                                           |
|                                                                                                         |                                                                                                                                                                                                              | Permanent Dentition (eruption of third molars)                                                                                                                                                                                                                                                 |
| <b>New patient<sup>a</sup></b><br>All new patients to assess dental diseases and growth and development | Posterior bitewing examination if proximal surfaces of primary teeth cannot be visualized or probed                                                                                                          | Individualized radiographic examination consisting of periapical/occlusal views and posterior bitewings or panoramic examination and posterior bitewings                                                                                                                                       |
|                                                                                                         |                                                                                                                                                                                                              | Individualized radiographic examination consisting of posterior bitewings and selected periapicals<br>A full-mouth intraoral radiographic examination is appropriate when the patient presents with clinical evidence of generalized dental disease or a history of extensive dental treatment |
| <b>Recall patient<sup>b</sup></b><br>Clinical caries or high-risk factors for caries <sup>b</sup>       | Posterior bitewing examination at 6-month intervals or until no carious lesions are evident                                                                                                                  | Posterior bitewing examination at 6-month intervals or until no carious lesions are evident                                                                                                                                                                                                    |
| No clinical caries and no high-risk factors for caries <sup>b</sup>                                     | Posterior bitewing examination at 12- to 24-month intervals if proximal surfaces of primary teeth cannot be visualized or probed                                                                             | Posterior bitewing examination at 18- to 36-month intervals<br>Individualized radiographic examination consisting of selected periapical and/or bitewing radiographs for areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically                    |
| Periodontal disease or a history of periodontal treatment                                               | Individualized radiographic examination consisting of selected periapical and/or bitewing radiographs for areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically | Individualized radiographic examination consisting of selected periapical and/or bitewing radiographs for areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically                                                                                   |
| Growth and development assessment                                                                       | Usually not indicated                                                                                                                                                                                        | Periapical or panoramic examination to assess developing third molars                                                                                                                                                                                                                          |

<sup>a</sup>Clinical situations for which radiographs may be indicated include:

- A. Positive Historical Findings**
1. Previous periodontal or endodontic therapy
  2. History of pain or trauma
  3. Familial history of dental anomalies
  4. Postoperative evaluation of healing
  5. Presence of implants

- B. Positive Clinical Signs/Symptoms**
1. Clinical evidence of periodontal disease
  2. Large or deep restorations
  3. Deep carious lesions
  4. Malposed or clinically impacted teeth
  5. Swelling
  6. Evidence of facial trauma
  7. Mobility of teeth
  8. Fistula or sinus tract infection
  9. Clinically suspected sinus disease
  10. Growth abnormalities
  11. Oral involvement in known or suspected systemic disease

12. Positive neurologic findings
13. Evidence of foreign objects
14. Pain and/or dysfunction
15. Facial asymmetry
16. Abutment teeth
17. Unexplained bleeding
18. Unexplained sensitivity of teeth
19. Unusual eruption, spacing
20. Unusual tooth morphology
21. Missing teeth with unknown history

<sup>b</sup>Patients at high risk for caries demonstrate any of the following:

1. High level of caries experience
2. History of recurrent caries
3. Poor quality existing restorations
4. Poor oral hygiene
5. Inadequate fluoride exposure
6. Prolonged nursing (bottle or breast)
7. Diet with high sucrose frequency
8. Poor family dental health
9. Developmental enamel defects
10. Developmental disability
11. Xerostomia
12. Genetic abnormality of teeth
13. Many multisurface restorations
14. Chemo/radiation therapy

The recommendations contained in this table were developed by an expert dental panel composed of representatives from the Academy of General Dentistry, American Academy of Dental Radiology, American Academy of Oral Medicine, American Academy of Pediatric Dentistry, American Academy of Periodontology, and the American Dental Association under the sponsorship of the Food and Drug Administration (FDA). The chart is being reproduced and distributed to the dental community by Eastman Kodak Company in cooperation with the FDA.

## PRECAUTIONS IN LOANING RADIOGRAPHS

The dentist should never give radiographs to the patient. The dentist should realize that the radiograph is the greatest protection against a possible claim of negligence. It can be devastating when a dentist is sued for malpractice and the radiographs that would have proved competency have been misplaced or lost.

There are times when the dentist may want to lend the patient's radiographs to another dentist for viewing. When lending radiographs to another dentist, the following suggestions are given:

1. The second dentist should request the radiographs in writing. This letter should be placed in the patient's folder.
2. The original radiographs should be duplicated, and the duplicate set sent by registered or certified mail.
3. Original radiographs should not be sent to the requesting dentist unless he or she promises, in writing, to send back original radiographs within 1 week after they have been duplicated. Although the patient may move to another city, the dentist is not legally bound to send the patient's radiographs to a second dentist. The radiographs are still the dentist's legal property. This is a case in which duplicate radiographs are useful. Alternately, an image of the radiographs can be sent by teleradiography, much like a fax.

the postal receipt should be kept in the patient's folder.

5. The patient's records should be kept for at least 6 years.

## LIABILITY ARISING OUT OF FAILURE TO USE RADIOGRAPHS

The dentist must use professional judgment as to whether taking radiographs should be used as a diagnostic procedure. Certainly, there are instances when radiographs are not necessary to render a diagnosis. However, one of the most common causes for malpractice suits is the failure of the dentist to use radiographs in the diagnosis or in the management of cases involving pain, swelling, or infection.

Consider this case cited by Sarner (1963). A dentist in Kentucky refused to expose a radiograph of a patient's jaws when there was a question as to whether he had left a root tip in the patient's jaws after an extraction. The patient visited a second dentist, who found a root tip in the jaws by means of a radiograph. It is now considered a dental principle that a dentist who fails to expose a radiograph in some circumstances is guilty of malpractice (*Agnew v City of Los Angeles*, 97 Cal. App. 557, 218 p. 2d 66, 1950). Therefore, if there is any doubt in the mind of the dentist if radiographs should be exposed, then radiographs should be taken. The use of radiographs has been so embedded in the minds of the public that a jury in

most cases will find the dentist negligent if there is a failure to use x-rays. There are times when a patient will refuse radiographs for some reason. In such a situation, Miller (1970) suggests two alternative procedures for the dentist to take to minimize a malpractice suit.

### If A Patient Refuses A Radiograph

1. The refusal should be recorded in the patient's record, and the patient should sign it.
2. The dentist should offer to take the radiographs at no charge for his or her records.

Either of these procedures would lessen the possibility of a malpractice suit against the dentist for failure to use radiographs. In either instance, the dentist should strongly consider not treating the patient if the patient refuses to have the radiographs taken.

## RADIOGRAPHS AS EVIDENCE

In a court of law, one must remember that the best evidence is that which is factual. Radiographs are **factual evidence**. Of course, the radiographs must be of good diagnostic quality, as they reflect the competency of the dentist. Radiographs of inferior quality should be retaken for two reasons (Miller, 1970):

### Reasons for Retakes

1. These radiographs will be of no use as evidence.
2. They will reflect on the dentist's ability as a practitioner and could cause irreparable harm to the dentist's reputation.

If a dentist retains radiographs of inferior quality in patients' records, they will only prove incompetency if produced as evidence in court. There is no substitute for good radiographs.

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 8.1. CHECKING FOR TIMER FAILURE

#### Materials and Equipment Needed

1. Step-wedge.
2. X-ray machine and processor.
3. Two No. 2 intraoral films.

#### Instructions

**Step 1:** Make a step-wedge from film packet lead foil as follows:

1. Cut out a piece of cardboard exactly the size and shape of a No. 2 intraoral film.



2. Using clear tape, affix one thickness of lead foil 3 mm from the edge of the cardboard.
3. Follow this with three thicknesses 6 mm from the edge, six thicknesses 9 mm from the edge, and so on.
4. Trim the extra lead foil at the other end of the cardboard template.

**Step 2:** Expose reference film using a standardized exposure such as 65 or 70 kVp, 7 or 10 mA, and 20 impulses (1/3 second). (Place the step-wedge on top of the plain side of the film.)

**Step 3:** Simulate timer failure by taking a shorter exposure of 10 impulses (1/6 second).

**Step 4:** Process reference film and compare it with the test film.

## EXERCISE 8.2. CHECKING FOR DARKROOM FOG

### Materials and Equipment Needed

1. Step-wedge.
2. Darkroom and safelight.
3. Coin.
4. One No. 2 intraoral film.

### Instructions

**Step 1:** Expose a reference film as in Step 2 of the previous exercise.

**Step 2:** Enter the darkroom.

**Step 3:** Unwrap the preexposed reference film and place it on the counter top beneath the safelight.

**Step 4:** Place a coin on top of the film.

**Step 5:** Leave this in place for 15 minutes; process the film.

**Step 6:** Observe the fogged areas where the coin could not protect the film from fog.

## EXERCISE 8.3. CHECKING FOR DEVELOPER SOLUTION FAILURE

### Materials and Equipment Needed

1. Two No. 2 intraoral films.
2. Processor(s) or manual processing facility.

### Instructions

**Step 1:** Expose two reference films as in Step 2 of the first exercise.

**Step 2:** Process one of the preexposed reference films.

**Step 3:** After the remainder of the class has completed Step 1, now simulate developer solution depletion by diluting it with water (6 to 12 ounces).

**Step 4:** Process the second reference film.

**Step 5:** Observe the light or low-density image caused by the depleted developer.

**Note:** A similar effect can be observed by placing ice cubes in the developer solution. The cold and diluted solution produces a light film.

## CASE-BASED PROBLEM-SOLVING

1. You have intraoral radiographs that consistently turn out lighter than expected. You realize there is a problem. List as many causes for a light or low-density image that you can. Any kind of exposure, processing, or other problem you can think of is fair game! Good luck!
2. Design a quality assurance program for a facility that takes less than 100 periapical films per week. The facility uses only intraoral film and manual processing.

## REVIEW QUESTIONS

1. In evaluating the timer of a self-rectified x-ray machine, 25 separate densities (dots) were produced by use of a spinning top; the exposure time was set for 0.5 seconds. Does the timer meet the evaluation criteria?
  - A. Yes, the reading is 5% off the set time.
  - B. No, the reading is 5 dots off the set time.
  - C. Yes, the reading is the same as the set time.
  - D. No, the reading is 10 dots off the set time.
2. Which x-ray field diameter is acceptable if the source-to-skin distance is 16 inches or more?
  - A. 2.60 inches.
  - B. 2.75 inches.
  - C. 2.50 inches.
  - D. None of the above.
  - E. All of the above.
3. Which parameters should be inspected if a film monitoring strip differs by more than two steps from the standard?
  1. Temperature regulating system.
  2. Rate of replenishment.
  3. Exposure conditions.
  4. Integrity of solutions.
  - A. 1, 2, and 3 only.
  - B. 2 and 4 only.
  - C. 2, 3, and 4 only.
  - D. 1, 2, 3, and 4.

4. Which of the following is not considered an advantage of keeping a retake log?
  - A. Provides clues for the source of most retakes.
  - B. Serves as a guide for continuing education topics.
  - C. Provides some measure of the operator's competence.
  - D. Reduces the amount of paperwork.
5. The half-value layer test is used to evaluate which of the following?
  - A. Filtration.
  - B. Collimation.
  - C. kVp.
  - D. mA.
  - E. Beam alignment.
6. When using a radiographic normalizing and monitoring device, there is a difference of two or more steps noted for a monitoring film when compared with a baseline density number determined previously under ideal conditions. What should you do?
  1. Take a preexisting reference film from the refrigerator and develop it.
  2. Take a reference film from the refrigerator, expose it with standard exposure factors, and develop it.
  3. If the reference film matches within two steps, the problem is most likely a processing problem.
  4. If the reference film matches within two steps, the problem is most likely in the x-ray equipment or technique.
  5. If the reference film does not match within two steps, the problem is a processing problem.
  - A. 1 and 3.
  - B. 1 and 5.
  - C. 2 and 5.
  - D. 2 and 4.
  - E. 2 and 3.
7. Which of the following are true statements regarding the legal aspects of dental radiography?
  1. The patient's radiographs rightfully belong to the patient.
  2. The patient's radiographs are legal property of the dentist.
  3. The dentist should not give original radiographs to the patient.
  4. Radiographs should always be taken before and after each tooth extraction.
5. One of the most common causes of dental malpractice suits is the use of radiographs by the dentist when they are not necessary to render a diagnosis.
  - A. 2, 4, and 5.
  - B. 1 and 5.
  - C. 2, 3, and 5.
  - D. 1 and 4.
  - E. 2 and 3.
8. A patient is moving to another city. He stops by your dental office before leaving and asks you for the radiographs that you took previously. What is the correct method to handle this situation?
  - A. Give the radiographs to the patient. After all, they legally belong to the patient because the patient paid for them.
  - B. Give the radiographs to the patient and tell the patient to give them to his dentist in the other city.
  - C. Tell the patient he cannot have the radiographs because the radiographs legally belong to the dentist.
  - D. Tell the patient that after he has found a new dentist in the other city, the new dentist should send a written request for the radiographs.
9. To perform the coin test for darkroom fog:
  - A. Use the slowest film available.
  - B. Use an exposed film.
  - C. Turn off the safelight.
  - D. Use a panoramic or cephalometric film if only intraoral radiographs are taken.
10. Before performing the coin test for safelight fog, you should:
  - A. Eliminate all sources of extraneous white light.
  - B. Be certain all extraneous sources of white light are "on."
  - C. Avoid checking safelight bulb wattage, filter, and distance until later.
  - D. B and C only.
11. When two mA settings, such as 10 and 15 mA, are available on a machine, these circuits are checked by:
  - A. mAs reciprocity.
  - B. mA meter (ammeter).
  - C. Multiplying the output at 10 mA by 1.5.
  - D. A professional technician, as this cannot be done in the office.



12. A test tool that reads in line pairs per millimeter is used:
  - A. To detect fog.
  - B. To check kVp.
  - C. To check mA.
  - D. To check collimation accuracy.
  - E. None of the above.
13. A pocket dosimeter is used to:
  - A. Check the timer.
  - B. Measure radiation output.
  - C. Determine proper exposure time.
  - D. Check film contrast.
  - E. Quantify fog.
14. A spinning top is used to:
  - A. Check the timer.
  - B. Measure radiation output.
  - C. Determine proper exposure time.
  - D. Check film contrast.
  - E. Quantify fog.
15. A densitometer is used:
  - A. In conjunction with a sensitometer to check processing quality.
  - B. To produce three small, round spots of varying densities.
  - C. To emit a small amount of x-radiation to produce a measured density on a film.
  - D. To verify collimation of the x-ray machine.
  - E. To measure the specific gravity of a solution.

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# Panoramic and Special Imaging Techniques

- CHAPTER 9 Concepts of Panoramic Radiography
- CHAPTER 10 Troubleshooting Panoramic Techniques
- CHAPTER 11 Special Imaging Techniques





# Concepts of Panoramic Radiography

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *Relate the basic principles of panoramic image formation.*
2. *Explain the concept of image layer analysis.*
3. *List the seven concepts of panoramic image formation.*
4. *Relate the importance of the seven concepts in recognizing a technically good panoramic image.*
5. *Identify technique-related panoramic anatomical landmarks.*
6. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                                     |                                     |                                  |                              |
|-------------------------------------|-------------------------------------|----------------------------------|------------------------------|
| air spaces                          | double images                       | horizontal plane                 | sharply depicted plane       |
| anatomical structures               | double real images                  | image layer analysis             | single images                |
| center of rotation                  | effective focal spot                | intraoral source                 | single real images           |
| central plane                       | effective projection radius         | layer formation                  | soft tissue                  |
| continuous radiographic image       | flattened image of a curved surface | panoramic film speed             | tangential                   |
| continuously moving rotation center | focal trough                        | real images                      | vertical projection          |
| defined curved path                 | functional focus                    | rotational panoramic radiography | x-ray beam movement patterns |
|                                     | ghost images                        |                                  |                              |

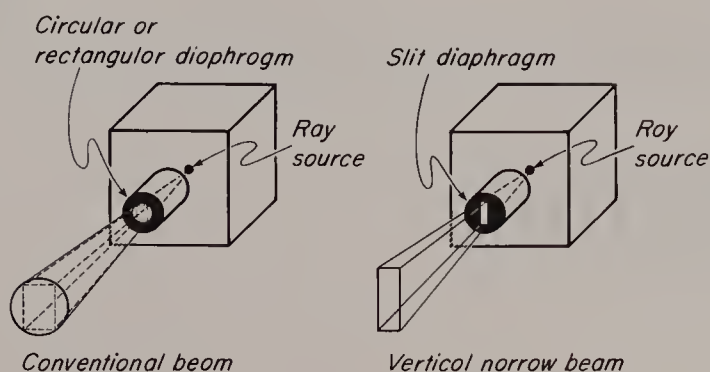
## INTRODUCTION

A basic understanding of the principles underlying rotational panoramic radiography is necessary for the optimum use of the technique. This chapter examines the process by which the image is formed and the characteristics of the panoramic radiograph that result from this unique process of image formation. The use of the bitewing and periapical radiographs as a diagnostic aid is a major component of this book. However, periapical and bitewing radiographs are somewhat limited in their overall coverage of the mandibulofacial structures. By using panoramic radiography, many of these limitations can be overcome. In panoramic radiology, the radiation dose to the patient is approximately 10 times less than the full-mouth survey using the long, round BID and E+ film; it is 4 times less than 4 bitewings using the long, round BID and E+ film. The

panoramic dose is about equal to that of four bitewings using the long, rectangular BID and E+ film. There are many advantages of panoramic radiography.

Some of the advantages of panoramic radiology are as follows:

1. Increased overall coverage of the dental arches and associated structures.
2. Production of relatively undistorted anatomical images.
3. Significantly reduced radiation dose to the patient.
4. Simplicity and rapidity of the procedure.
5. Reduced superimposition of anatomical structures.
6. Minimal infection control procedures.
7. Possibility of detecting caries, periodontal disease, and pulp-associated periapical changes earlier.



**Figure 9.1 Narrow Beam in Panoramic Radiography.** A narrow vertical beam is used in rotational panoramic radiography.

## PRINCIPLES OF PANORAMIC RADIOGRAPHY

Rotational panoramic radiography is accomplished by rotating a narrow beam of radiation in the horizontal plane around an invisible rotational axis that is positioned intraorally. In rotational panoramic radiography, a vertical narrow x-ray beam is used compared with the much larger circular or rectangular x-ray beams used in conventional intraoral radiography (Fig. 9-1).

### PROJECTION IN THE VERTICAL PLANE

The vertical dimension of the panoramic image is unaffected by the horizontal rotation of the beam, because the vertical dimension of the panoramic image is the result of a conventional radiographic projection. Therefore, the focal spot in the x-ray tube anode serves as the functional focal spot for the vertical aspect or dimension of the projection (Fig. 9-2). There is a slight negative angulation of the beam so the x-ray beam will pass beneath the occipital portion (base) of skull. This angle is  $-4$  to  $-7^\circ$ .

### PROJECTION IN THE HORIZONTAL PLANE

The horizontal dimension of the panoramic image is affected by the horizontal rotation of the beam. Therefore, in the horizontal dimension, the x-rays appear to diverge from an intraoral source although they really originate outside the patient at the focal spot of the x-ray tube. This apparent intraoral x-ray source is called the center of rotation and is, therefore, called the “effective focal spot of the projection” for the horizontal dimension of the x-ray image (Fig. 9-3).

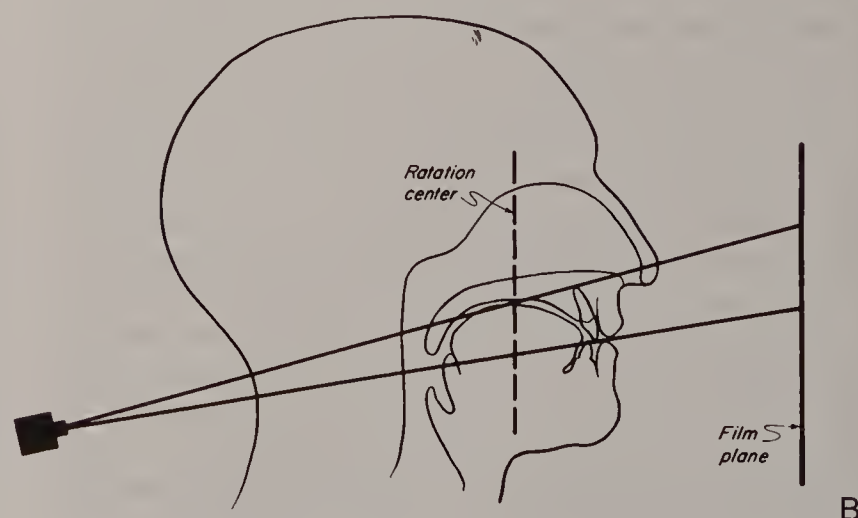
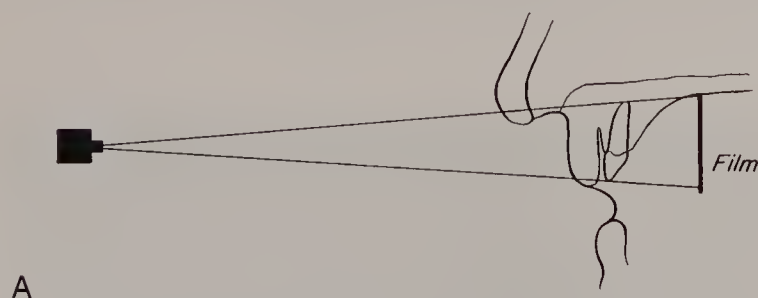
### PRINCIPLE OF IMAGE LAYER FORMATION

If this rotating narrow beam were used to project the object onto a stationary film, the magnification in the horizontal dimension would always be greater than that in the vertical dimension (Fig. 9-3). The discrepancy in horizontal versus vertical magnification can be eliminated by using a moving film to equalize the magnification in the horizontal dimension (Fig. 9-4). The film moves in a direction opposite to the horizontal rotation of the beam.

In some cases, the movement of the film is accomplished by placing the film on a circular drum, which moves by rotating on its own axis. In other cases, the film is placed in a moving flat cassette. By adjusting the speed of the film in respect to projection of the beam, it is possible to reduce the horizontal magnification to match the vertical magnification. The vertical and horizontal dimensions match only when the object lies within a particular plane called the central plane or sharply depicted plane of the image layer. Objects outside this sharply depicted plane but still within the image layer will always be somewhat distorted in shape and will appear unsharp or fuzzy.

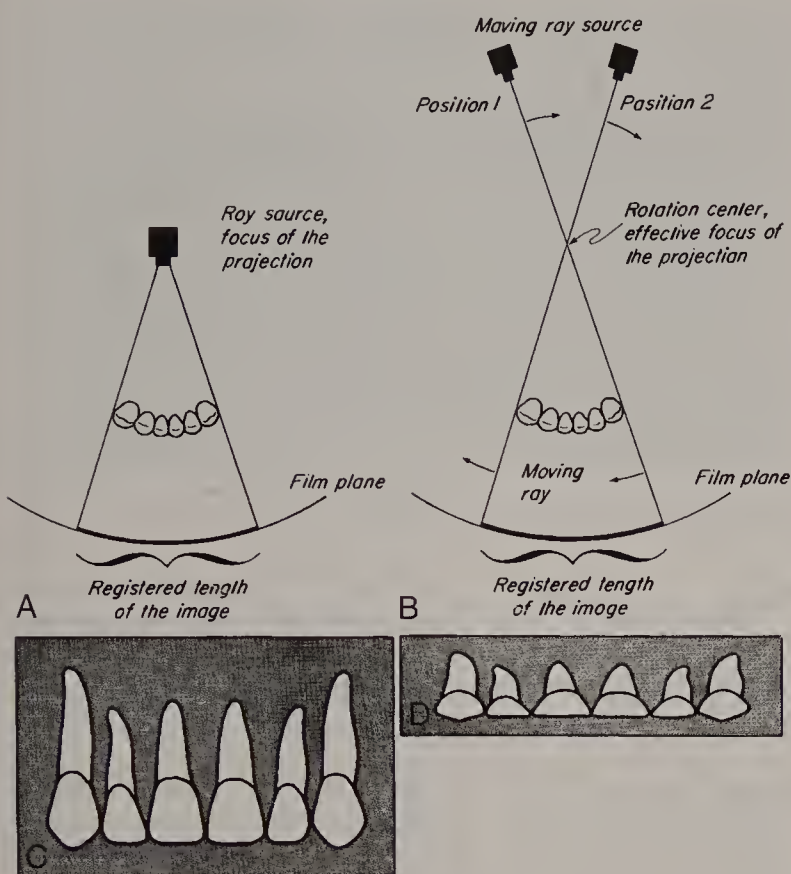
#### Image Layer or Focal Trough

The image layer, often referred to as the focal trough, is a zone in an object defined as containing those object points depicted with sufficient detail to be distinguished.



**Figure 9.2 Principle of Projection in the Vertical Dimension.** (A) The conventional projection of an intraoral radiograph is a central projection. In a central projection, the divergent rays have a common origin at a focal spot. The film is perpendicular to the central ray. (B) The projection geometry in the vertical plane in rotational panoramic radiography.





**Figure 9.3 Stationary Source Compared with Moving Source.** (A) The true central projection that results from the use of an intraoral x-ray source. (B) A rotating ray will create a true central projection in the rotation plane. The effective focus is at the rotation center. (C) With an intraoral x-ray source, the ratio between the focus-to-film and focus-to-object distances is such that the magnification will be uniformly marked in all planes. (D) Compare the magnification when a rotating beam projects the object onto a stationary film. It will be equal in the rotation plane but different in the vertical plane.

#### Width of the Image Layer

The width of the image layer is dependent on two important factors:

1. The image layer width is directly related to the distance from the center of rotation to the central plane of the image, which is called the "effective projection radius." The width of the layer depends on the length of the radius (Fig. 9-5). The longer the radius, the thicker the layer.
2. The layer thickness is inversely proportional to the width of the long, narrow slit beam. The narrower the x-ray beam, the wider the image layer (Fig. 9-1).

#### Position of Image Layer or Focal Trough

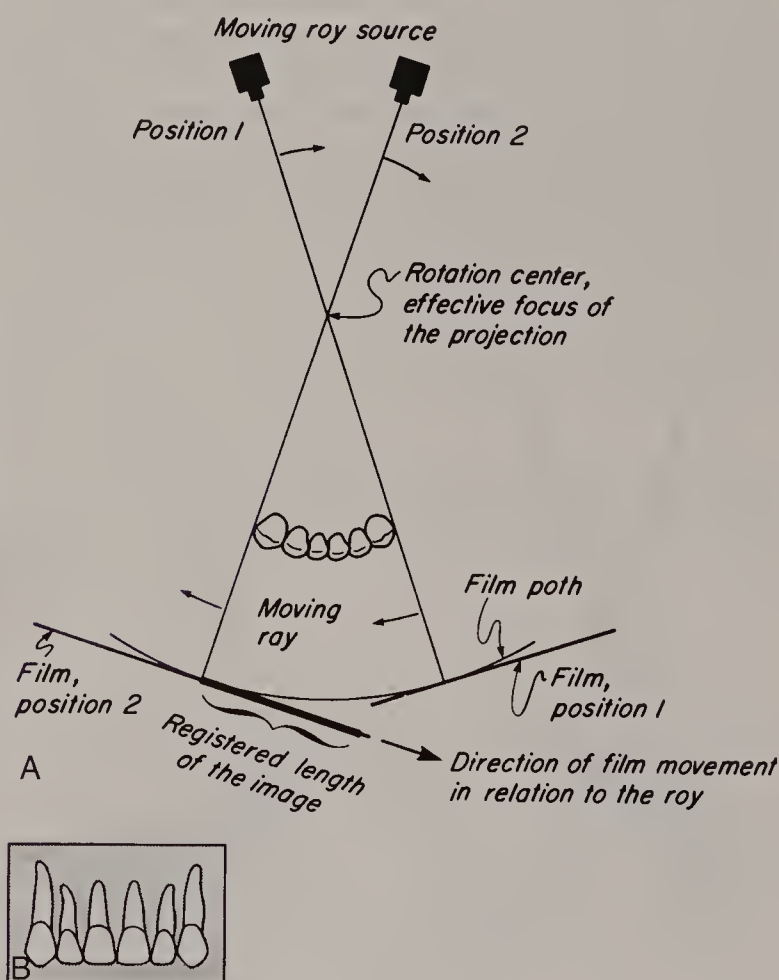
Acceleration of the panoramic film speed shifts the image layer away from the rotation center, and a wider image layer results (Fig. 9-6A). By decelerating the film speed, the image layer shifts closer to the rotation center and becomes narrower (Fig. 9-6B). In this way, the image layer is shaped to center the jaws and nearby structures within its boundaries. In so doing, the anterior part of the layer is unavoidably narrower than the posterior part of the layer.

#### Movement Pattern of the X-Ray Beam

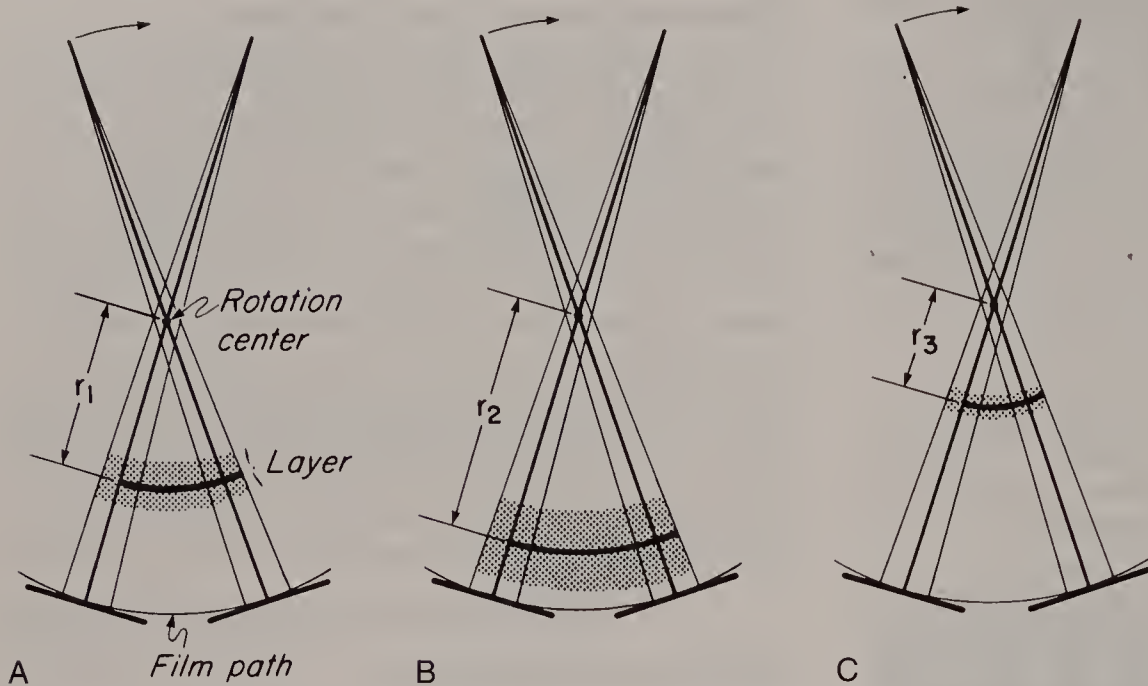
The movement pattern of the x-ray beam is chosen to obtain a favorable projection of the jaws. The most popular mechanical movement patterns are those that use a continuously moving rotation center. The x-ray beam is given a sliding movement throughout the total excursion so that the effective projection center or functional focus, called the "effective center of rotation," is continuously shifted along a defined path. The central ray of the beam is always tangential (touching at a point) to a defined curved path of the rotation center at any point (Fig. 9-7). The form of the defined curved path dictates the direction of the x-ray beam (because it is always tangential to the defined curved path) and hence defines the projection of each successive part of the jaws. This results in a continuous radiographic image.

#### IMAGE LAYER ANALYSIS

Even in a correctly positioned patient, objects that are buccal or toward the film will be narrowed, and objects that are lingual or toward the source will be widened. Ad-



**Figure 9.4 Combination of Rotating Beam and Moving Film in Panoramic Radiography.** (A) The combination of a rotating beam and a moving film changes the horizontal dimensions of the recorded image, but the projection of the object remains the same. (B) The resulting image in the rotational panoramic system has its proportions restored.



**Figure 9.5 Width of Image Layer.** The distance from the rotation center of the beam to the central plane of the image layer has been called the effective projection radius ( $r$ ). The longer the radius, the thicker the layer. Note image layer thicknesses among **A**, **B**, and **C** compared with  $r_1$ ,  $r_2$ , and  $r_3$ .

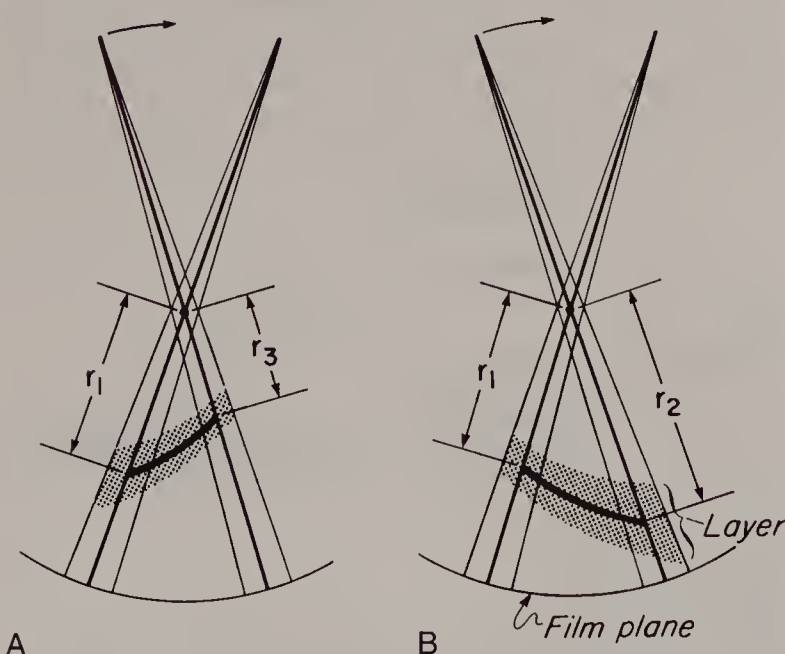
ditionally, because of the negative projection angle of the beam, buccal objects will be projected lower and lingual objects will be projected higher than objects in the central plane of the layer. For example, if a mandibular premolar has erupted lingually or has been pushed lingually by a tumor, it will be wider than the opposite premolar and higher up in the image than the adjacent teeth in the arch. Conversely, a buccal object, such as the mental foramen in the mandible, would be narrowed and projected downward with respect to another object in the middle of the layer. Also, if a patient is positioned too far forward, the

anterior teeth will be narrowed; if a patient is positioned too far back, the anterior teeth will be widened. Overall, objects in the center of the layer are magnified 20 to 30%.

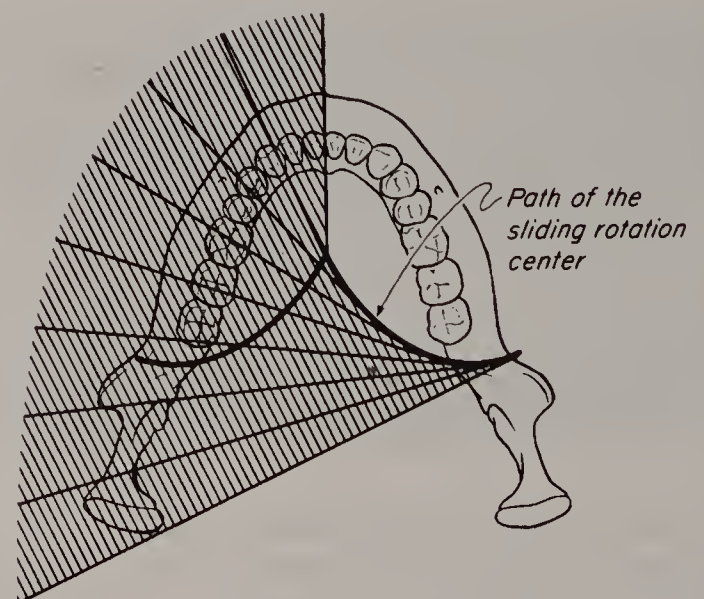
## CONCEPTS OF NORMAL PANORAMIC ANATOMY

### INTRODUCTION

Certain peculiarities of the panoramic system result in a unique projection of many anatomical structures in the

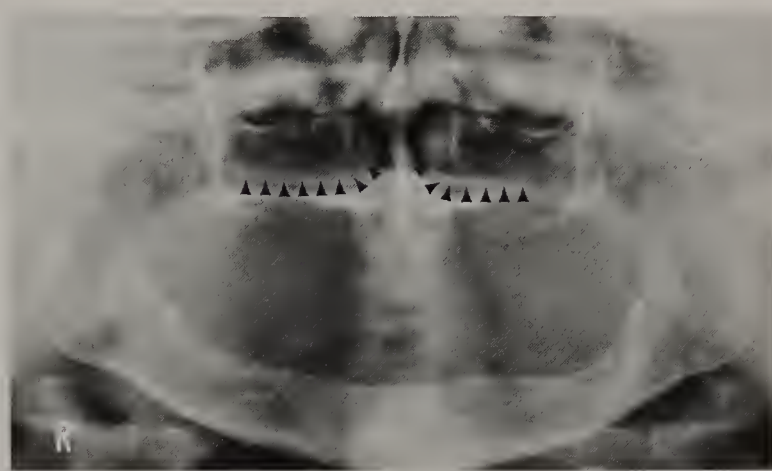
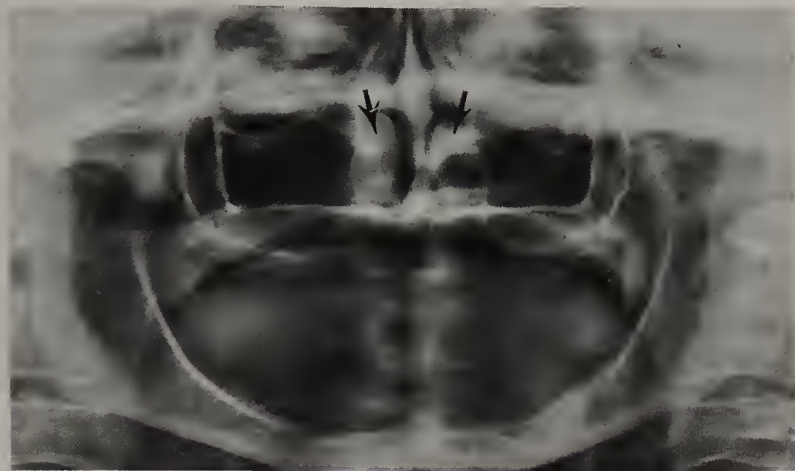


**Figure 9.6 Position of Image Layer.** The position of the layer depends on the film speed. **(A)** If the speed of the film is increased, the position of the image layer shifts away from the rotation center. **(B)** If the speed of the film is decreased, the position of the image layer shifts toward the rotation center. Note the simultaneous change in layer thickness.



**Figure 9.7 Movement Pattern of the X-Ray Beam.** The movement pattern of the rotation center is chosen to obtain a favorable projection of the object. The most popular mechanical movement patterns are those that use a continuously sliding rotation center, as shown here. The form of the defined curved path dictates the direction of the x-ray beam, because it is always tangential (touching at a point) to a defined curved path. This results in a continuous radiographic image.





**Figure 9.8 Concept 1. Structures Are Flattened and Spread-Out.** (A) Correct projection of nasal turbinates (arrows) within nasal fossa. (B) Nasal turbinates are spread-out across the maxillary sinus due to a patient positioning error (arrowheads).

image. This produces several unusual anatomical relationships in the panoramic image that are not found in any other kind of radiographic projection. We have developed a conceptual approach to understanding the panoramic image and have found that most peculiarities of normal structural relationships can be explained by one or more of the following seven concepts.

#### Concept 1: Structures Are Flattened and Spread-Out

In panoramic radiography, the patient remains stationary as the x-ray tube and film cassette holder both rotate around the patient during the exposure cycle. The cassette holder has a protective lead front, and the film is exposed through a long narrow slit opening in the lead front of the cassette holder. The film that is inside the cassette moves across the narrow slit opening as the x-ray tube rotates. The radiographic image is “laid out” as the film in the cassette passes the slit opening, in the same way that paint is applied to a wall with a roller. The resultant radiograph is a **flattened** image of a curved surface. In the panoramic radiograph, the jaws and structures of the maxillofacial complex as well as the spine are portrayed as if they were split vertically in half down the midsagittal plane with each half folded outward, such that the nose remains in the middle, the right and left sides of the jaws are on each side of the film, and the spine (having been split in half) appears beyond the rami at the extreme right and left edges of the film (Fig. 9-8A). This is much like opening a book with the narrow part of the binding facing the reader; when opened, the front and back covers can be seen.

One of the undesirable effects of the panoramic technique is that if the patient is positioned improperly in the machine, certain structures will also be flattened and spread-out although they normally would not be. For example, when the patient’s chin is tipped too low, the hyoid bone is spread-out and projected across the mandible. In the same way, the inferior turbinates and meati of the

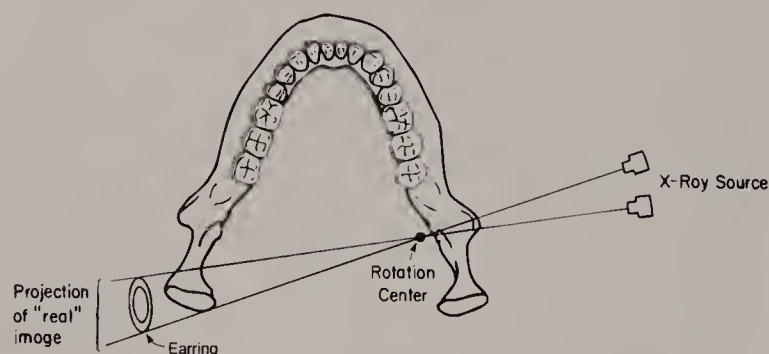
nose are spread-out and projected across the maxillary sinus when the patient is positioned too far back. This is undesirable, as the image of these **flattened and spread-out** structures obscures other structures that need to be seen (Fig. 9-8B). To explain why these undesirable effects occur, one needs to understand the second concept.

#### Concept 2: Midline Structures May Project as Single Images or Double Images

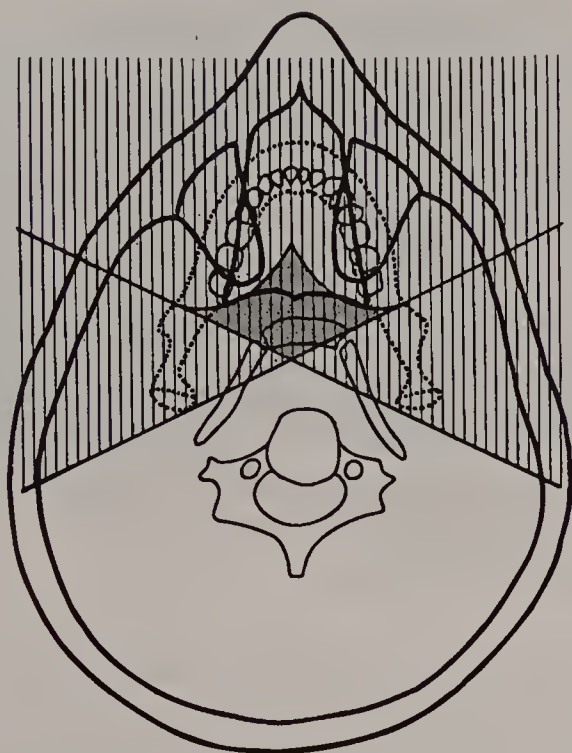
In this concept, we refer to the formation of “real” images as opposed to “ghost” images. Further, we have subdivided real images into single and double real images. We will consider ghost images in the next concept.

**Real Image Formation.** A real, single image is formed when the anatomical structure (object) is located between the rotation center of the beam and the film; that is to say, the object is in front of the rotation center (Fig. 9-9). The anatomical regions where real images are formed are shown in Figure 9-10.

Double real image formation occurs in the central portion of the oral and maxillofacial region in a **diamond-shaped zone** where objects are intercepted twice by the beam (Fig. 9-10).



**Figure 9.9 Concept 2. Real Images.** Formation of the real image of an earring. The earring is located between the rotation center of the beam and the film.

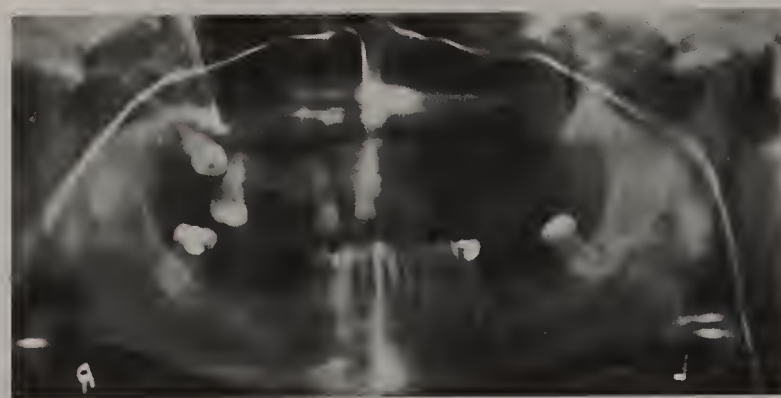


**Figure 9.10 Concept 2. Region Where Real Images Are Formed.** The zone where real images are formed when a continuous movement pattern is used (vertical hatch marks). Double images are formed in the central diamond-shaped region (shaded area).

Double images have the following five characteristics:

1. One image is the mirror image of the other.
2. Both images are real images.
3. Each image will have similar proportions.
4. Each image will have the same location on the opposite side.
5. Double images only occur with midline objects falling in the diamond-shaped zone in the midline.

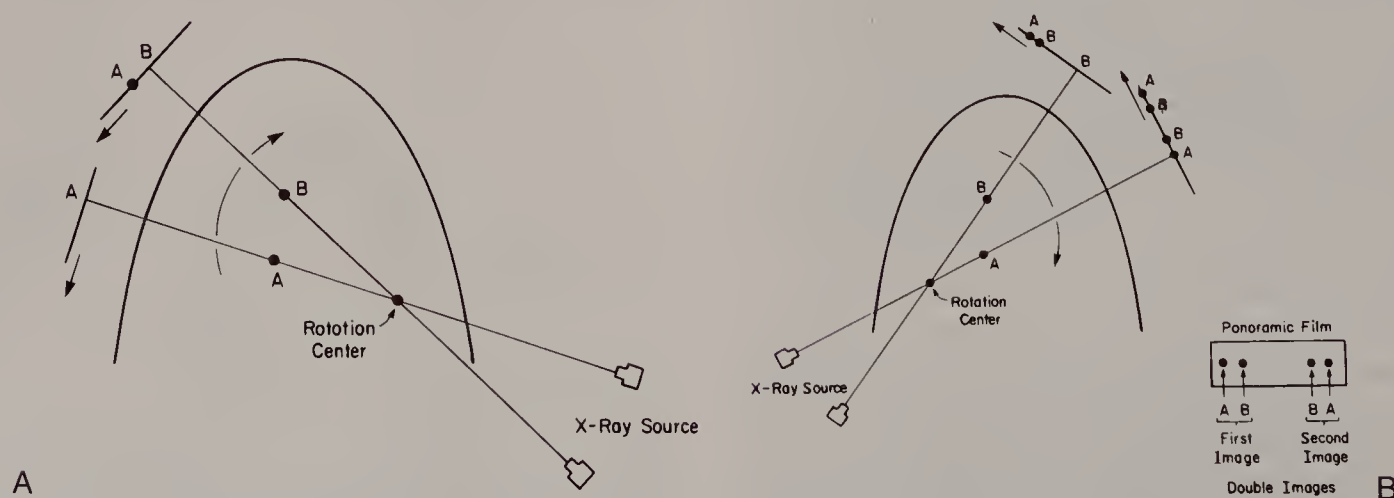
The diamond-shaped region (Fig. 9-10, shaded pattern) corresponds to the patient's midline from about the



**Figure 9.11 Concept 2. Double Real Images.** Double image of a single radiopaque tube inserted into the right nasal passage. When tube passes through the central diamond-shaped region, as depicted in Figure 9-10, double real images are formed.

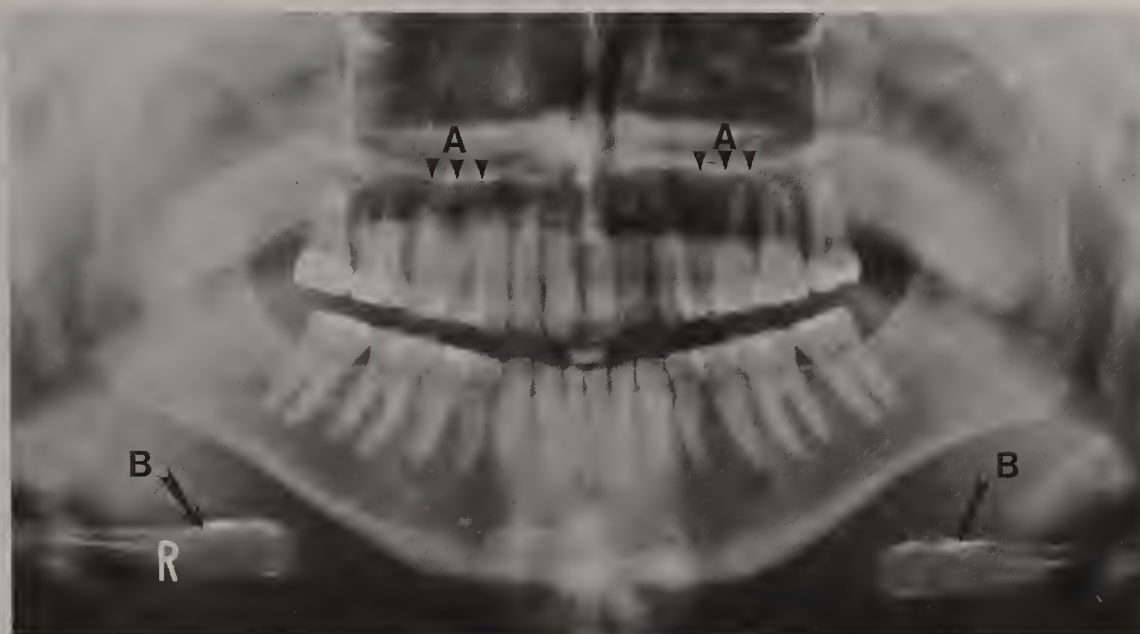
middle of the image to the most posterior extent of the radiograph. A double real image is a pair of real images formed by an object lying within this zone. An example of a double real image is shown in Figure 9-11. Here, a single radiopaque tube inserted in the nasal passage appears in two locations (double real images) on the panoramic radiograph. The structural configuration of such double real images may be understood by examining the sequence in which the beam intersects an object during its projection onto the film. Figure 9-12 shows the formation of the double real image of two adjacent points A and B. In the formation of the first image, the beam first intercepts A and then B. On the opposite side of the scan, B is intercepted before A. The result is that double real images are reversed with respect to one another. That is to say, double images are mirror images of each other.

Some examples of structures that normally produce double real images are the hard and soft palate, palatal torus, body of the hyoid bone, epiglottis, and cervical spine (Fig. 9-13). Only midline structures located in the diamond-shaped area can do this. When the patient is malpositioned, the turbinates of the nose, body of the hy-



**Figure 9.12 Concept 2. Double Real Images.** Formation of double images of points A and B. (A) Formation of the first image. (B) Formation of the second image.



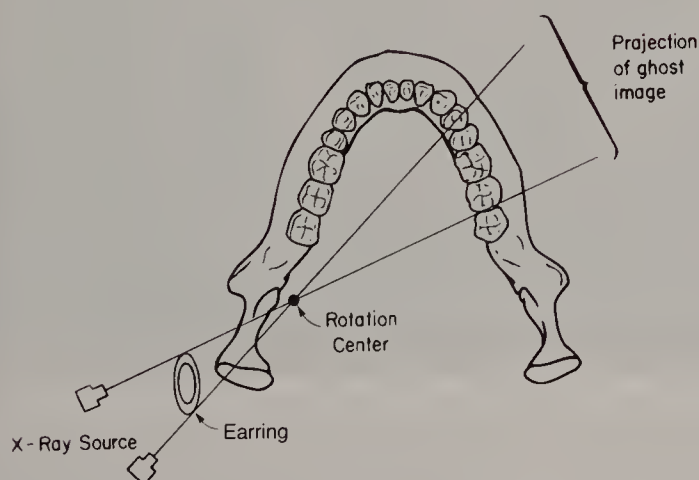


**Figure 9.13 Concept 2. Double Real Images.** (A) Hard palate. (B) Hyoid bone. These structures fall in the diamond-shaped area.

oid, and spine enter into this diamond-shaped area and produce undesirable double images. However, these undesirable double images help to identify patient positioning errors (see Chapter 10).

### Concept 3: Ghost Images Are Formed

A ghost image is formed when the object is located between the x-ray source and the center of rotation (Fig. 9-14). That is to say, anatomically the object is behind the rotation center. The radiograph in Figure 9-16 shows two ghost images of two earrings. Each ghost image corresponds to the earring on the opposite side. The regions satisfying the preceding requirement for the formation of ghost images are shown in Figure 9-15. Structures situated within this region can appear as ghosts (phantoms), whereas structures situated elsewhere cannot.

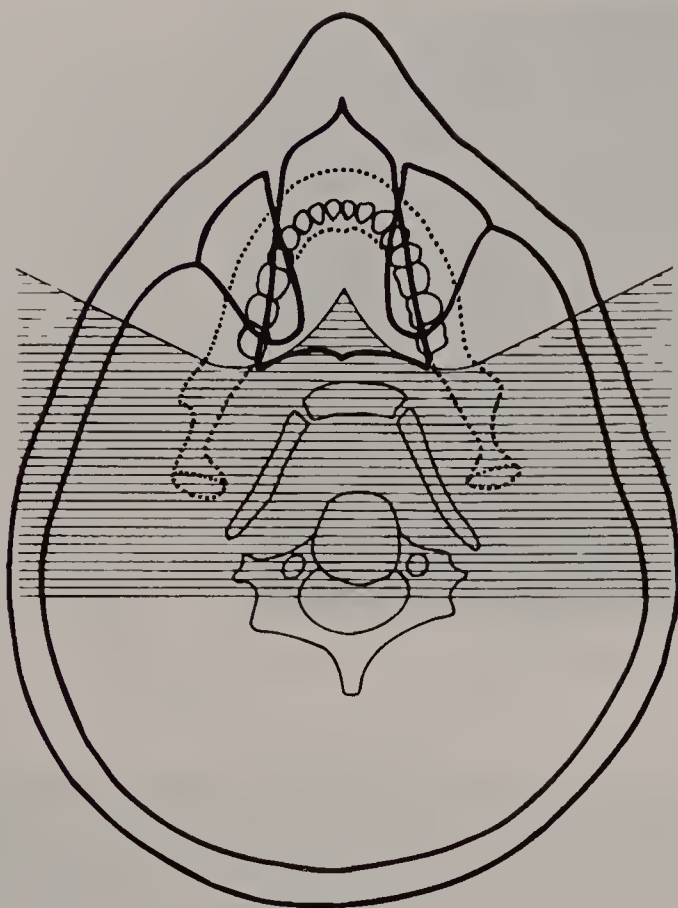


**Figure 9.14 Concept 3. Formation of Ghost Images.** Formation of the ghost image of an earring. The earring is now located between the x-ray source and the center of rotation. Compare with Figures 9-7 and 9-9.

Ghost images have the following six characteristics (Fig. 9-16):

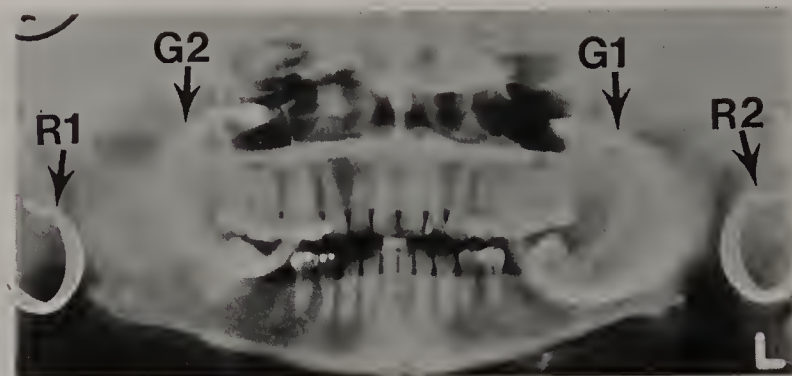
1. The ghost image has the same general shape as its real counterpart (no mirror image formation).
2. The ghost image appears on the opposite side of the radiograph from its real counterpart.
3. The ghost image appears higher up on the radiograph than its real counterpart.
4. The ghost image is more blurred than its real counterpart.
5. The vertical component of a ghost image is more blurred than the horizontal component.
6. The vertical component of a ghost image is always larger than its real counterpart, whereas the horizontal component of a ghost image may or may not be severely magnified.

To understand the differences among the first three concepts, study Figure 9-17, which is a composite diagram showing the zones giving rise to single and double real images and ghost images. Note that two areas in the horizontal plane contain structural details that project only real or ghost images, as the case may be. This diagram depicts the properly positioned patient. Where only vertical hatch marks are seen, structures such as the body of the mandible, the teeth, and the antrum (maxillary sinus) may only produce real images. In the area of the horizontal hatch marks, the spine, neck chains, and horns of the hyoid usually produce only ghost images. The projection geometry of most panoramic machines is such that these ghost-only images are not usually projected onto the film, that is, they are not seen in an image of a properly positioned patient. In the area where both vertical and horizontal hatch marks are seen, both single real and ghost images of the structures included therein may be produced in



**Figure 9.15 Concept 3. Region Where Ghost Images are Formed.** The anatomical region where ghost images are formed is marked by horizontal hatch marks and lies behind the rotation center.

the same image. These include the greater horns of the hyoid bone, ramus/condyle of the mandible, earrings, necklaces, and coat zippers. In the diamond-shaped area, double real and ghost images may be produced.

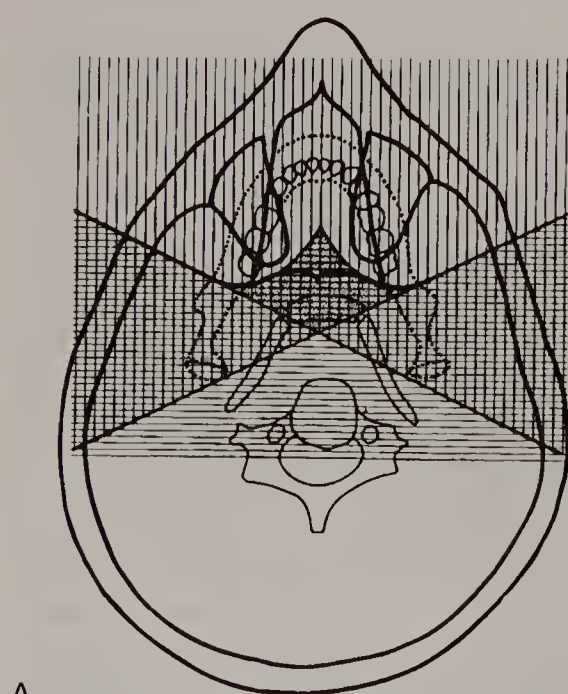


**Figure 9.16 Concept 3. Ghost Image Characteristics.** (R1) Real image of earring. (G1) Corresponding ghost image of earring (R1). (R2) Real image of earring. (G2) Corresponding ghost image of earring (R2). Check ghost images G1 and G2 for the six characteristics of ghost images.

Examples include the body of the hyoid bone and the posterior aspect of the hard palate (Fig. 9-22). Generally, the presence of ghost images is the result of technique errors. Some include ghost images of earrings, necklaces, spine (Fig. 9-23), and rami of the mandible. Recognition of these undesirable ghost images helps to identify and eliminate technique errors.

#### Concept 4: Soft Tissue Shadows Are Seen

One of the unique advantages of panoramic radiography is that some soft tissue structures attenuate the beam of radiation to a sufficient degree to become visible in the radiograph (Fig. 9-18). This is especially true in the posterior and superior regions, where there are no teeth, and in all regions of edentulous patients. Fluids and cartilaginous tissues such as the ear, nose, and epiglottis are also included in this concept. Other soft tissues include soft palate and uvula, dorsum of the tongue, posterior pha-



**Figure 9.17 Concepts 2 and 3. Composite Diagram Showing Real and Ghost Images.** (A) Composite diagram showing the zones giving rise to real (single and double) and ghost images in continuous image machines. The zones are marked as in previous figures. (B) Panoramic radiograph depicts structures within these zones mentioned in A. Real single images of (1) central incisors, (2) real single image of nasal septum, (3) real single image of soft tissue outline of nose, (5) double real image of hyoid bone, (6) double real image of spine, (7) double real images of palate, and (8) ghost images of palate.





**Figure 9.18 Concept 4. Soft Tissue Shadows.** (1) Earlobes, (2) soft palate, (3) posterior pharyngeal wall, (4) dorsum of the tongue, and (5) turbinates. All these structures can be seen bilaterally. Also note (6) mucous retention cyst in maxillary sinus.

ryngeal wall, palatine tonsil, lips, nasolabial fold, and the soft tissues of the nasal turbinates and septum. Additionally, the gingiva, retromolar pad, and operculum of erupting teeth may be seen. Although some soft tissue shadows are normally seen, visualization of the tongue, ears, nose, and nasal turbinates spread-out are an indication of technique errors.

#### Concept 5: Air Spaces Are Seen

Because areas containing air do not attenuate the x-ray beam as much as soft or hard tissues, air spaces usually appear black (Fig. 9-19). Some of the air spaces that may be seen include those of the hypopharynx (laryngopharynx), oropharynx, and nasopharynx; the maxillary sinus; and the nasal fossa (meati). These air spaces are normal components of the panoramic image. If an air space is noted above the dorsum of the tongue or in association with the anterior teeth, an error in technique has occurred. Undesirable air spaces help to identify technique errors.

#### Concept 6: Relative Radiolucencies and Radiopacities Are Seen

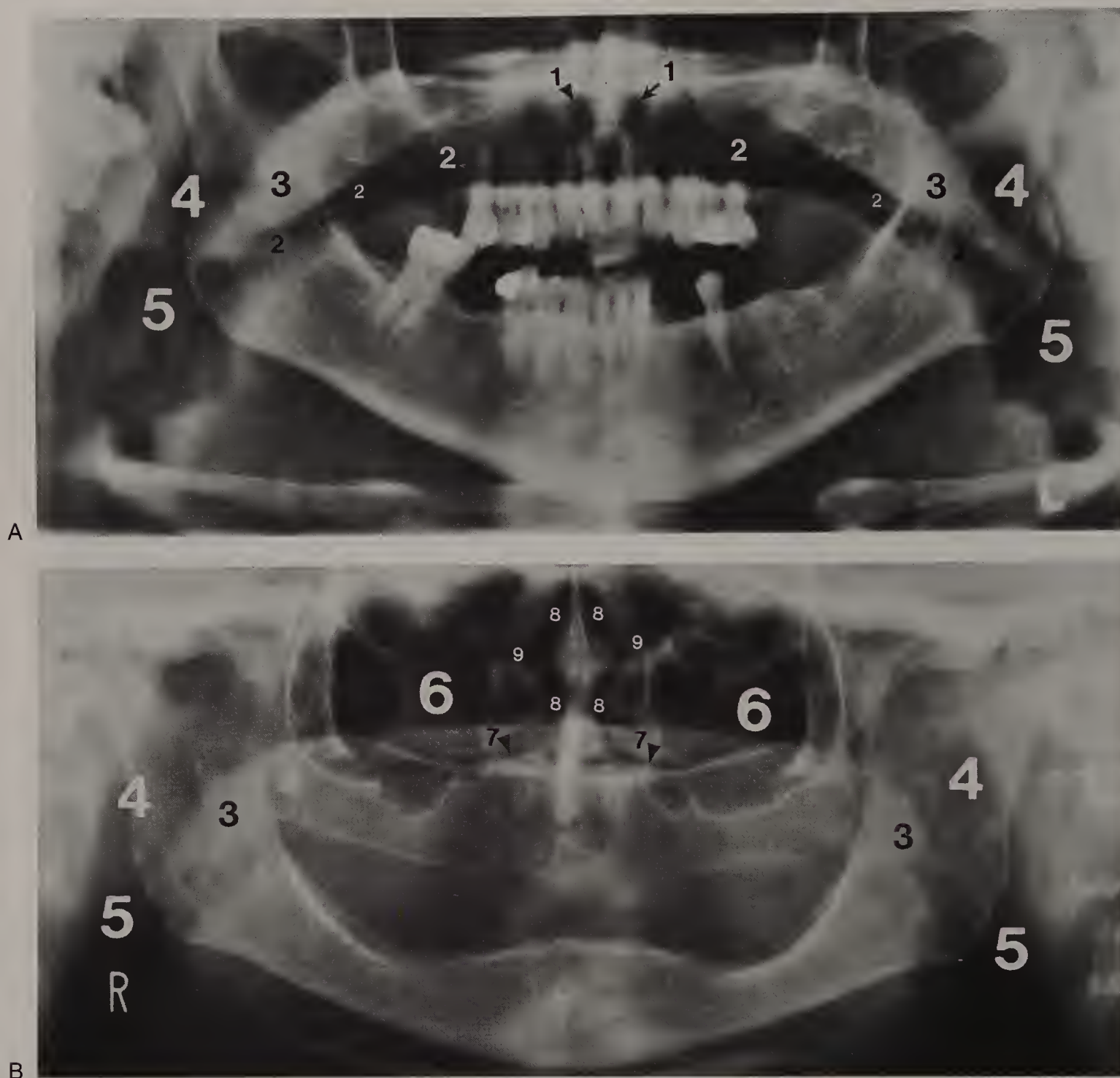
In any image, it is important to separate shadows originating from parts of the machine from those coming from the patient. Machine components seen in the image are made of plastic, have a density similar to that of soft tissue, and are usually easy to identify because of their geometric or linear configuration. One may think of the patient as being made of three basic components: hard tissue

(teeth and bone), soft tissue (including cartilage and fluid), and air. All these machine and patient components may produce single and/or double real images and/or ghost images. Thus, multiple areas consisting of relative density changes are produced (Fig. 9-20).

To understand and separate multiple density changes, the following should be remembered (Fig. 9-21):

1. Air obscures hard tissues.
2. Soft tissue obscures air.
3. Hard tissue obscures soft tissue.
4. Ghost images obscure everything.

This concept ties the previous five together and can allow the dental health-care practitioner to use the panoramic radiograph in a meaningful way to detect disease and to troubleshoot errors. If a pathologic process is present, it will consist of hard tissue, soft tissue, or fluid. In addition, it will affect one or more of the three tissue components in the patient as follows. Conditions producing hard tissue cause all three patient components to become relatively more radiopaque in the region of the disorder. A soft tissue pathologic condition within the mineralized component causes it to become more radiolucent, whereas the soft tissue and air components become more radiopaque when a soft tissue disorder is present. Thus, when a soft tissue lesion encroaches on an air space, such as the nasopharynx or maxillary sinus, it becomes



**Figure 9.19 Concept 5. Air Spaces (A, B)** (1) Nares of nose, (2) glossopalatine air space, (3) soft palate, (4) nasopharyngeal air space, (5) oropharyngeal air space, (6) maxillary sinus (antrum), (7) inferior meatus, (8) common meatus, and (9) middle meatus.

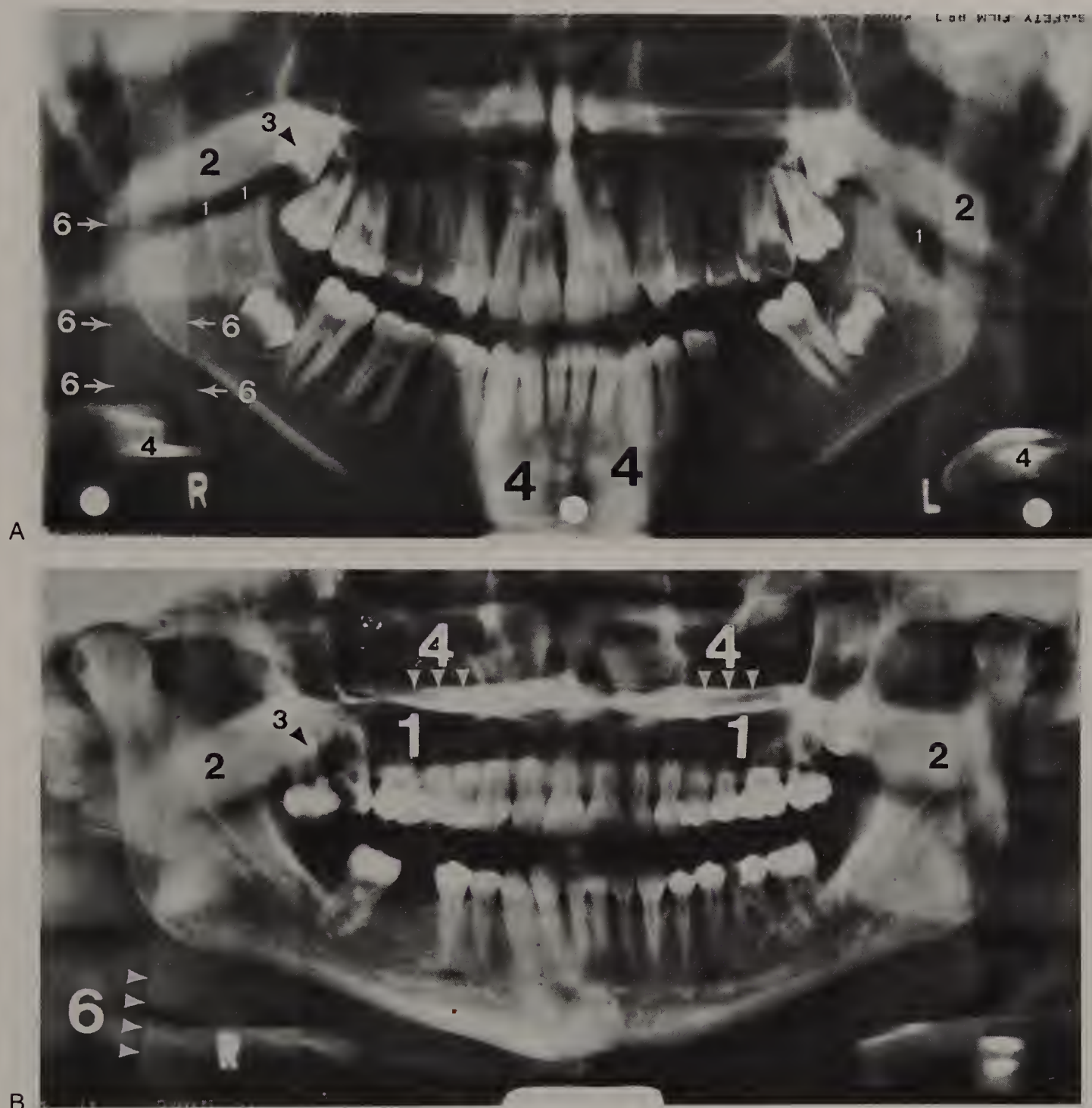
visible as an opacity superimposed on the air space. When errors are present, further relative radiolucencies and opacities may also appear and affect the three tissue types in the same way. The recognition of these is essential to identify and correct operator errors. Pathology or the absence thereof should only be interpreted from a properly exposed and processed panoramic radiograph.

#### **Concept 7: Panoramic Radiographs Are Unique**

The scope of assessment and interpretive potential from panoramic radiographs in many ways exceeds that of the

full-mouth intraoral survey. In the study of teeth, angular interrelationships of structures are accurate in panoramic radiographs. Therefore, the relationships of teeth with each other and with other structures may be studied in treatment planning, such as crown and bridge abutment tooth parallelism, the path of insertion of partial dentures, the orthodontic tipping of teeth, and the surgical removal of impacted teeth. Because each intraoral film is taken individually, these interrelationships cannot always be studied accurately using full-mouth intraoral surveys. Areas such as the ramus, styloid process, temporomandibular joint, upper portions of the sinus, and tissues



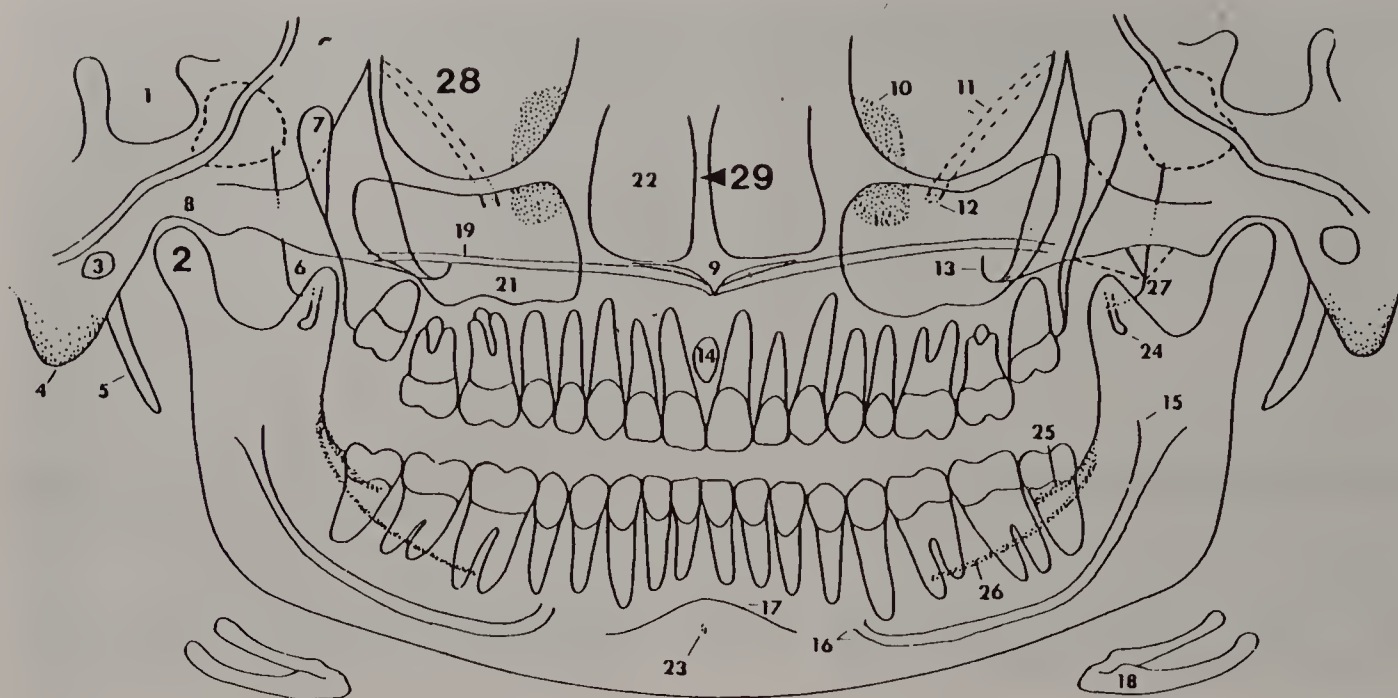


**Figure 9.20 Concept 6. Separation of Multiple Density Changes.** (A, B) (1) Air obscures hard tissues (ramus), (2) soft tissue (soft palate) obscures air (pharyngeal air space), (3) hard tissue (tooth) obscures soft tissue (soft palate), (4) ghost images (R and L markers, spinal column, and hard palate) obscure everything (hyoid bone, mandible, and maxillary sinus), and (6) external machine components such as the side guides produce relative density changes as shown here.

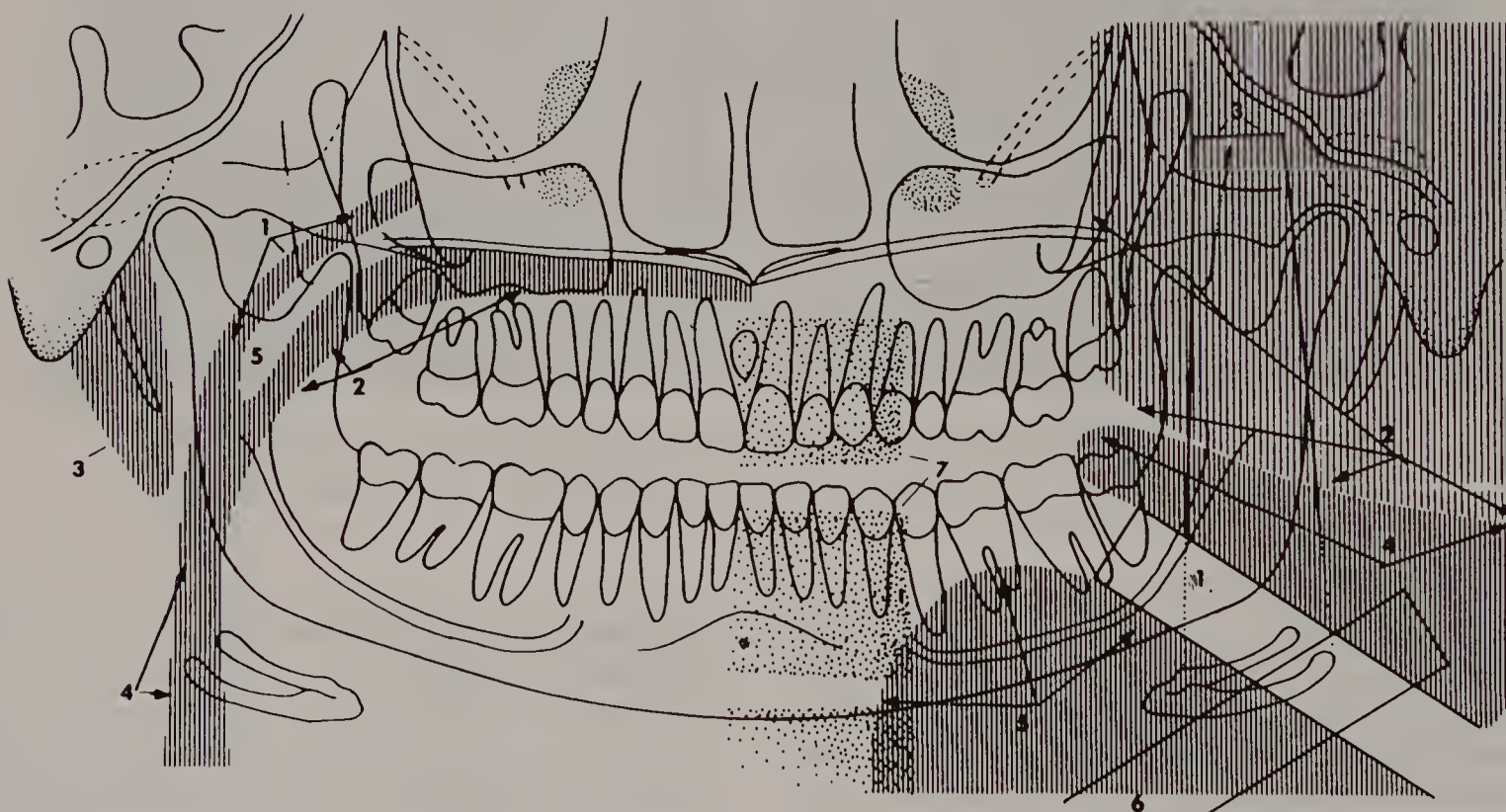
below the jaws all give rise to pathologic conditions that are not visualized in intraoral radiographs. The panoramic radiograph is an excellent imaging modality in patients with trismus or trauma, because such patients cannot open their mouths and this is not needed to take a panoramic film. The uniqueness of the panoramic technique is that it results in an excellent projection of a variety of structures on a single film, which no other imaging system can achieve. Individual structures may be imaged by other methods, once pathologic conditions have been detected using the panoramic radiograph.

## ATLAS OF ANATOMICAL STRUCTURES

The remainder of this chapter is presented in atlas format. The reader should first try to learn the basic bony landmarks needed for technique troubleshooting, then learn the others. It will be impossible to see all anatomical structures on a single panoramic radiograph. It will take various panoramic radiographs to show detailed bony landmarks and soft tissue shadows (Figs. 9-21—9-23).

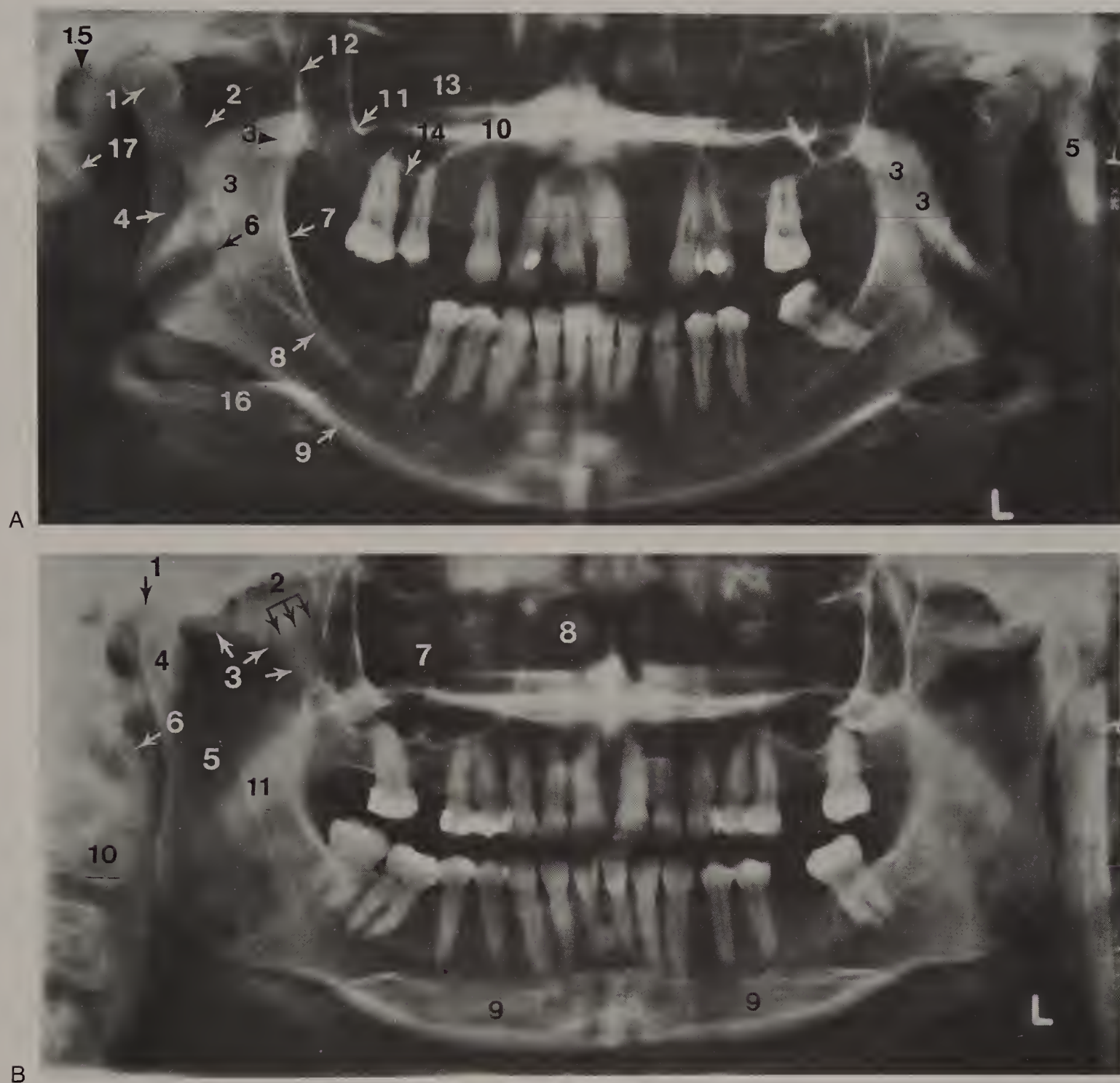


**Figure 9.21 Panoramic Image of Atomic Landmarks.** Common anatomical structures. (1) Sella turcica, (2) mandibular condyle, (3) external auditory meatus, (4) mastoid process, (5) styloid process, (6) lateral pterygoid plate, (7) pterygomaxillary fissure, (8) articular eminence, (9) anterior nasal spine, (10) ethmoid sinuses, (11) infraorbital canal, (12) infraorbital foramen, (13) zygomatic process of the maxilla, (14) incisive or nasopalatine foramen, (15) mandibular foramen, (16) mandibular canal and mental foramen, (17) mental ridge, (18) hyoid bone, (19) hard palate, (21) maxillary sinus, (22) zygomatic arch, (23) zygomatic arch, (24) orbit, and (25) nasal septum.



**Figure 9.22 Soft Tissue, Ghost and Artifact Shadows.** *Soft Tissue Shadows (Left).* (1) Nasopharyngeal air space, (2) palatoglossal air space, (3) shadow of the ear, (4) glossopharyngeal air space, (5) soft palate. Note that all artifact areas and shadows are bilateral. *Ghost and Artifact Shadows (Right).* (1) Chin rest (opposite side—ghost), (2) opposite mandible (ghost), (3) head positioning device, (4) soft tissue space (radiolucency) between the mandible and the chin rest on the opposite side, (5) area of increased radiolucency due to the absence of superimposed hard or soft tissue structures, (6) chin rest (true image), (7) cervical vertebra and intervertebral spaces (faint areas of increased radiopacity).





**Figure 9.23 Common Anatomical Structures (Panoramic Radiograph).** (A) (1) Condyle, (2) nasopharyngeal air space, (3) soft palate, (4) oropharyngeal air space, (5) soft tissue of ear, (6) glossopalatal air space, (7) external oblique malar (malar) bone, (12) posterior wall of maxillary sinus, (13) maxillary sinus (antrum), (14) lower border (floor) of maxillary sinus, (15) external auditory meatus, (16) hyoid bone, and (17) stylohyoid process. (B) (1) Glenoid fossa, (2) nasopharyngeal air space, (3) zygomatic arch, (4) condyle, (5) oropharyngeal air space, (6) stylohyoid process, (7) maxillary sinus, (8) inferior turbinate, (9) ghost of hyoid bone, (10) spinal column, and (11) soft palate.

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 9.1. PANORAMIC ANATOMY

#### Materials and Equipment Needed

1. A panoramic radiograph of a patient.
2. Orthodontic tracing sheets and pencil.
3. Viewbox.

#### Instructions

Trace and use numbered arrows (to the best of your ability) to identify the following key anatomical structures. Use the same numbers as listed below. Some of these structures may not be present in every panoramic radiograph.

1. Mandibular condyles
2. Ramus of mandible
3. Cervical spine
4. Maxillary sinus
5. Nasal fossa
6. Inferior turbinate
7. Real image(s) of hard palate
8. Ghost image(s) of hard palate
9. Soft palate
10. Inferior cortex of the mandible
11. Inferior alveolar canal
12. Mental foramen
13. Hyoid bone
14. Tongue
15. Nasopharyngeal and pharyngeal air spaces

**NOTE TO INSTRUCTORS:** The authors will supply reasonable numbers of panoramic radiographs of patients for student reuse. Alternatively, specially labeled panoramic radiographs are also available on a very low cost-recovery basis. Please call (210) 567-3341 or fax (210) 567-3334.

### REVIEW QUESTIONS

1. In panoramic radiography, the thickness of the image layer increases with:
  1. Widening of the collimator slit.
  2. Narrowing of the collimator slit.
  3. Increased distance between the center of rotation and the layer.
  4. Decreased distance between the center of rotation and the layer.
  - A. 1 and 3.
  - B. 1 and 4.
  - C. 2 and 3.
  - D. 2 and 4.
2. In panoramic radiography, the image layer is narrowest in the:
  - A. Incisor region.
  - B. Premolar region.
  - C. Molar region.
  - D. Ramus region.
3. In panoramic radiography, when an object is on the buccal or film side of the layer, the image is:
  - A. Projected upward and widened.
  - B. Projected upward and narrowed.
  - C. Projected downward and widened.
  - D. Projected downward and narrowed.
4. In panoramic radiography, when an object is on the lingual or tubehead side of the layer, the image is:
  - A. Projected upward and widened.
  - B. Projected upward and narrowed.
  - C. Projected downward and widened.
  - D. Projected downward and narrowed.
5. In panoramic radiography, the effective focal spot is:
  - A. At the target of the x-ray tube.
  - B. At a tangent to the center of rotation.
  - C. The center of rotation at any given point.
  - D. Within the diamond-shaped area.
6. In panoramic radiography, the central ray of the beam is:
  - A. At the target of the x-ray tube.
  - B. At a tangent to the path of the center of rotation.
  - C. The center of rotation at any given point.
  - D. Within the diamond-shaped area.
7. In panoramic radiography, the radiation dose to the patient is the same as four bitewings with E+ speed film and the:
  - A. Long, round BID.
  - B. Long, rectangular BID.
  - C. Short, round BID.
  - D. Short, pointed BID.
8. In panoramic radiography, ghost images are produced when structures:
  - A. Lie in front of the rotation center.
  - B. Fall in the rotation center.
  - C. Lie behind the rotation center.
  - D. Do not produce real images.
9. If in panoramic radiography the width of the image layer is large:
  - A. Patient positioning is more critical.
  - B. Patient positioning is less critical.

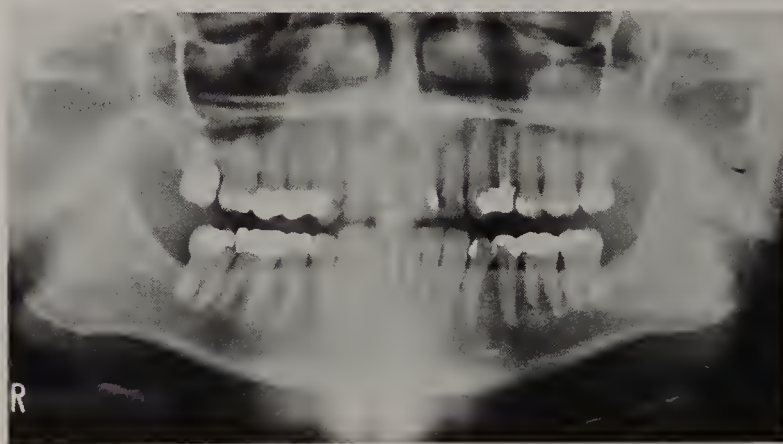


- C. Objects in the middle of the layer are sharper.  
D. Patient positioning can be compensated by image sharpness.
10. In a panoramic radiograph the real image of the palate is:
- Below the ghost image of the palate.
  - Bilateral.
  - In the diamond-shaped area of the beam.
  - Superimposed on maxillary sinus.
  - All of the above.
11. The ghost image of the corresponding real image is usually:
- Above the real image.
  - On the contralateral side of the real image.
  - Larger than the real image.
  - Fuzzier than the real image.
  - All of the above.
12. Which of the following statements is true?
- Air obscures hard tissues.
  - Soft tissues obscure air.
  - Hard tissue obscures soft tissue.
  - Ghost images obscure everything.
- 1 and 2 only.
  - 3 and 4 only.
  - 2, 3, and 4.
  - 1, 2, 3, and 4.
  - 1, 3, and 4.
13. In a properly exposed panoramic radiograph, the image of the hyoid bone is:
- Not seen.
  - Seen immediately beneath mandibular midline.
  - Seen bilaterally beneath the angles of the mandible.
  - Seen bilaterally and in the midline.
14. Which of the following is a characteristic of a double image?
- One image is the mirror image of the other.
  - Both images are ghost images.
  - Each image will vary in size and shape.
  - Double images are limited to those occurring in the midline outside the diamond-shaped zone.
- 4 only.
  - 1, 2, 3, and 4.
  - 1, 2, and 3 only.
  - 1 only.
  - 1 and 2 only.
15. Which of the following represents an undesirable effect due to a technique error?
- Turbinates are spread-out across to the maxillary sinuses.
  - Images of the soft palate are projected bilaterally.
  - The hyoid is spread-out and projected across the mandibular midline.
  - Air space above the tongue is absent.
- 1 and 3 only.
  - 2 and 4 only.
  - 3 and 4 only.
  - 1 and 2 only.

### CASE-BASED QUESTIONS

#### CASE 9.1

One concept of panoramic radiography is that structures are flattened and spread-out (like taking a horseshoe and straightening it out). In some cases—such as for the mandible, maxilla, and maxillary sinuses—this is desirable because it avoids the superimposition of right- and left-sided structures on top of one another.



### QUESTIONS

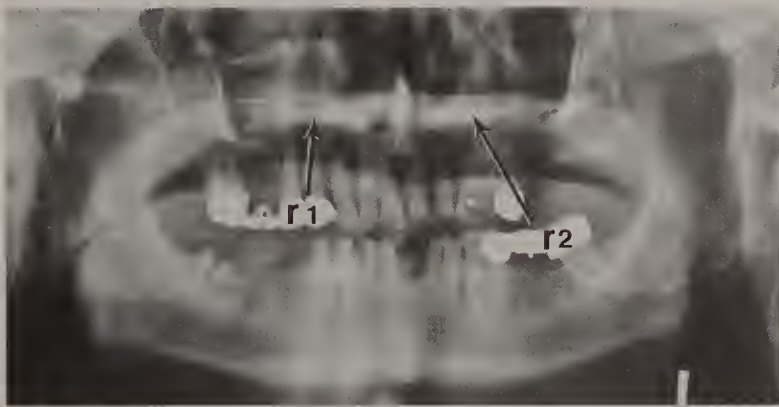
- This patient is malpositioned in the machine, and one structure is flattened and spread-out that should not be flattened and spread-out. If you recognize this feature, you will know which positioning error has occurred (see Chapter 10). The structure inappropriately flattened and spread-out is the:
- Hyoid bone.
  - Nasal turbinate.
  - Hard palate.
  - Occlusal plane.

2. Another concept learned in this chapter is that soft tissues obscure air spaces. Which of the following statements is correct?

- When the turbinate is spread-out, it obscures the air space in the upper half of the sinus.
- When a mucous retention cyst is seen in an air space (such as the maxillary sinus [left side]), it is because body fluids, like soft tissues, obscure the air space.
- A and B.
- None of the above.

### CASE 9.2

One concept of panoramic radiography is that air can obscure mineralized structures such as teeth and bone. This can occur as a result of the patient malpositioning the tongue.



### QUESTIONS

With respect to an air space located on this panoramic image, indicate which statements are true or false.

- \_\_\_\_ The air between the dorsum of the tongue and hard palate obscures the root and apical regions of the maxillary teeth.
- \_\_\_\_ The air of the nasopharynx and oropharynx obscures portions of the ramus bilaterally.
- \_\_\_\_ The air in the maxillary sinuses is not obscured by the turbinates.

Another concept learned is how structures located within the diamond-shaped area can produce both double real images and ghost images. Even in a well-positioned patient, this phenomenon is seen with the hard palate. In this case, the two real images of the hard palate have been labeled r1 and r2. With respect to images of structures falling in the diamond-shaped area, which statements are true or false?

- \_\_\_\_ r2 is the mirror image of r1.
- \_\_\_\_ The ghost image of r1 is the radiopaque line immediately above r1.

- \_\_\_\_ The ghost image of r2 is the radiopaque line immediately above r1.
- \_\_\_\_ There are two real (double) images of the hard palate.
- \_\_\_\_ There are four ghost images of the hard palate.
- \_\_\_\_ Sometimes only the real images of the hard palate are seen.
- \_\_\_\_ Air spaces obscure bone or teeth; however, a ghost image of a tooth or bone (this case hard palate) can obscure air.

### CASE 9.3

One concept of panoramic radiography is that soft tissues can be seen in the panoramic image, especially cartilaginous tissues or soft tissues at the edge of or within an air space. The recognition of these can be used to identify positioning errors.



### QUESTIONS

With respect to the following features seen in this case, indicate which statements are true or false.

- \_\_\_\_ The ears can be seen bilaterally and indicate an error in patient positioning.
- \_\_\_\_ The double image of the epiglottis can be seen bilaterally and indicates an error in patient positioning.
- \_\_\_\_ The nose can be seen in the midline and indicates an error in patient positioning.
- \_\_\_\_ The soft palate be seen bilaterally and indicates an error in patient positioning.
- \_\_\_\_ The outline of the dorsum of the tongue can be seen and indicates an error in patient positioning.
- \_\_\_\_ Mandibular tori can be seen bilaterally and indicate an error in patient positioning.



- 7. \_\_\_\_ The ghost image of a neck chain can be seen in the midline and indicates an error in patient positioning.
- 8. \_\_\_\_ The turbinate is spread-out across the upper part of the right maxillary sinus only and indicates an error in patient positioning.
- 9. \_\_\_\_ The black lines on the lower left second molar are caused by static electricity.
- 10. \_\_\_\_ This is a good panoramic radiograph.

| Column A      | Column B             |
|---------------|----------------------|
| Arrows 1 ____ | A. Ala of nose       |
| Arrow 2 ____  | B. Soft palate       |
| Arrows 3 ____ | C. Ears              |
| Arrows 4 ____ | D. Dorsum of tongue  |
| Arrow 5 ____  | E. Epiglottis        |
| Arrows 6 ____ | F. Turbinate         |
| Arrows 7 ____ | G. Neck chain ghosts |
| Arrows 8 ____ | H. Tip of nose       |
| Arrows 9 ____ | I. Mandibular tori   |

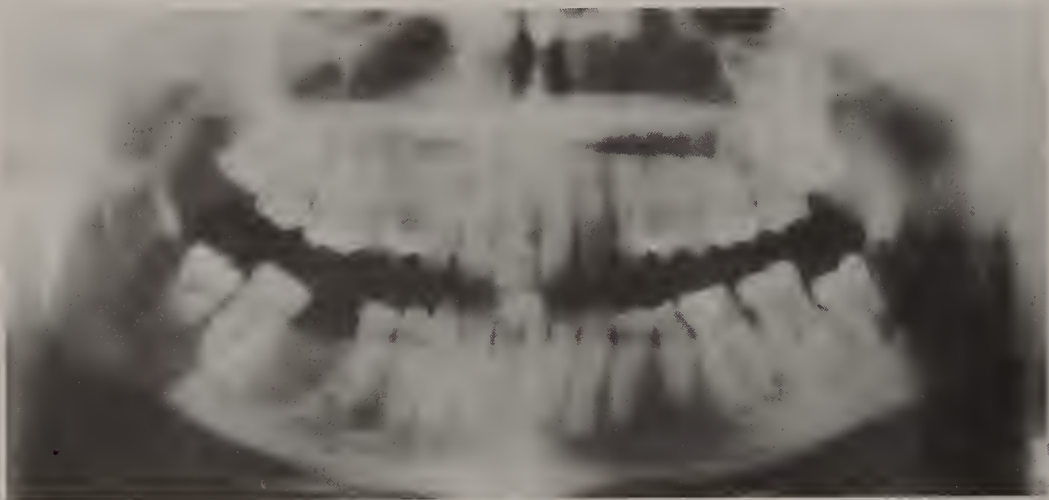
We have asked you questions about various structures in this image. Now be certain you were looking at the right thing by matching the numbered arrow(s) in Column A with the correct choice in Column B.

CASE 9.4

This patient was observed to have a round, oval-shaped nodule in the right tonsillar fossa.

QUESTION

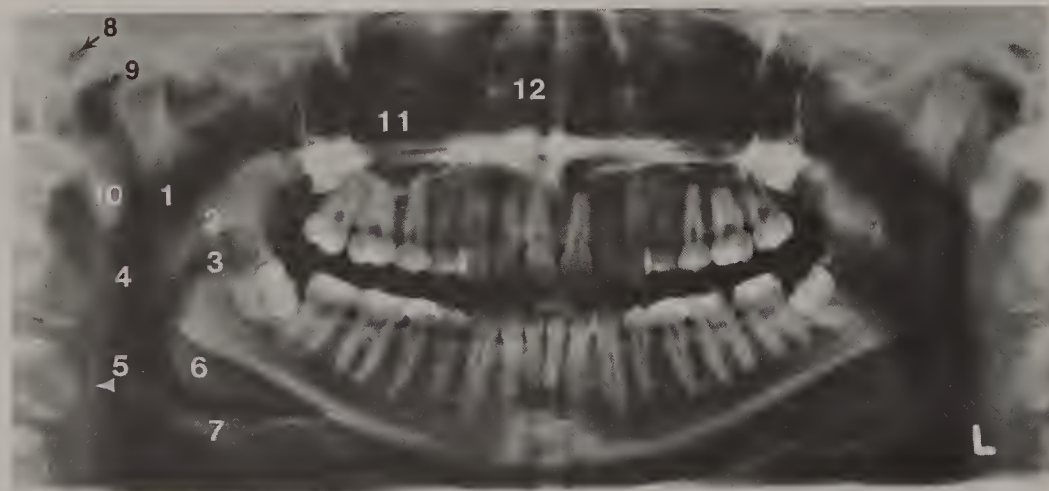
- 1. This soft tissue mass obscures the air space at the:
  - A. Mesial of the second molar.
  - B. Angle of the mandible.
  - C. Midramus area.
  - D. Patient's midline.



CASE 9.5

Match the numbered anatomical features in Column A with correct answer in Column B.

| Column A | Column B                     |
|----------|------------------------------|
| 1. ____  |                              |
| 2. ____  | B. Glossopalatal air space   |
| 3. ____  | C. Nasal fossa               |
| 4. ____  | D. Posterior wall of pharynx |
| 5. ____  | E. Maxillary sinus           |
| 6. ____  | F. Nasopharyngeal air space  |
| 7. ____  | G. Earlobe                   |
| 8. ____  | H. Base of tongue            |
| 9. ____  | I. Oropharyngeal air space   |
| 10. ____ | J. Hyoid bone                |
| 11. ____ | K. External auditory meatus  |
| 12. ____ | L. Soft palate               |



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# Troubleshooting Panoramic Techniques

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Master the six zones in overall assessment in the panoramic film.
2. Describe the five steps in the generic panoramic technique with mastery.
3. Identify panoramic patient positioning errors.
4. Recognize panoramic technical errors.
5. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

cassette resistance  
damaged screen  
film crimping  
fog  
foreign object on screen

generic panoramic  
technique  
“home base”  
multiple errors  
no identification

panoramic poncho apron  
panoramic positioning  
errors  
panoramic radiograph  
zones

removable items errors  
split cassette error  
static electricity error  
useful panoramic errors

## INTRODUCTION

In the normal course of events, the perfection of intraoral techniques is part of a dental health-care worker's formal education, whereas panoramic radiography is learned with varying degrees of competency on the job from a salesperson, another staff member, and/or (heaven help us!) by reading the owner's manual. Most dental health-care workers—including dentists, hygienists, and dental assistants—have little formal training in panoramic radiography. As a result, the quality of the images is poor and the expectations from the panoramic radiograph are often low on the part of both educators and practitioners alike.

## GENERIC PANORAMIC TECHNIQUE

All panoramic machines work in essentially the same manner, although they may differ in appearance. Our ap-

proach to learning this subject is to present it in conjunction with the generic panoramic technique that works for most machines. Each of the five technique steps will be explained carefully. Then the several errors, which can occur as miscues with each technique step, will be described and analyzed.

## GENERAL HINTS IN PANORAMIC TECHNIQUE

Patients have varying amounts of soft tissue, hair on the tops of their heads, and facial hair that may obscure the bony landmarks. Because the hard tissues cannot be seen by the health-care worker (Fig. 10-1), advantage should be taken of positioning lights and other accessory features (such as automatic exposure) to enhance technique. The operator should be certain that wigs, prostheses, jewelry, eyewear, and napkin chains have been removed before positioning the patient in the machine. With each of the five steps in the technique, the



**Figure 10.1 Anatomical Features in Patient Positioning.** Because we cannot see the hard tissues (as in **B**), we must use anatomical structures and machine devices to position the patient properly (as in **A**).

operator should go back over the previous step(s) to ensure that an alteration in positioning has not occurred. The patient's clothing and build should be inspected to ensure that bulky clothing, short neck, and/or muscular shoulders do not interfere with the motion of the machine. A machine component, such as the biteblock or side guide, should never be removed on a routine basis;

this can only lead to poor imaging and diminished performance unintended by the manufacturer. The fastest film/screen combination should always be used to minimize patient dose; currently, the authors recommend Kodak T-Mat G speed film with Kodak Lanex Regular Screens (Rochester, NY) or similar film/screen systems from other manufacturers.

## ZONE 1: THE DENTITION



**Figure 10.2 Zone 1: The Dentition.** The teeth should be separated and arranged with an upward curve posteriorly, producing a smile-like arrangement.



## OVERALL ASSESSMENT OF THE PANORAMIC FILM

Too many dental health-care workers are taught to try and identify all positioning errors by looking at the teeth. Although this is useful and encouraged, some patients are missing their anterior teeth or are edentulous, and in these cases another method to identify errors must be used. Therefore, with each error, what happens to the teeth will be described, and then several other undesirable anatomical changes that can be used to identify each error will be explained. This allows the recognition of errors even when the teeth look “pretty good” and in persons who have no or missing teeth. In the mind’s eye, the operator should divide the panoramic radiograph into six zones (Figs. 10-2–10-5): three are in the midline and three are bilateral on each side (see p. 220–223).

### Zone 1: Dentition (Fig. 10-2)

The teeth should be arranged with a smile-like upward curve posteriorly and be separated from each other. This separation produces an interocclusal space in the radiograph. The anterior teeth should be neither too large nor so narrow as to create “pseudospaces” between them.

The posterior teeth should not be larger or smaller on one side than the other, nor should there be excessive overlap of the premolars on one side versus the other. The apices of the maxillary or mandibular anterior teeth should not be cut off, nor should the crowns of the anterior teeth appear fractured or obscured.

### Zone 2: Nose-Sinus (Fig. 10-3)

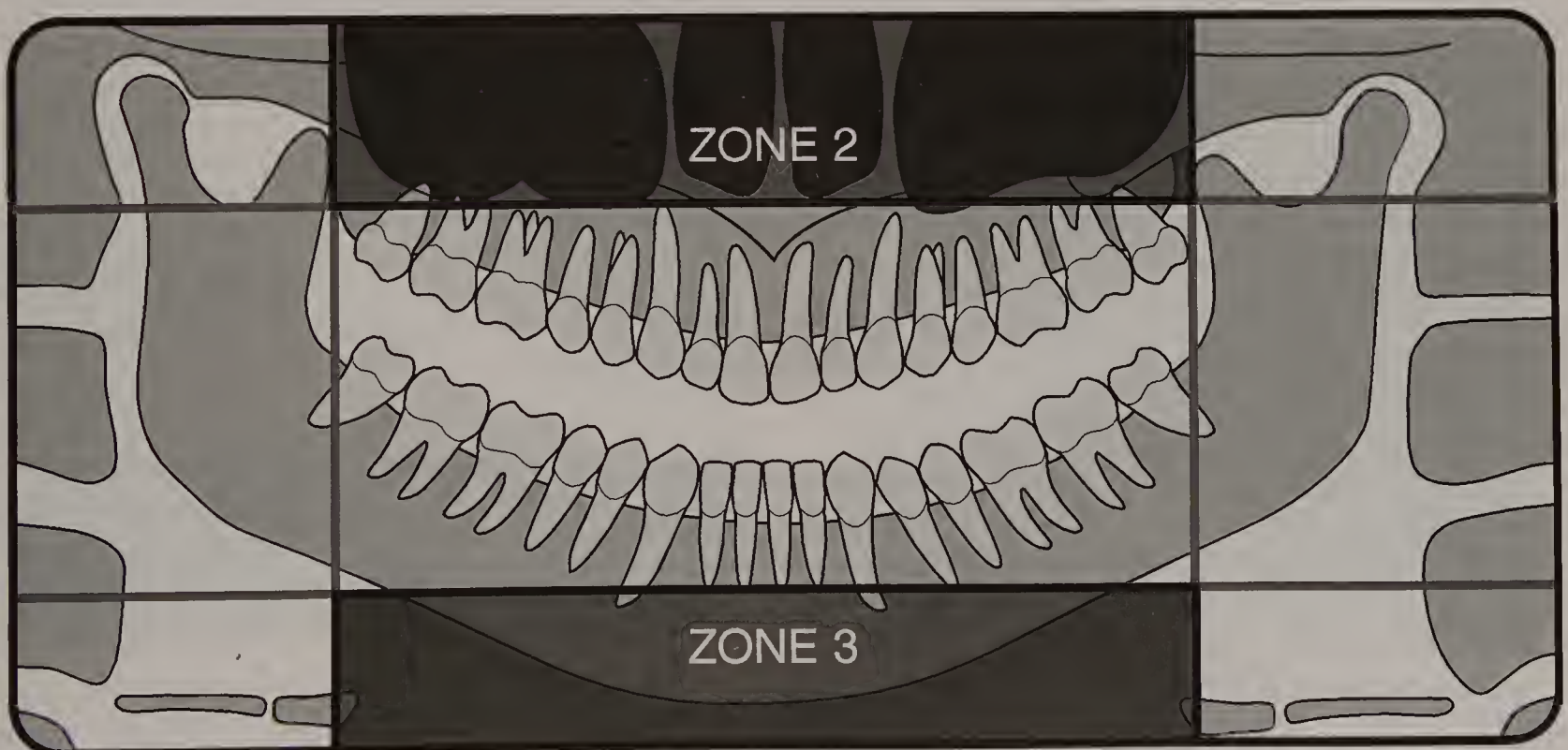
The images of the inferior turbinates and their surrounding air spaces (meati) should be contained within the nasal cavity. The soft tissue of the nose cartilage should not be seen. The hard palate shadow (double image) and sometimes the ghost images of the palate must be seen within the maxillary sinuses, well above the apices of the posterior teeth. The tongue should be in contact with the hard palate, with no intervening air between these structures.

### Zone 3: Mandibular Body (Fig. 10-3)

The inferior cortex of the mandible should be smooth and continuous. The double image, or ghost image of the body of the hyoid, should be absent in this area. The midline area should not be overly enlarged superiorly-inferiorly.

## ZONE 2: NOSE AND SINUS

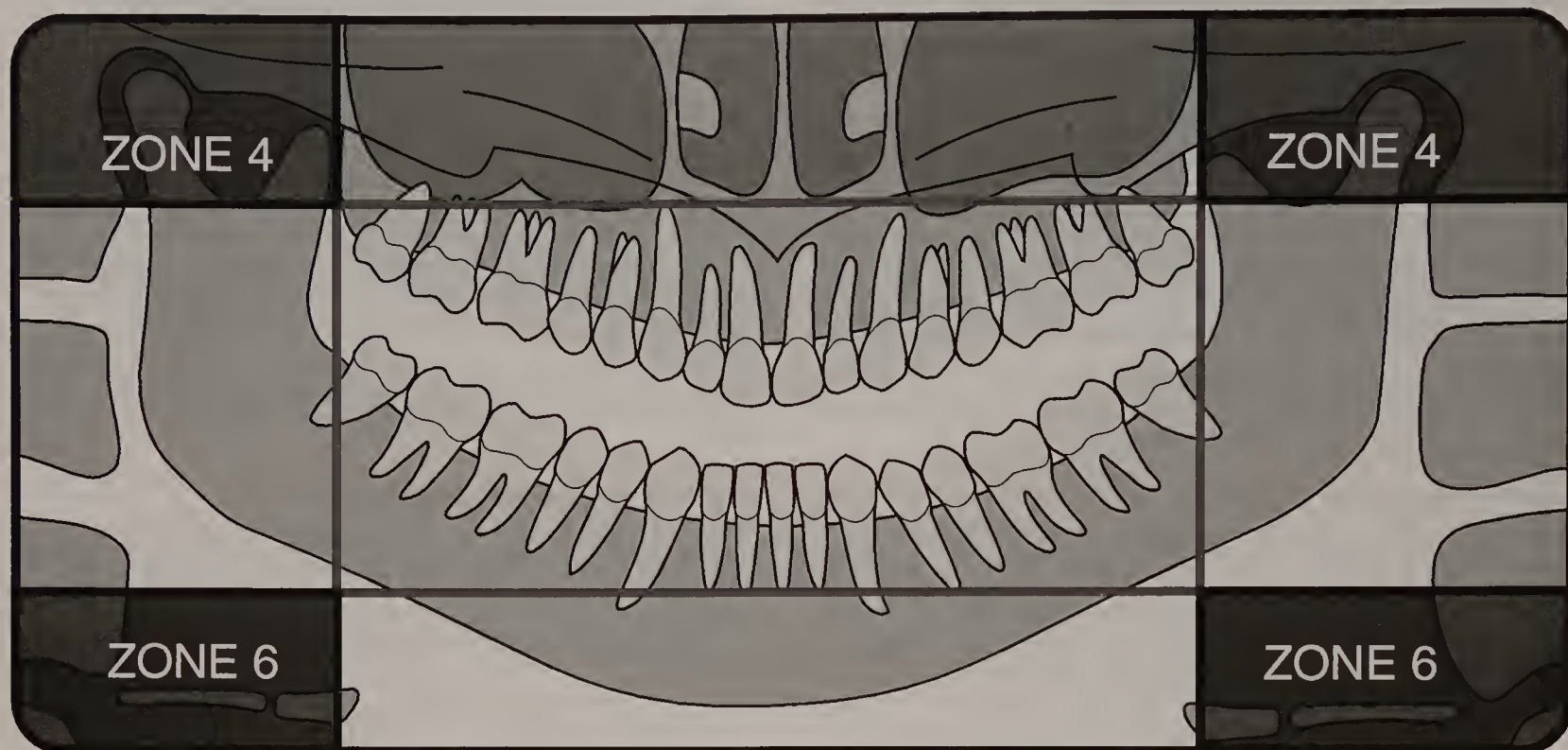
## ZONE 3: MANDIBULAR BODY



**Figure 10.3 Zones 2 and 3: Nose and Sinus and Mandibular Body.** Zone 2: The inferior turbinates should be within the nasal fossa, and the hard palate shadows above the root apices. Zone 3: The inferior cortex of the mandibular body should be smooth and uninterrupted.

## ZONE 4: TMJ

## ZONE 6: HYOID



**Figure 10.4 Zones 4 and 6: Four Corners.** Zone 4: The condyles are centered in this zone and are equal in size and position bilaterally. Zone 6: The hyoid bone should remain in this zone.

### Zones 4 and 6: Four Corners; Condyles and Hyoid (Fig. 10-4)

Zone 4 contains the condyles bilaterally. The condyles should be more or less centered within the zone and not move off the top or lateral edges of the film. The condyles should be of equal size and on the same horizontal plane (i.e., one condyle should not be higher or lower than the other). Zone 6 contains the body of the hyoid bone and sometimes the greater horn. It should appear as a double image equal in size bilaterally; although it may touch the mandible, it should not spread across the mandible.

### Zone 5: Ramus-Spine (Fig. 10-5)

The ramus of the mandible should be the same width bilaterally. The spine, although usually not seen, may be present so long as it does not superimpose on the ramus. When present, the distance between the spine and ramus should be the same bilaterally.

### PURPOSEFUL PATIENT POSITIONING ERRORS

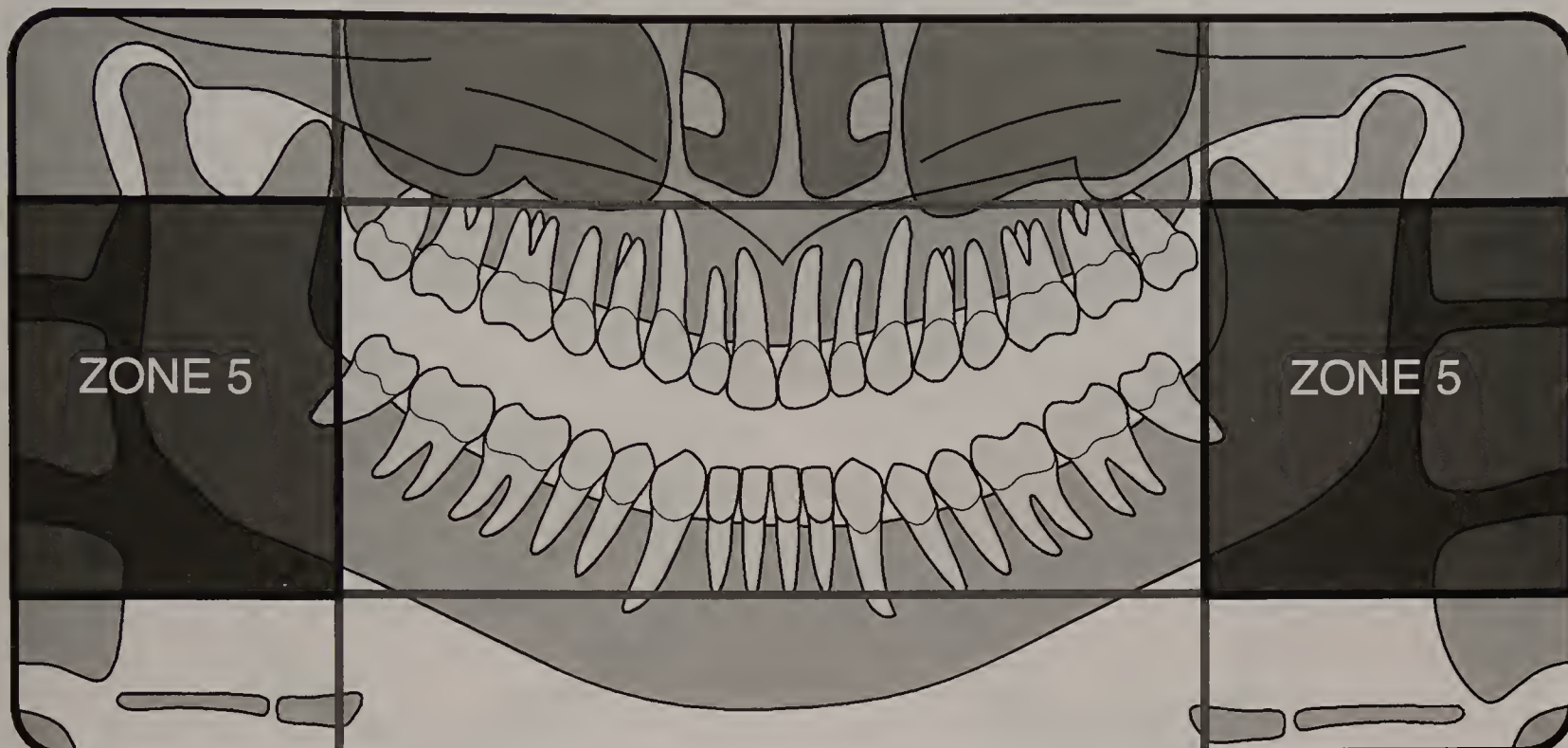
Because in most machines the focal trough or layer cannot be adjusted to the patient or be moved, it is critically important to position the patient in exactly the right place. However, with some errors, patient malpositioning will be done on purpose to better visualize a specific anatomical region. The following table describes useful panoramic errors.

**Table of Useful Panoramic Errors**

| Error           | Region of Improved Imaging  |
|-----------------|-----------------------------|
| Too far forward | Nasal fossa and sinus       |
| Chin too low    | Anterior maxilla and teeth  |
| Chin too high   | Anterior mandible and teeth |



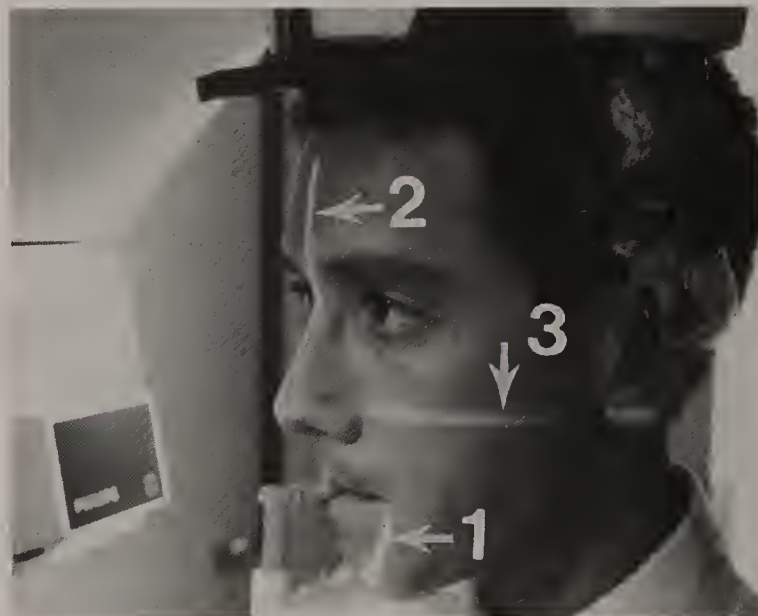
## ZONE 5: RAMUS-SPINE



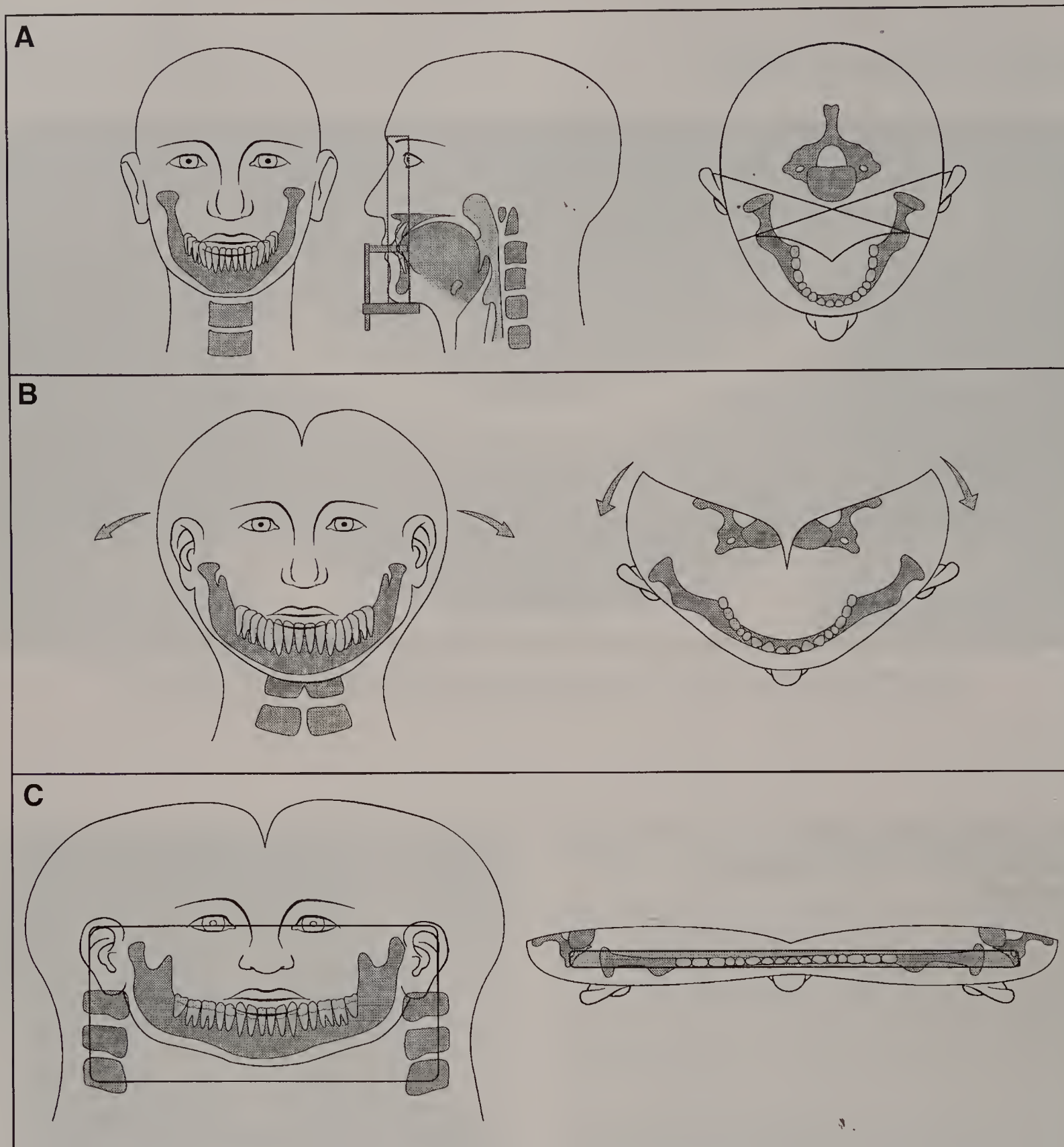
**Figure 10.5 Zone 5: Ramus-Spine.** The ramus should be equal in width bilaterally, and the spine should not be superimposed on the ramus.

## TROUBLESHOOTING PANORAMIC POSITIONING ERRORS

As previously mentioned, panoramic positioning errors may occur in association with the five steps in the panoramic technique. The correct procedure will be described first; then, the several errors occurring with that step will be described. Positioning lights (Fig. 10-6) serve as an aid to assure correct patient positioning before making an exposure. In a properly positioned patient, structures are projected onto the image with specific interrelationships to each other to form a pattern one can recognize as an error-free exposure (Fig. 10-7).



**Figure 10.6 Patient Positioning Lights.** (1) This vertical light should be at the corner of the mouth. (2) This vertical light is centered on patient's midline. (3) This horizontal light should be on the Frankfort plane. Variations in positioning lights exist in different machines.



**Figure 10.7 Correct Panoramic Projection of Anatomical Structures.** (A) Note the relation of anterior teeth and biteblock groove to the image layer and the path of the rotation center. (B) The unfolding of anatomical structures in three dimensions, much like opening a book with the cover toward you. (C) The relative position of key anatomical structures within the panoramic image (*left*) and within the image layer (*right*).



## STEPS IN THE GENERIC PANORAMIC TECHNIQUE

Most machines are operated in a similar way. It is easy to learn to operate another machine once one machine has been mastered. Much like driving a car, if you can drive a Chevrolet, you can rent a Ford and adapt quickly to the new automobile.

The following are the five steps in the generic panoramic technique:

| Step | Panoramic Technique                                 |
|------|-----------------------------------------------------|
| 1    | Bite in groove.                                     |
| 2    | Close side guides.                                  |
| 3    | Position the chin.                                  |
| 4    | Stand patient upright.                              |
| 5    | Swallow, press tongue against palate, hold, expose. |

### Panoramic Technique Step 1: Bite In Groove (Fig. 10-8A, B)

#### *Have the Patient Bite in the Groove in the Biteblock*

The purpose of this step is to get the anterior teeth into the middle of the anterior part of the layer, to separate the dentition in the image, and to center the patient in the machine. All current machines have a biteblock; older discontinued Panorex machines do not have a biteblock, but the teeth are separated by placing several cotton rolls between the anterior teeth. Some machines come with a light that should be at the corners of the mouth or in the mid-canine region. This helps to avoid errors. One machine has an auto focus beam, whereby the machine will automatically adjust to the patient. If the biteblock is removed or the patient has missing anterior teeth, the upper and lower teeth will not be separated in the image.



**Figure 10.8 Step 1: Bite in Groove of Biteblock.** (A) Patient biting groove of biteblock. (If there are missing anterior teeth, cotton rolls must be used.) (B) A special chin rest (arrow) is available for edentulous patients.

### Panoramic Technique Step 2: Close Side Guides (Fig. 10-9)

#### *Close the Side Guides*

The purpose of this step is to get the posterior teeth into the middle of the layer on both sides and to fix the head in position to stabilize it during the exposure. The best machine design is one in which the side guides drop down from the top of the machine. These are not usually seen in the image; side guides coming up from the chin rest area are less desirable, as they are usually seen in the image and may interfere with assessment of patient landmarks. Some machines have frontal or temporal guides near the patient's forehead instead of the side guides or in addition to the side guides to further stabilize the patient's head. In machines with a light, the beam should be aligned along the midsagittal plane or midline of the patient's nose and face.

### Panoramic Technique Step 3: Position the Chin (Fig. 10-10)

#### *Position the Patient's Chin on the Chin Rest*

The purpose of this step is to ensure that the chin is tilted downward 4 to 7° to counter the 4- to 7°-upward angle of the x-ray beam. Most chin rests are on a slightly downward angle for this reason. Also, the chin rest supports the chin to steady the patient; thus, the chin should rest on the chin rest. Some machines come with a light that is aligned along some anatomical plane, such as the Frankfort plane (lower orbit to tragus) or the ala of the nose to tragus line. This will indicate correct positioning of the chin.



**Figure 10.9 Step 2: Close Side Guides.** The purpose of this step is to get the posterior teeth into the middle of the layer on both sides.



**Figure 10.10 Step 3: Position Patient's Chin on the Chin Rest.** The chin should be tilted slightly downward to counter the upward projection angle of the x-ray beam.



### Panoramic Technique Step 4: Stand Patient Upright (Fig. 10-11)

#### *Stand the Patient Upright or Sit the Patient Up Straight*

The purpose of this step is to straighten the cervical spine (neck) vertically. Here the patient is asked to advance the feet as far forward as possible and to stand erect; thus, he or she must hold on to the machine handles to avoid falling backward. When positioning the patient in the machine, the operator can guide the patient with gentle hand pressure in the small of the back to encourage the patient to stand erect. In sit-down machines, a similar procedure is followed; cushions may be inserted at the base of the spine to help the patient sit in a more erect position. Some machines have sensors at the film plane that will change the mA and/or kVp automatically to minimize the effects of this error; for example, the kVp is increased to penetrate the broader profile of the spine.



**Figure 10.11 Step 4: Stand the Patient Upright.** When positioning the patient in the machine, the operator can guide the patient with gentle hand pressure in the small of the back to encourage the patient to stand erect. The patient should hold onto the machine handles to avoid falling backward.

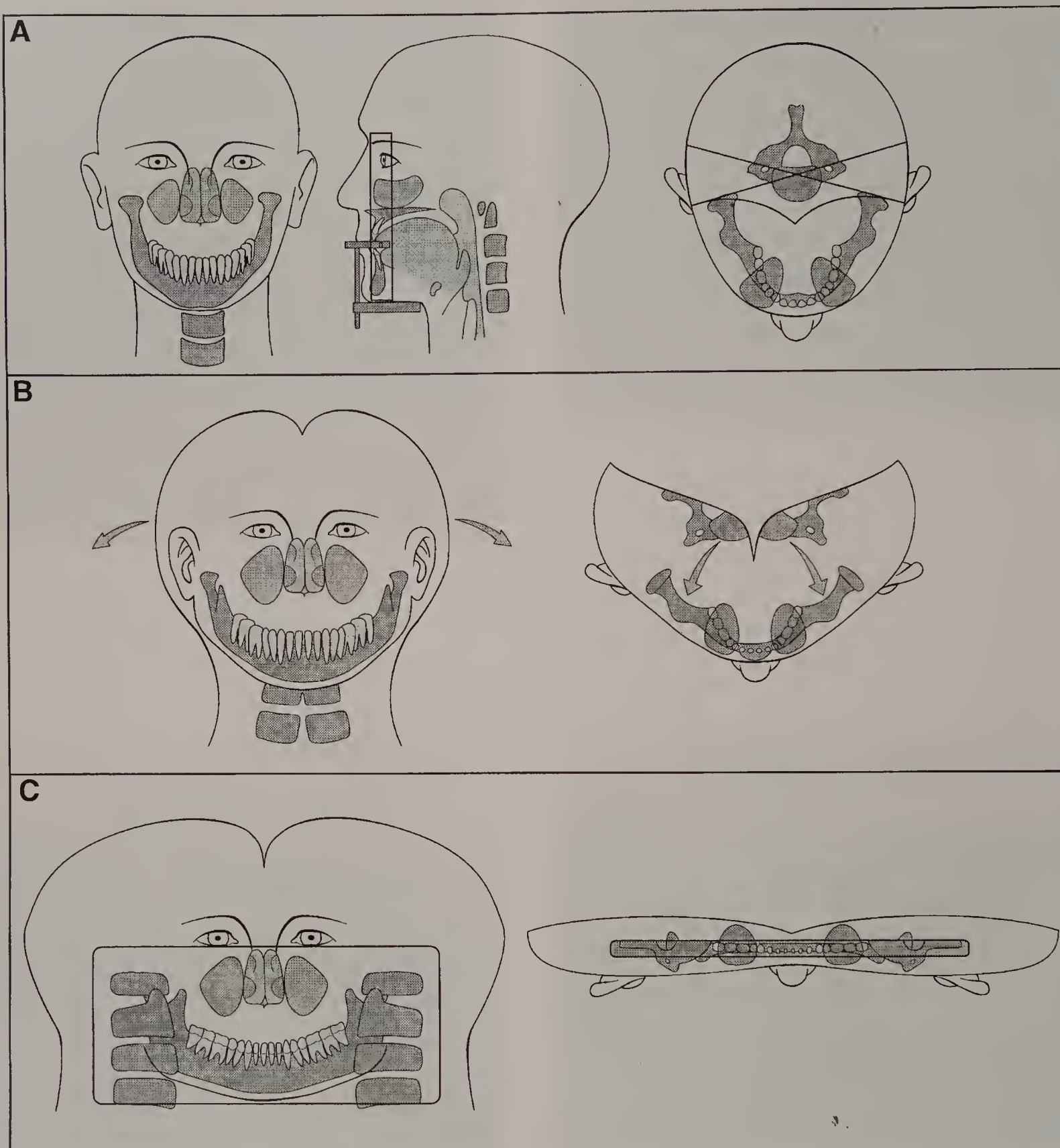
### Panoramic Technique Step 5: Swallow, Hold, Expose (Fig. 10-12)

#### *Have the Patient Place the Tongue on the Roof of the Mouth, Swallow, and Hold Still; Then Make the Exposure*

The purpose of this step is to be certain that the lips are sealed and the tongue is on the palate. This is done by asking the patient to swallow or suck on their tongue. Holding still is also important because the exposure time ranges from 14 to 22 seconds, depending on the machine. Patients with uncontrollable tremors are not good candidates for a panoramic radiograph. In most instances of movement, the patient is startled momentarily by the machine, especially if it glances against an item of clothing. Finally, the “exposure” means selecting the appropriate exposure factors for the patient’s size and build. The exposure time is fixed and not adjustable. The kVp is adjustable on all machines and is varied for patient size; the mA is adjustable on a few machines and may also need adjustment. Because each brand is a little different, it is necessary to use the specific exposure chart as provided by the manufacturer. Some machines adjust for incorrect exposure values automatically due to the function of a sensor at the film plane.

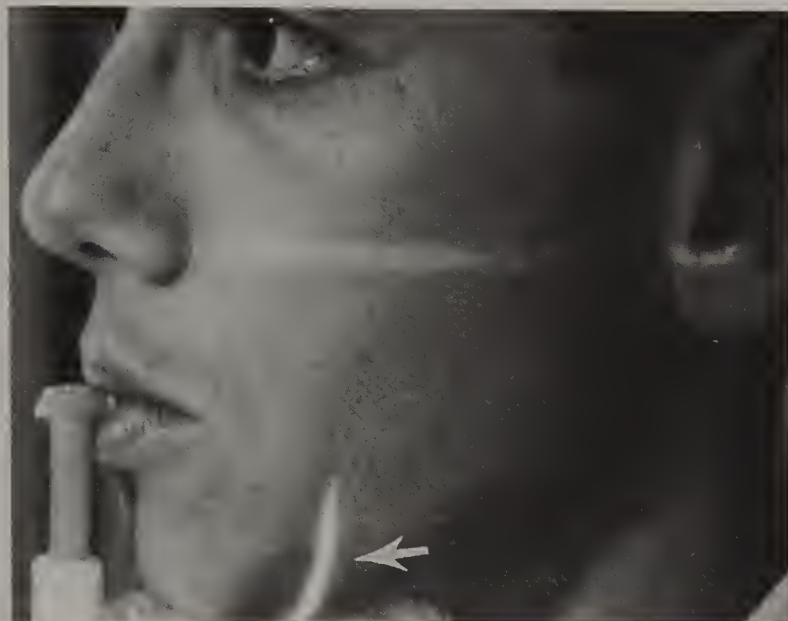


**Figure 10.12 Step 5: Swallow, Press Tongue Upward, Hold, Expose.** Note that the patient’s lips are tightly sealed around the biteblock. The kilovolts have been selected at the touch pad, and the operator is ready to stand behind a protective barrier and make the exposure.



**Figure 10.13 Patient Positioned Too Far Forward.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D) Photograph of a patient biting too far forward. Note positioning light (arrow). (E, F) Radiographs depicting typical features of this error. Note improved nasal fossa and sinus regions in the edentulous radiograph.





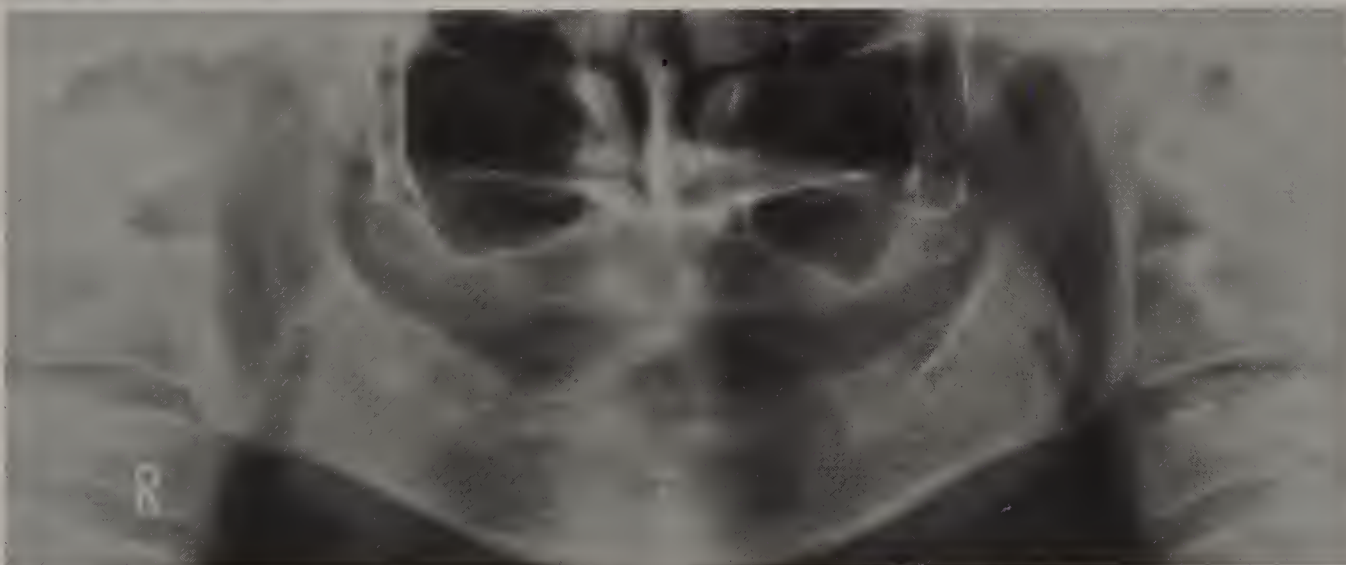
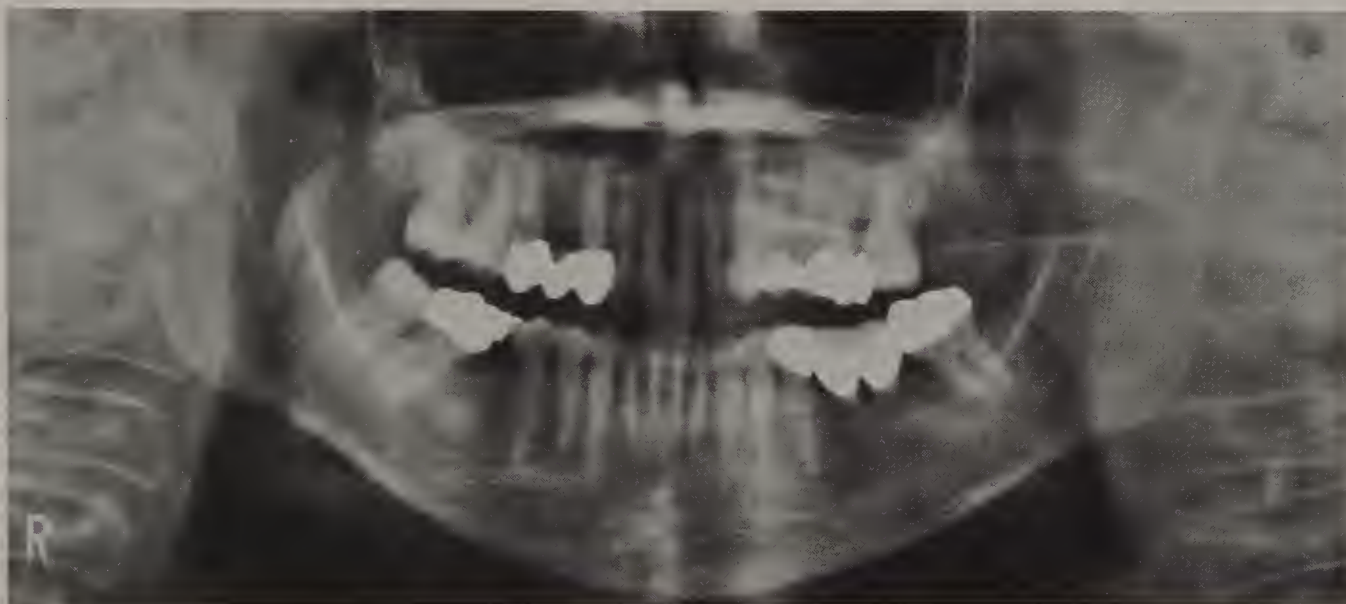
### Step 1: Bite in Groove—Error No. 1 (Fig. 10-13A-F)

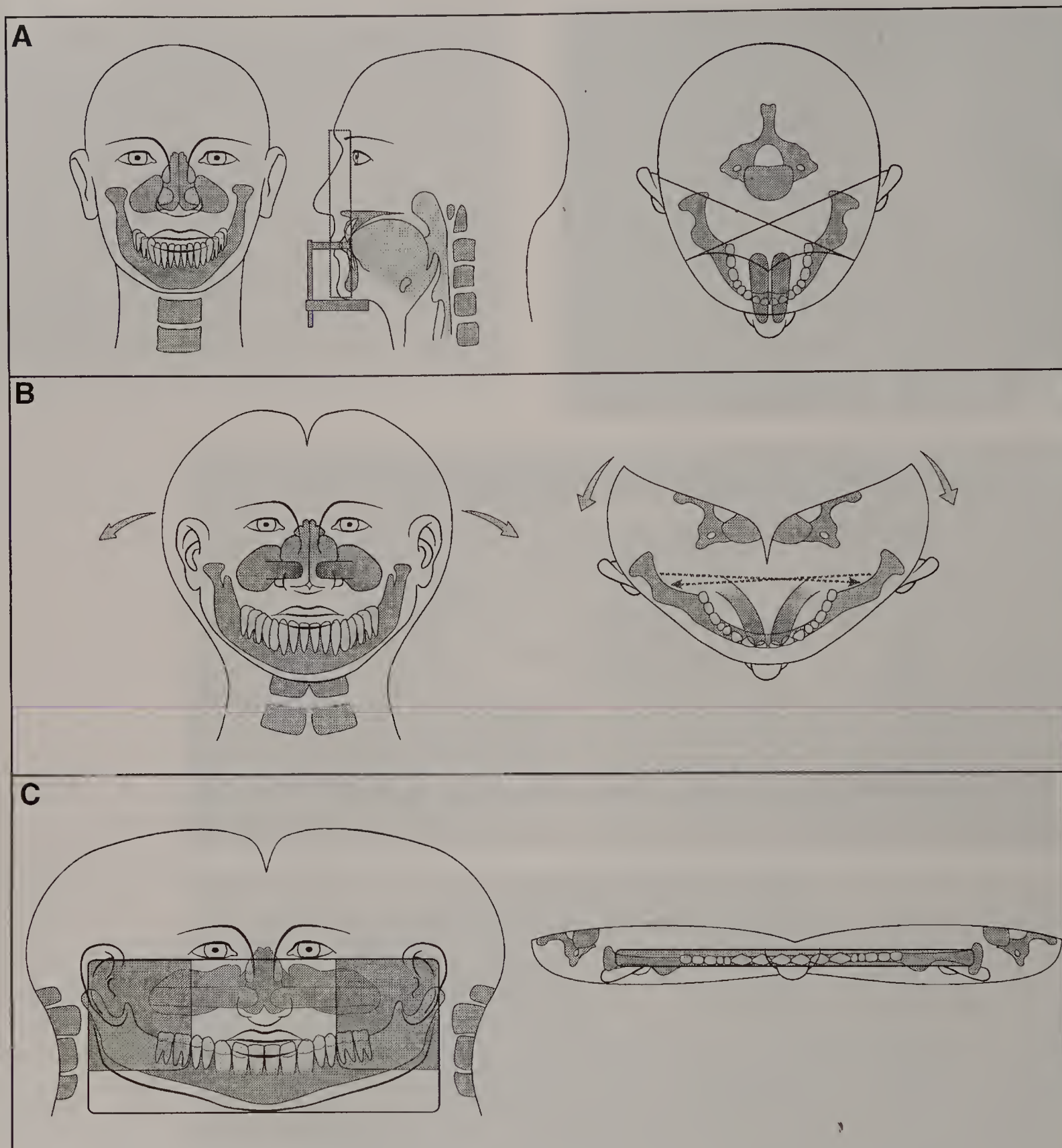
#### *The Patient Is Positioned Too Far Forward*

**Zone 1: Dentition.** The anterior teeth (especially the lowers) are narrowed, sometimes with pseudospaces between the teeth. Sometimes the crowns of the anterior teeth appear fractured because they are cut out of the image layer.

**Zone 5: Ramus-Spine.** The cervical spine is superimposed on the ramus and condyles symmetrically on both sides. Overall, the whole patient appears to have been narrowed with respect to the size of the panoramic film.

**Too Far Forward Purposeful Error.** Here the error results in an improved image of the nasal cavity and maxillary sinus. This radiograph makes it easier to detect sinus disease, extension of sinus disease into the nose, and deviated nasal septum.





**Figure 10.14 Patient Positioned Too Far Back.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D) Photograph of patient biting too far back. (E, F) Radiographs depicting typical features of this error.





### Step 1: Bite in Groove—Error No. 2 (Fig. 10-14A-F)

#### *The Patient Is Positioned Too Far Back*

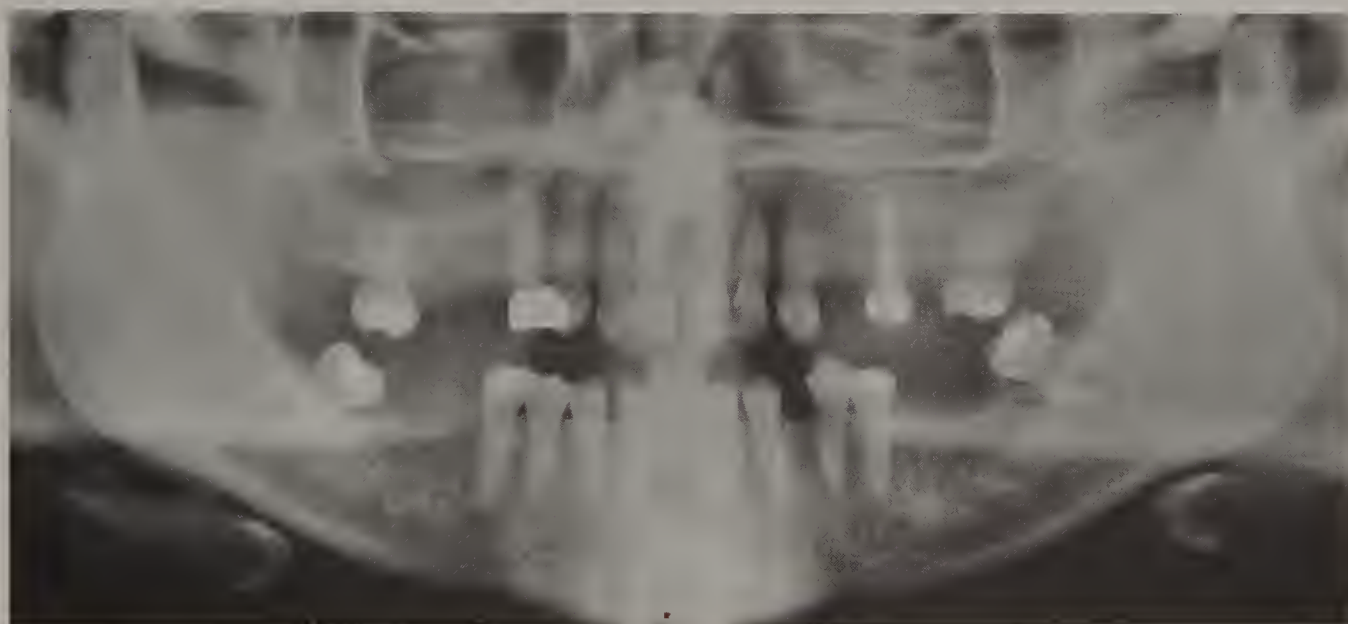
**Zone 1: Dentition.** The anterior teeth (especially the lowers) are widened. Widening of teeth is sometimes hard to judge.

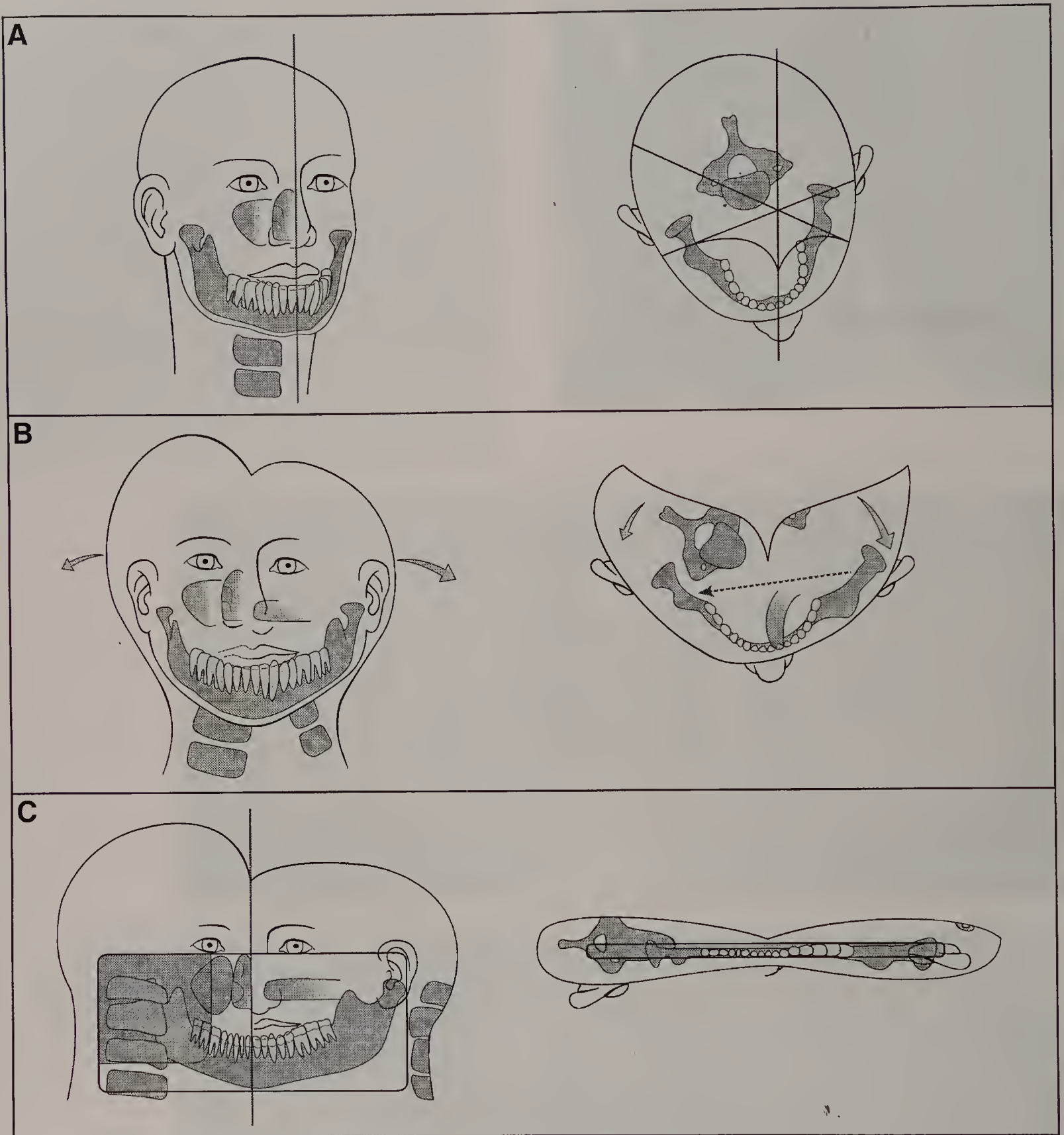
**Zone 2: Nose-Sinus.** The soft tissue image of the nose cartilage is seen. The lower turbinate and meati are spread out across the maxillary sinus bilaterally.

**Zone 3: Mandibular Body.** The inferior cortex of the mandible should be smooth and continuous. The double image, or ghost image, of the body of the hyoid should be absent in this area.

**Zone 4: Condyles.** The condyles appear close to or off the lateral edges of the film. The soft tissue outline of the cartilage of the pinna of the ear and earlobe can be seen.

**Zone 5: Ramus-Spine.** The ghost images of the contralateral rami are superimposed on the posterior molars and rami symmetrically bilaterally. Overall, the patient's image appears too large for the film.





**Figure 10.15 Patient Is Twisted or Turned in the Machine.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D) Photograph showing that the patient is twisted and that the side guides are open. (E, F) Radiographs depicting features of this error.





### Step 2: Close Side Guides—Error No. 1 (Fig. 10-15A-F)

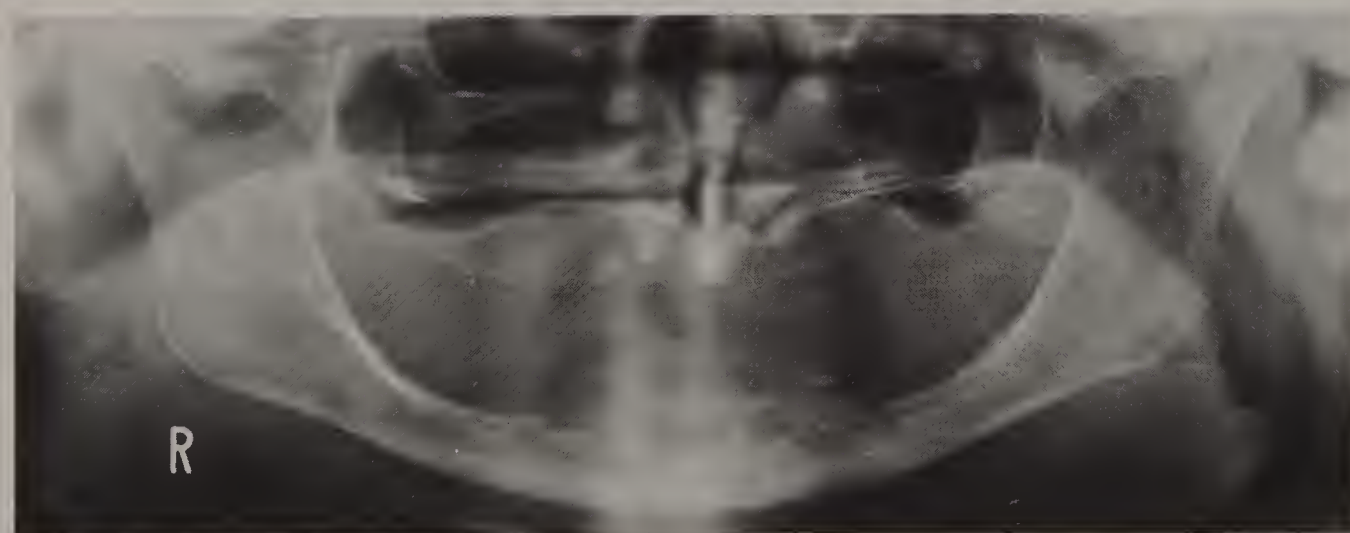
#### *The Patient Is Twisted or Turned in the Machine*

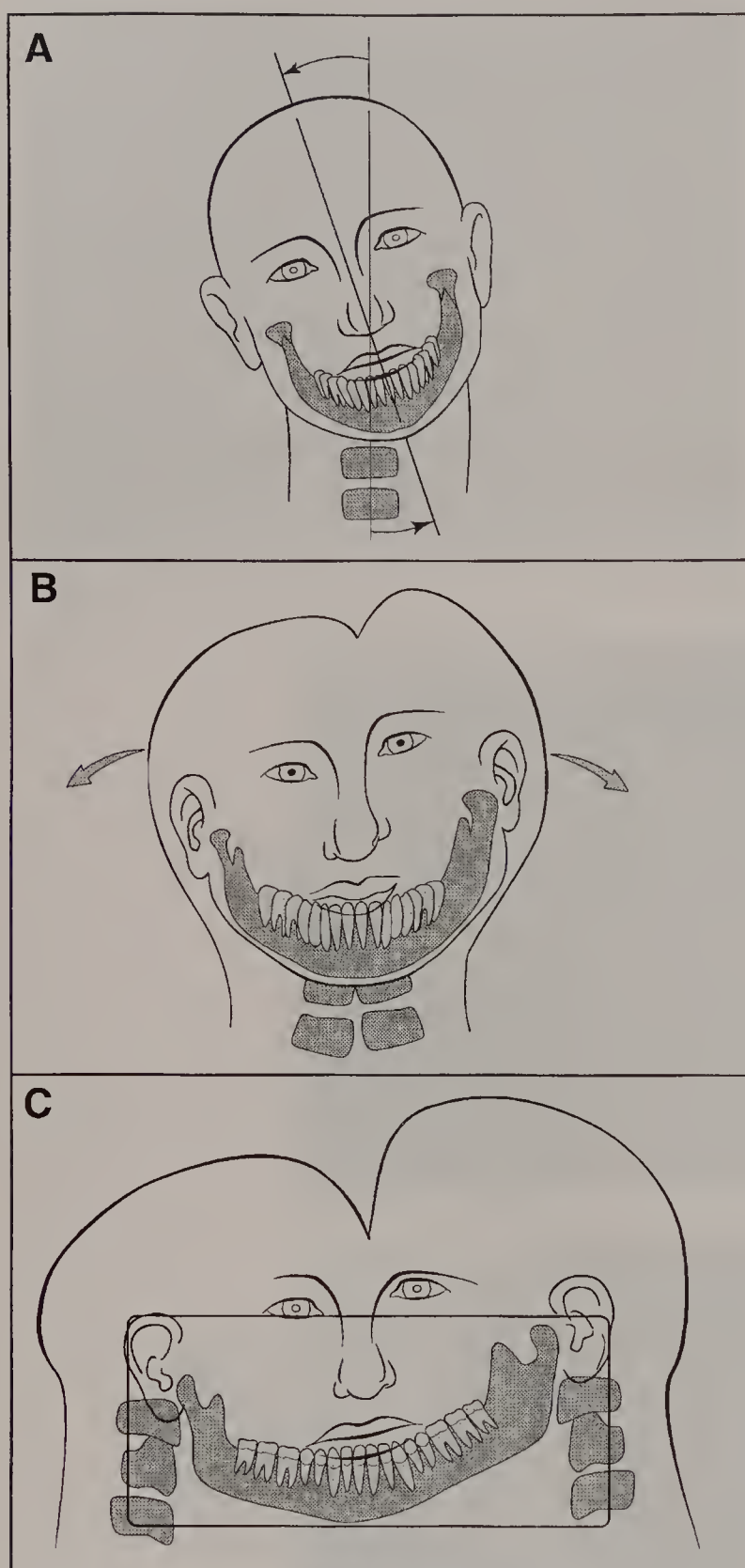
**Zone 1: Dentition.** The posterior teeth on one side are widened and overlapped interproximally. On the other side, the posterior teeth are narrowed.

**Zone 2: Nose-Sinus.** On the side with the wide ramus, the inferior turbinate and meati are spread out across the maxillary sinus; the opposite maxillary sinus may have an improved image.

**Zone 4: Temporomandibular Joint (TMJ).** On the side with the wide ramus, the earlobe can be seen.

**Zone 5: Ramus-Spine.** On the side with the wide posterior teeth, the ramus is widened; on the other side, the ramus is narrowed and intersected by the ghost image of the contralateral ramus—the spine may approach or superimpose on the ramus on this side.





**Figure 10.16 Patient Tilted in the Machine.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D, E) Photographs of patient's head tilted in the machine. Note side guides are open and malalignment of positioning light, as viewed through the machine mirror. (F) Radiograph depicting the features of this error.

### Step 2: Close Side Guides—Error No. 2 (Fig. 10-16A–F)

#### *The Patient's Head Is Tilted in the Machine*

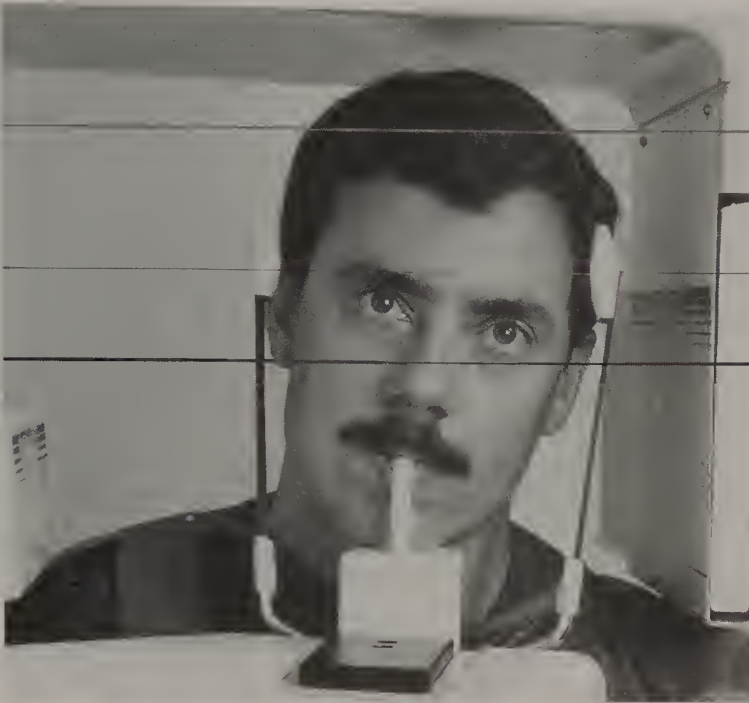
**Zone 1: Dentition.** The posterior teeth may be slightly widened on one side, with a widening gap between the upper and lower teeth in a posterior dentition; on the other side, the interocclusal gap is narrowed.

**Zone 3: Mandible Body.** The lower edge of the mandible on one side is almost horizontal; on the side with the widened interocclusal gap, the mandible is enlarged and the lower edge appears to be directed upward above the horizontal plane.

**Zone 4: TMJ.** On the side with the widened interocclusal gap, the condyle is enlarged and above the contralateral condyle, which is smaller and lower in the image.

In general and especially throughout the upper one-third of the image (Zones 2 and 4), the bony details appear fuzzy or streaked, rendering them anatomically indistinguishable.





D



E



F

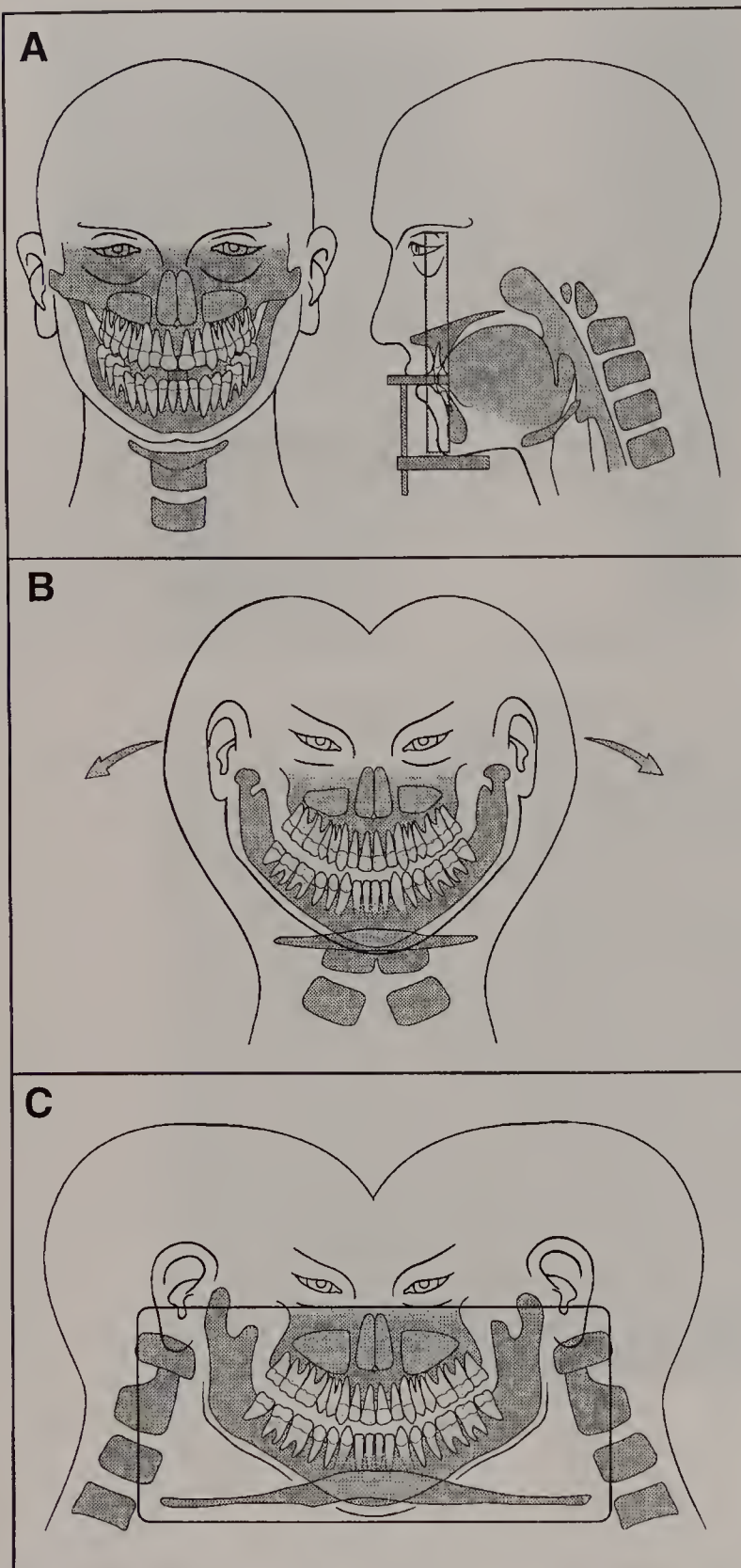
**Step 3: Position the Chin—Error No. 1 (Fig. 10-17A-F)*****The Chin Is Tipped Too Low***

**Zone 1: Dentition.** The “smile” line created by the interocclusal gap is exaggerated. The apices of the mandibular anterior teeth are “cut-off.” The maxillary anterior teeth are better than in the normal projection

**Zone 3: Mandible.** The mandible is widened vertically in the anterior region; and there is poor imaging of the trabecular pattern. The mandible is traversed by the elongated double image and/or ghost of the hyoid bone.

**Zone 4: TMJ.** The condyles approach the upper edge of the film or are cut off by the upper edge of the film symmetrically bilaterally.

**Chin Tipped Too Low Purposeful Error.** This error is made to improve the image of the maxillary anterior region, especially the teeth and surrounding bone.



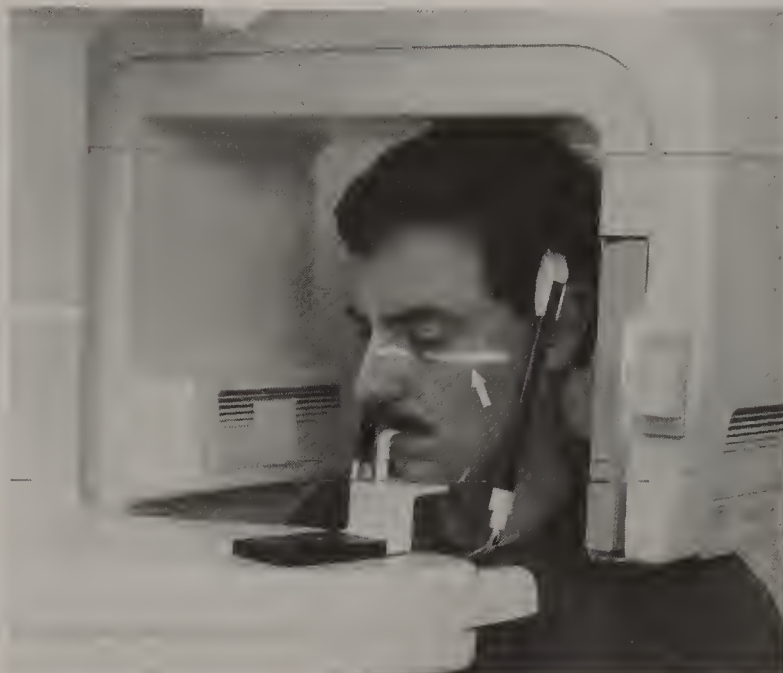
**Figure 10.17 Patient's Chin Is Tipped Too Low.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D, E) Photographs of patients whose chins are tipped too low. Note malalignment of positioning light (arrow in E). (F) Radiograph depicting the features of this error.



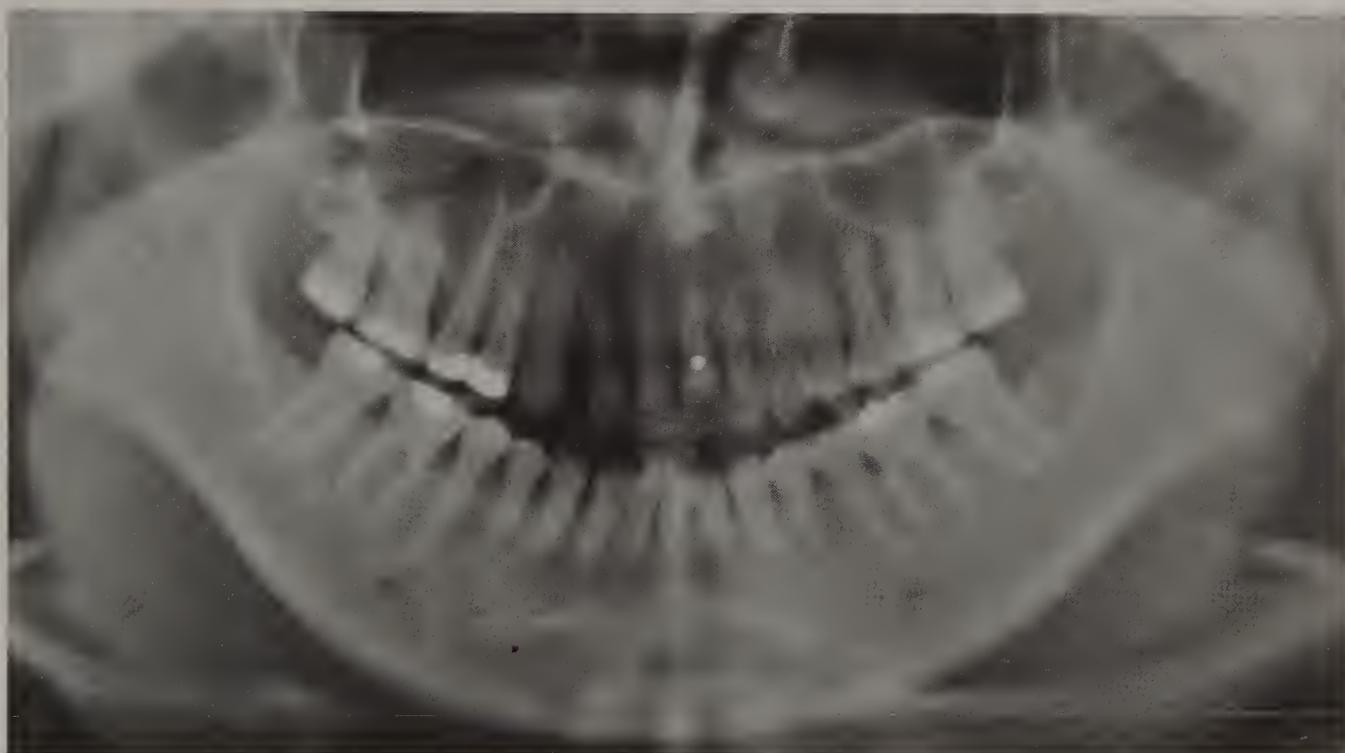
D

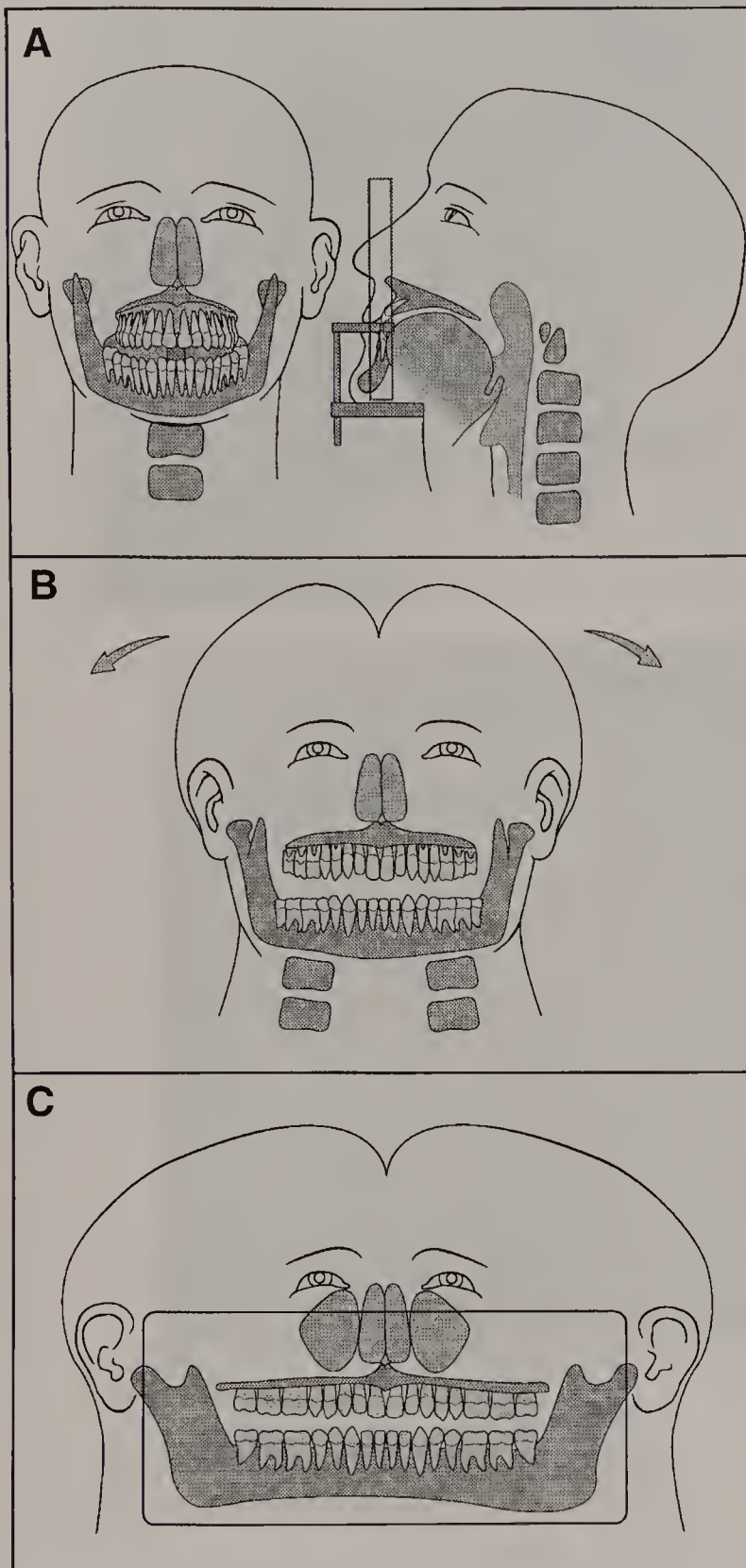


E



F





**Figure 10.18 Patient's Chin Is Tipped Too High.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D) Photograph of patient's chin tipped too high. Note malalignment of positioning light (arrow). (E, F) Radiographs depicting the features of this error.

### Step 3: Position the Chin—Error No. 2 (Fig. 10-18A-F)

#### *The Chin Is Tipped Too High*

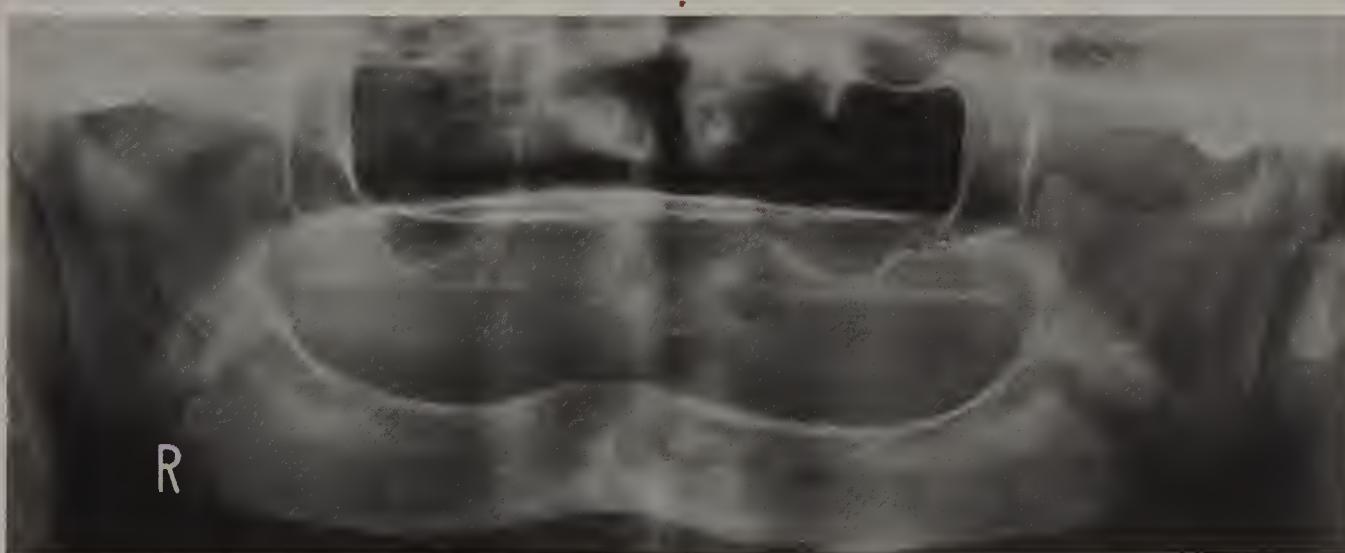
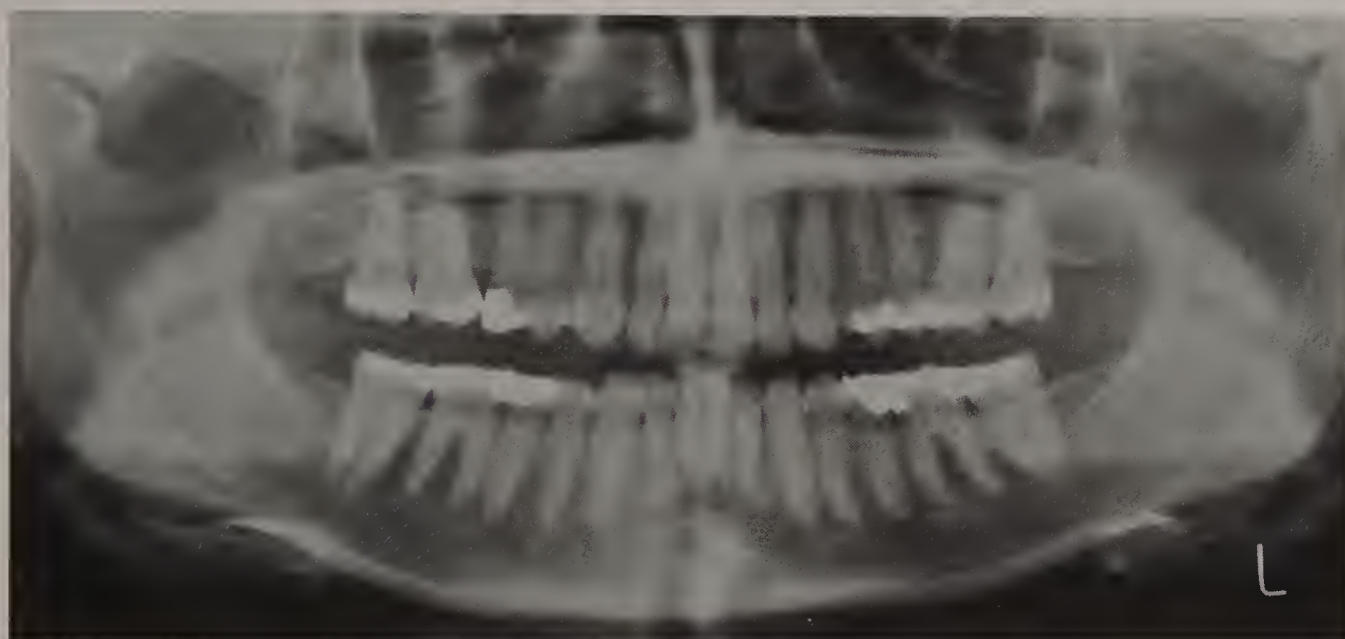
**Zone 1: Dentition.** The “smile” line created by the interocclusal gap is lost entirely; the occlusal plane appears flat or even in a reverse curve or “sad” configuration. The apices of the maxillary anterior teeth are “cut-off.” The mandibular anterior teeth are better than in the normal projection.

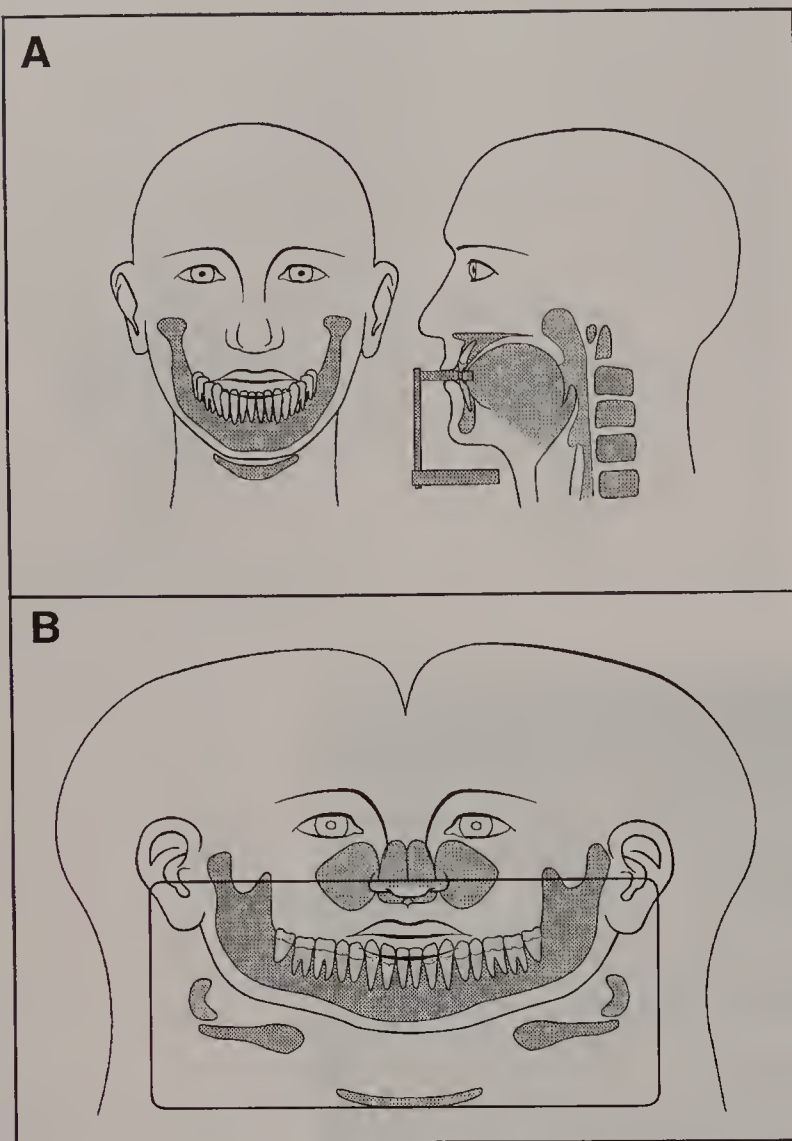
**Zone 2: Nose-Sinus.** The real, double, and ghost images of the palate form a widened, prominent, radiopaque line that is projected downward to approximate or superimpose on the apices of the maxillary teeth.

**Zone 4: TMJ.** The condyles approach the lateral edges of the film or are projected off the edges of the film symmetrically bilaterally.

**Chin Tipped Too High Purposeful Error.** This error is made to improve the image of the mandibular anterior region, especially the teeth and surrounding bone.







#### Step 4: Stand the Patient Upright—Error No. 1 (Fig. 10-19A-E)

##### *The Chin Is Not on the Chin Rest*

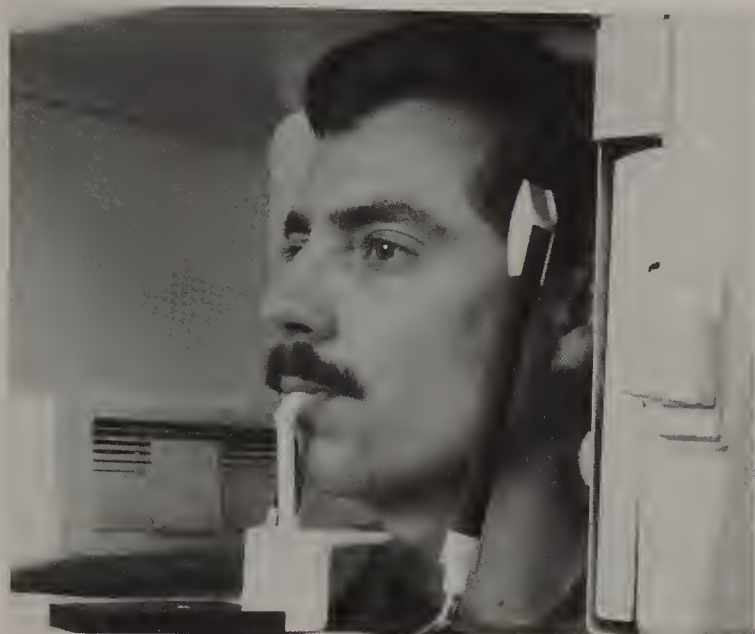
**Zone 1: Dentition.** This error has no effect on the dentition.

**Zones 2 and 4: Nose-Sinus and TMJ.** These zones across the upper one-third of the film contain structures from lower down that are “cut-off” by the upper edge of the film. The lower edge of the film corresponds with the lower edge of the chin rest; naturally, when the operator asks the patient to stand upright, the chin can come off the chin rest. The machine must now be brought up to meet the chin.

**Zones 3 and 6: Mandible Body and Hyoid.** These zones across the bottom one-third of the film do not contain the structures; instead, only soft tissue shadows and sometimes the unoccupied chin rest are centered at the lower edge of Zone 3.

**Figure 10.19 Chin Is Not on the Chin Rest.** (A, B) Diagrams show incorrect projection of anatomical structures. (C) Photograph of a patient who does not have his chin on the chin rest. (D, E) Radiographs depicting features of this error.

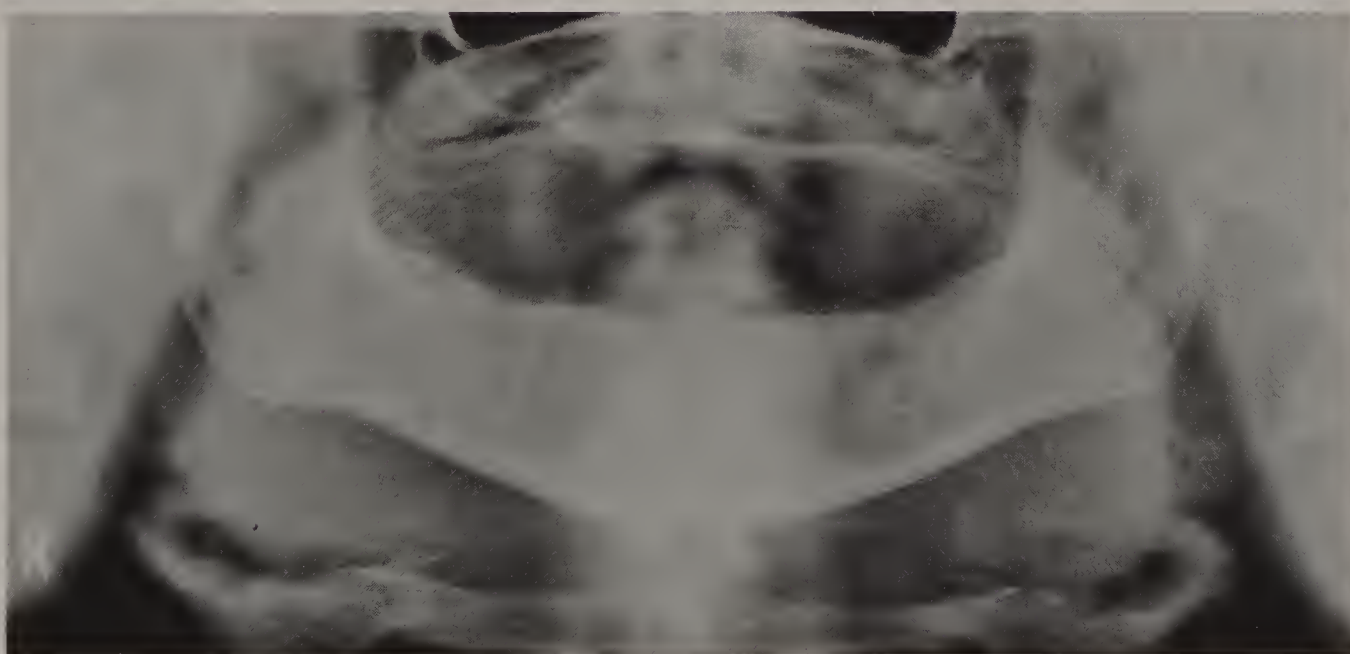




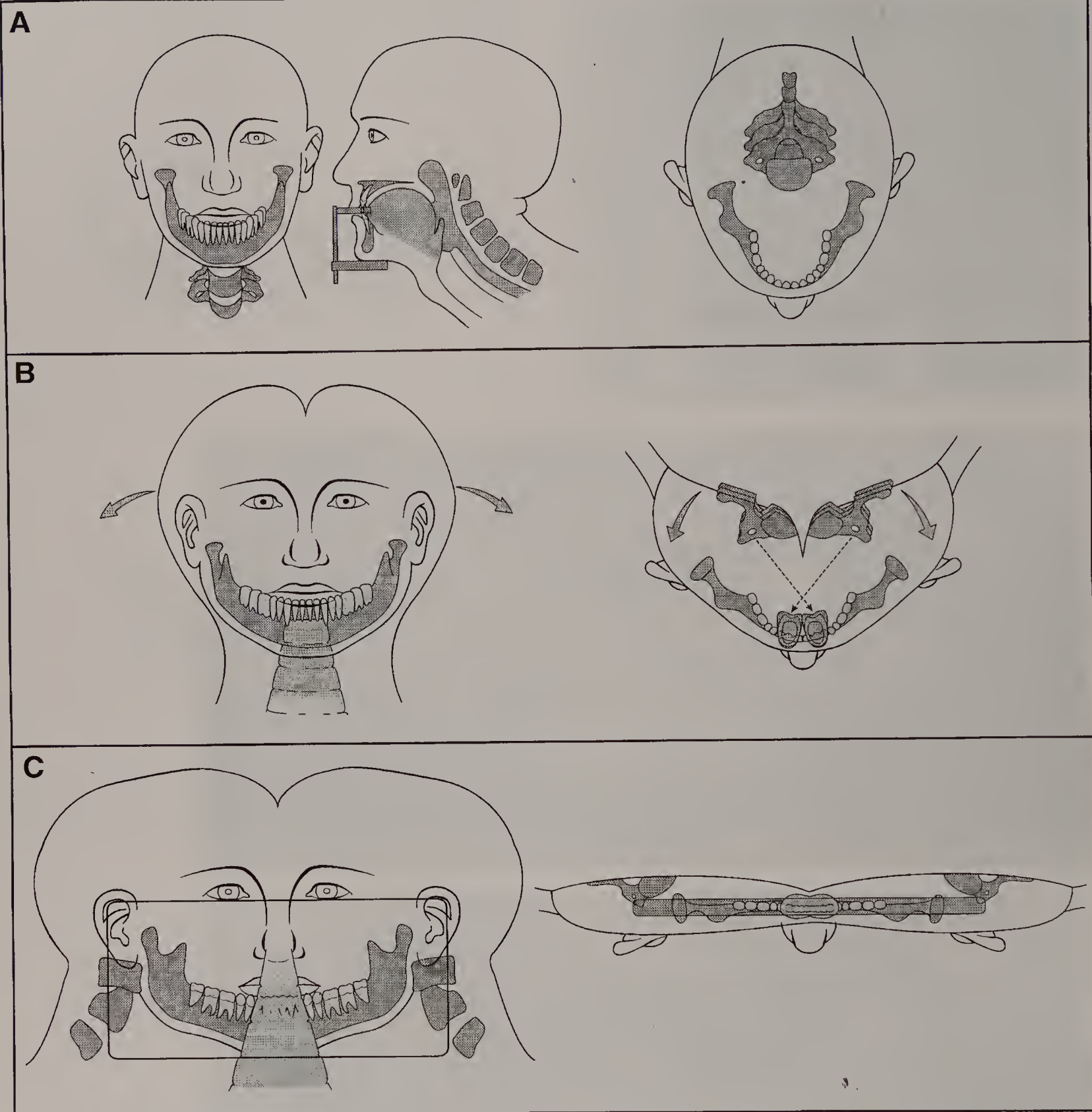
C



D

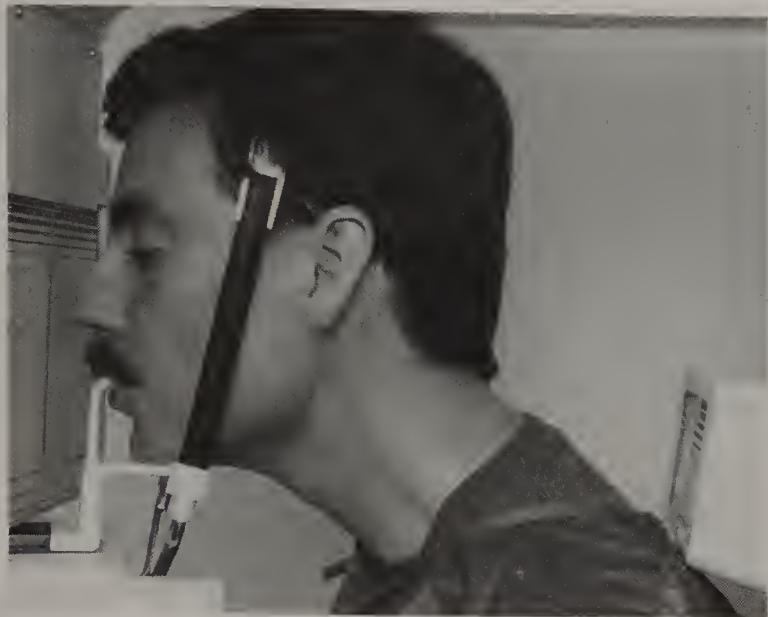


E



**Figure 10.20 Patient Is Slumped.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D) Photograph of patient slumped in x-ray machine. (E, F) Radiographs depicting features of this error.



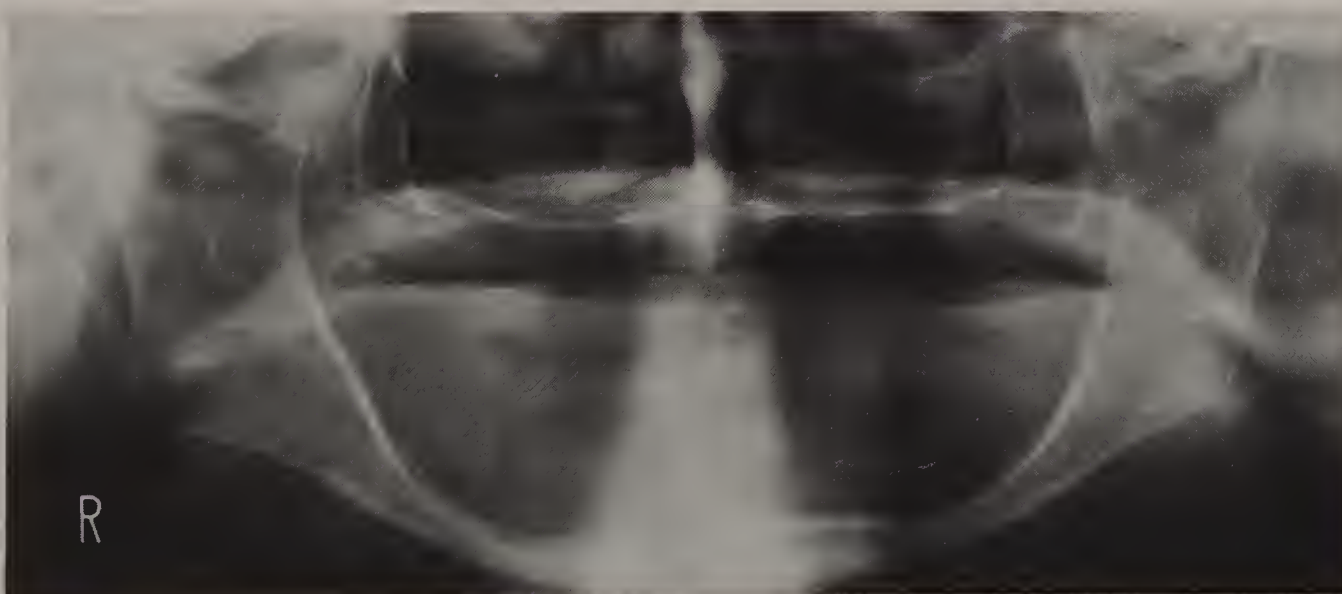
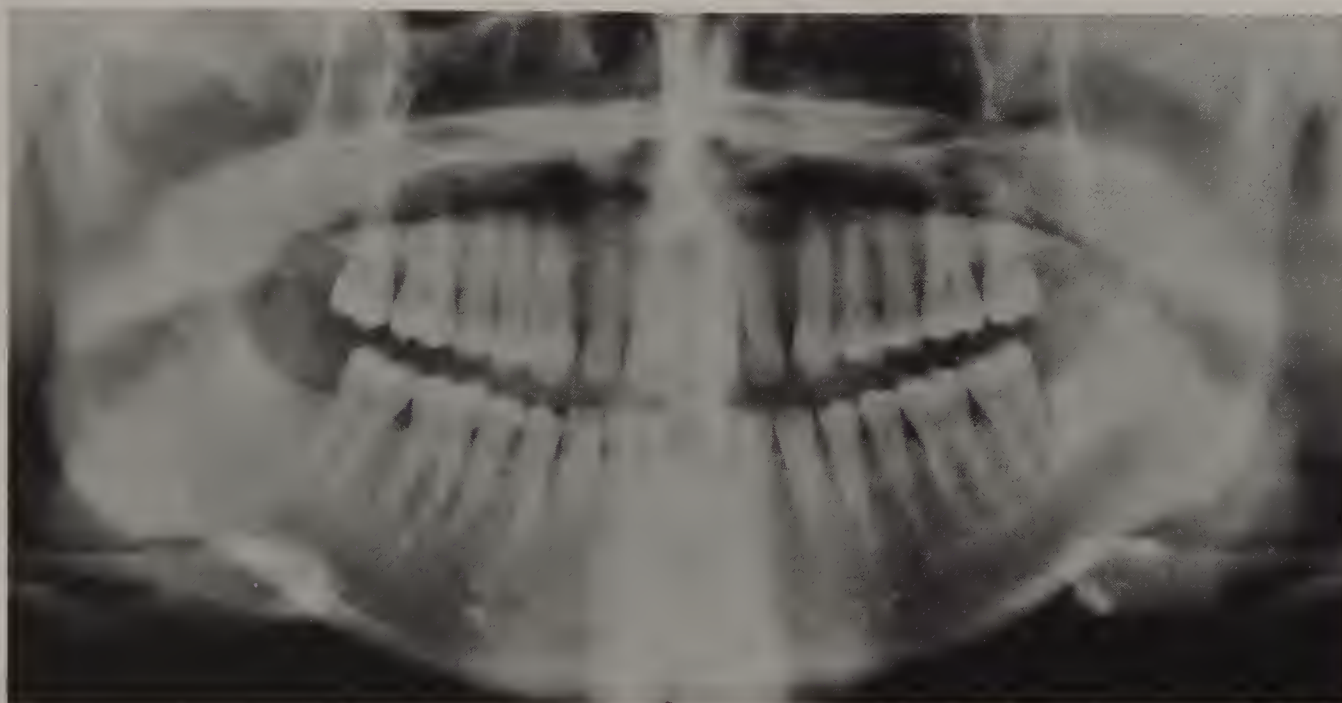


**Step 4: Stand the Patient Upright—Error No. 2 (Fig. 10-20A–F)**

***The Patient Is Slumped***

**Zone 1: Dentition.** The anterior teeth are difficult to see, especially the lowers, as the ghost radiopaque image of the spine has been superimposed on this area and obliterated it. There are no effects on any other zones with this error. Slumped means the patient's neck is stretched forward on a slant; this causes a ghost image of the spine to be produced in the middle of the film.

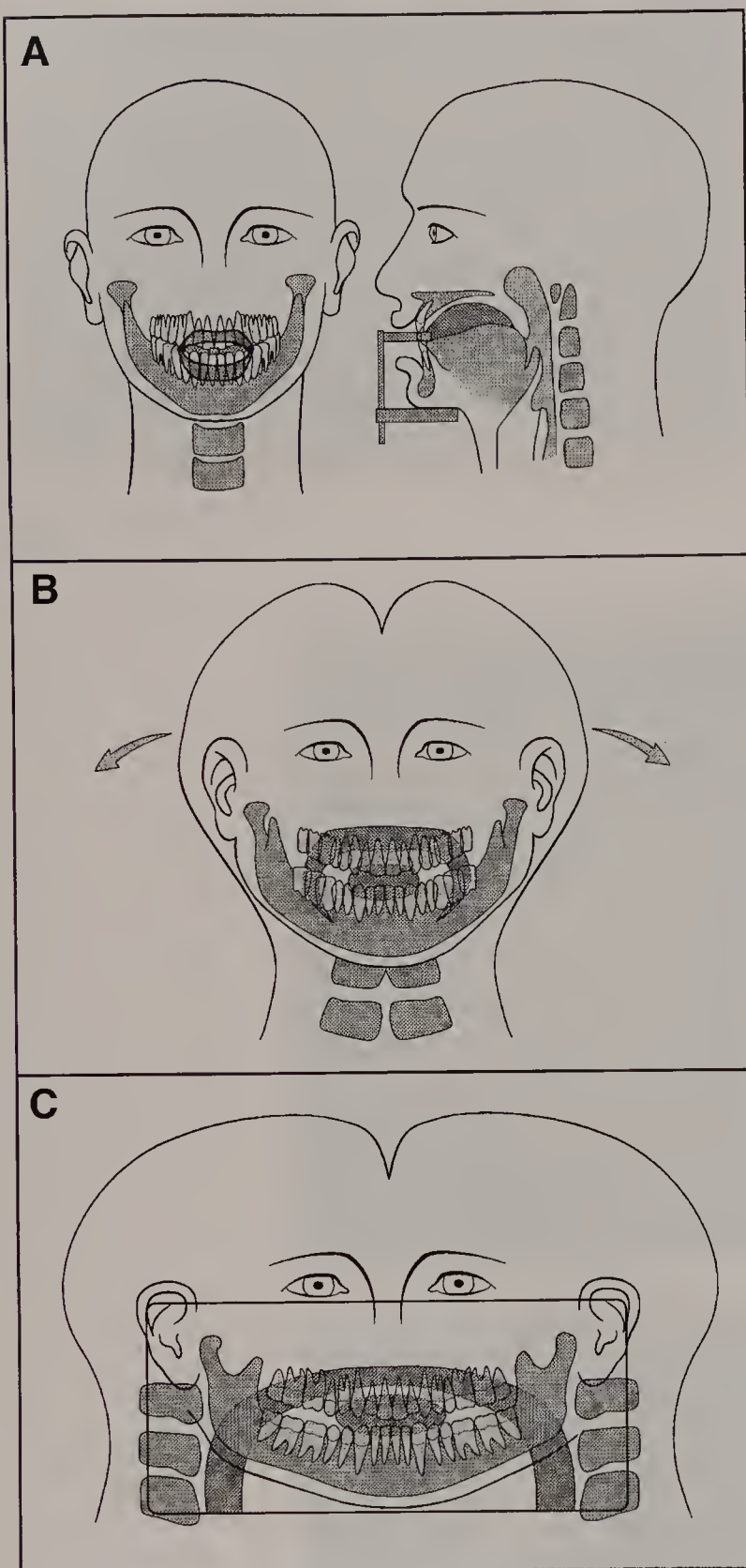
**Zone 3: Mandibular Body.** The ghost image of the spine extends downward beyond the mandibular teeth to obscure the mid-portion of the mandible.



**Step 5: Swallow, Tongue Placed on the Roof of the Mouth, Hold Still, and Expose—Error No. 1 (Fig. 10-21 A-F)*****The Lips Are Open and/or the Tongue Is Not on the Palate***

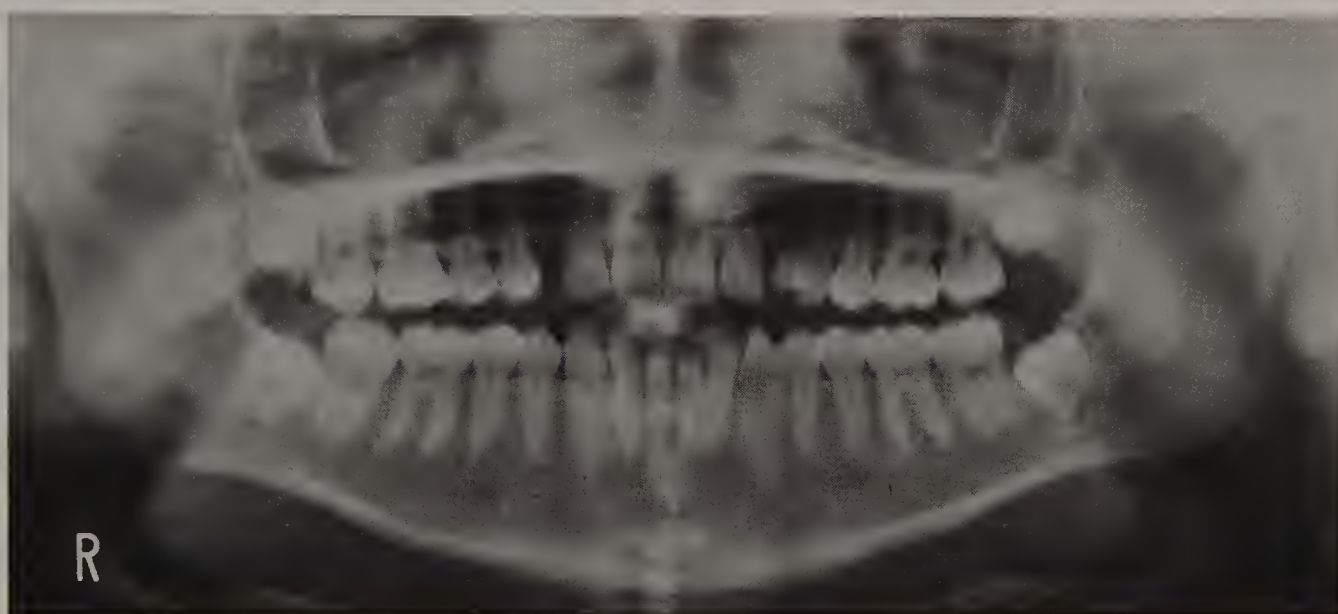
**Zone 1: Dentition.** The crowns of the upper and lower anterior teeth are obscured by the air between the parted lips. The apical region of the maxillary teeth is obscured by the dark air space between the dorsum of the tongue as well as the hard and soft palates (palatoglossal air space).

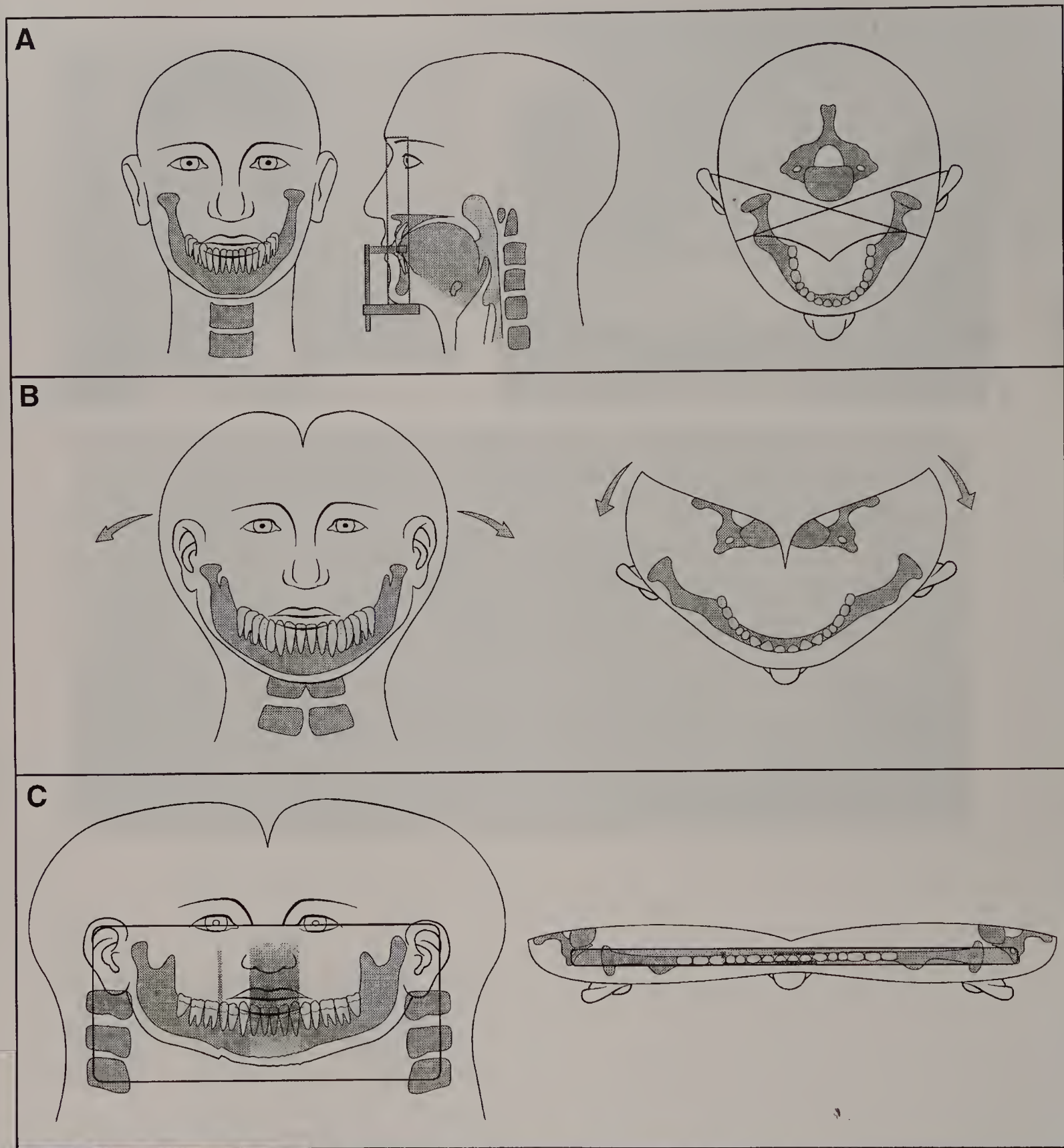
**Zone 2: Nose-Sinus.** The maxillary apical alveolar bone, which is also in this zone, is obscured by the palatoglossal air space.



**Figure 10.21 Lips Are Open and Tongue Is Not on Palate.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D, E) Photographs of patients with lips open and tongue not on palate. In D, the operator is not paying attention to patient's positioning in the machine. (F) Radiograph depicts features of this error.







**Figure 10.22 The Patient Moved.** (A, B, C) Diagrams show incorrect projection of anatomical structures. (D) Photograph of patient moving during exposure cycle. (E, F) Radiograph depicts features of this error (arrowheads).

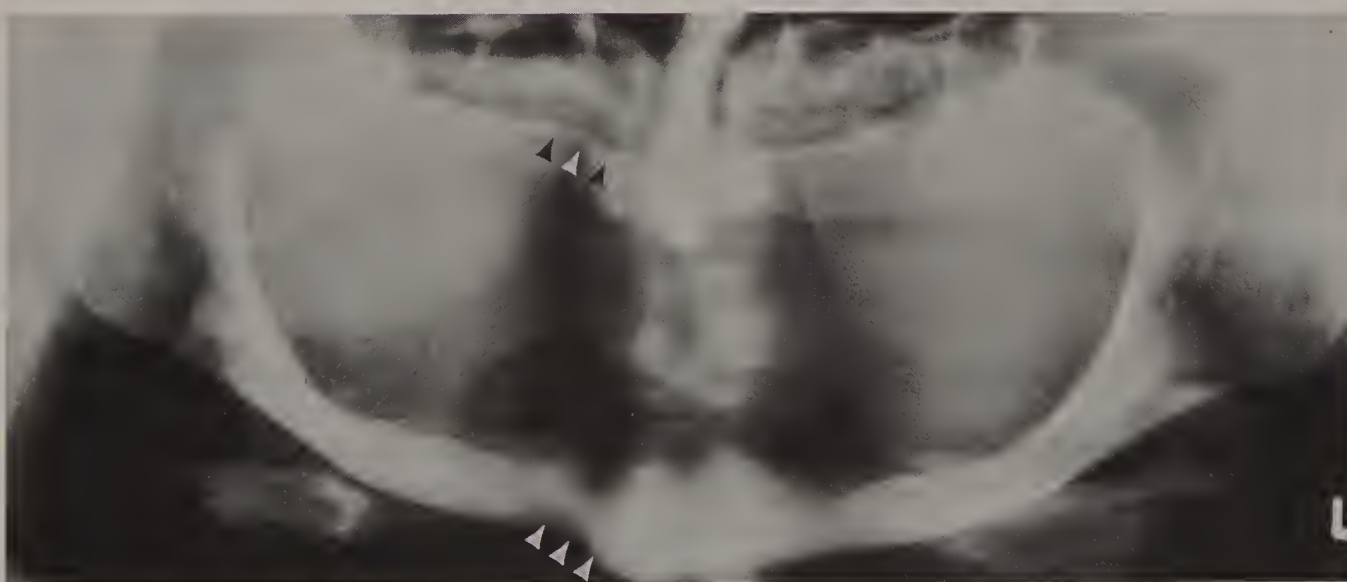




**Step 5: Swallow, Tongue Placed on the Roof of the Mouth, Hold Still, Expose—Error No. 2 (Fig. 10-22A–F)**

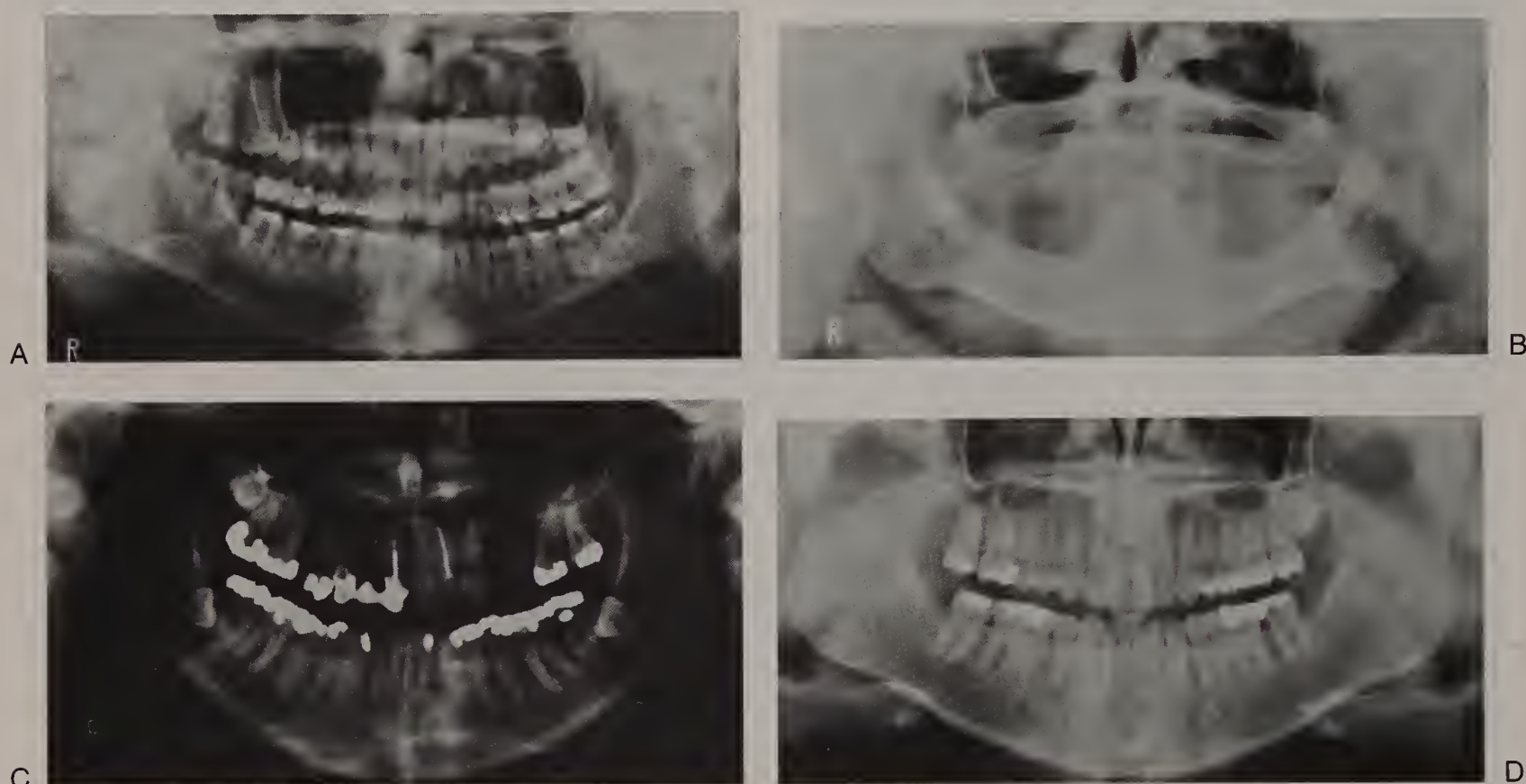
**Zone 1: Dentition.** This area is minimally affected by this error.

**Zone 3: Mandibular Body.** Along the inferior cortex of the mandible, an interruption in its continuity can be seen, especially in the molar area. Also, a wavy image of the inferior cortex is sometimes seen at the inferior cortex of the mandible near the midline. If the observer looks at the other zones above the distorted area of the inferior cortex, unsharpness will be seen throughout the vertical dimension of the image due to the movement.



**Step 5: Swallow, Hold Still, Expose—Error No. 3 (Fig. 10-23A–D)*****The Film Is Improperly Exposed***

There are a variety of possibilities for this error, including a double exposure, in which two sets of teeth are seen; the film is too light due to insufficient kVp or too dark due to too much kVp; the film is improperly labeled with a missing “R” or “L” marker; or the film is missing the patient identification label.



**Figure 10.23 Radiographs Improperly Exposed.** (A) Double exposure of radiograph. (B) Radiograph is too light due to insufficient kilovolts. (C) Radiograph is too dark due to “too high” kilovolts. (D) Radiograph with missing “R” and “L” markers.

## MULTIPLE PATIENT POSITIONING ERRORS

When errors are made, they are not necessarily made in single doses. Operators often make **multiple** errors during the same exposure. The result is called “hybrid effects,” in which several errors compound to produce unique changes in the image. However, most multiple errors can usually be identified in the image by sorting and separating the undesirable effects of each error. The good news is

that nobody makes *all* the errors. Because individuals are usually very faithful to their own particular mistakes, these can be corrected easily once they have been identified. The best thing is to learn the technique properly, to be exact with the five patient positioning steps, and to avoid the errors altogether. The machine should never be altered and the manufacturer’s instructions should never be modified on a continuing basis. Table 10-1 shows a summary of panoramic patient positioning errors.



**TABLE 10-1. Analysis of Panoramic Patient Positioning Errors**

| <i>Error and Cause</i>    | <i>Identifying Features</i>                                                                                                                                                                                                                                                                      | <i>Correction</i>                                                                                                                                                               |
|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Patient too far forward   | Narrow blurred anterior teeth with pseudospace<br>Superimposition of spine on ramus<br>Bicuspid overlap bilaterally                                                                                                                                                                              | Use incisal bite guide<br><br>Line up incisal edge of teeth with notch<br>Edentulous patients should bite about 5 mm behind notch                                               |
| Patient too far back      | Wide, blurred anterior teeth<br>Ghosting of rami; spread-out turbinates, ears, and nose in image; condyles off lateral edges of film                                                                                                                                                             | Use incisal bite guide<br>Line up incisal edge of teeth with notch                                                                                                              |
| Chin tipped too low       | Excessive curving of the occlusal plane<br>Loss of image of the roots of the lower anterior teeth<br>Narrowing of the intercondylar distance and loss of head of the condyles at the top of the film                                                                                             | Tip chin down, but ala-tragus line should not exceed $-5$ to $-7^\circ$ downward<br>Use chin rest                                                                               |
| Chin raised too high      | Flattening or reverse curvature of occlusal plane<br>Loss of image of the roots of the upper anterior teeth<br>Lengthening of intercondylar distance and loss of head of the condyles at the edges of the film<br>Hard palate shadow wider and superimposed on the apices of the maxillary teeth | Tip chin down $-5$ to $-7^\circ$<br><br>Use chin rest.                                                                                                                          |
| Head twisted              | Unequal right-left magnification particularly teeth and ramus<br>Severe overlap of contact points and blurring                                                                                                                                                                                   | Line up patient's midline with middle of incisal bite guide<br>Close side guide                                                                                                 |
| Head tilted               | Mandible appears tilted on film<br>Unequal distance between mandible and chin rest at a given point on the right and left sides<br>One condyle is higher and larger than the other                                                                                                               | Position the chin firmly on both sides of the chin rest<br>Close side guide                                                                                                     |
| Slumped position          | Ghost image of cervical spine superimposed on the anterior region                                                                                                                                                                                                                                | Stand-up machines: have the patient step forward or place feet on markers<br>All machines: be certain the patient is sitting or standing erect                                  |
| Chin not on the chin rest | Sinus not visible on the film<br>Top of condyles are cut off<br>Excessive distance between inferior border of the mandible and the lower edge of the film                                                                                                                                        | Position the chin on the chin rest                                                                                                                                              |
| Bite guide not used       | Incisal and occlusal surfaces of the upper and lower teeth overlapped                                                                                                                                                                                                                            | Use bite guide<br><br>Compensate for missing anterior teeth with cotton rolls                                                                                                   |
| Tongue not on palate      | Relative radiolucency obscuring apices of the maxillary teeth (palatoglossal air space)                                                                                                                                                                                                          | Place the tongue firmly against the palate<br><br>Ask the patient to swallow or suck on his or her tongue                                                                       |
| Lips open                 | Relative radiolucency on the coronal portion of the upper and lower teeth                                                                                                                                                                                                                        | Close lips                                                                                                                                                                      |
| Patient movement          | Wavy outline of cortex of the inferior border of the mandible<br>Blurring of the image above wavy cortical outline                                                                                                                                                                               | Ask the patient to hold still and not swallow<br><br>Explain the function of the machine to avoid startling the patient<br>Be certain the patient's clothing will not interfere |
| Prostheses                | Evidence of prostheses in the image<br>Acrylic denture teeth and bases do not show                                                                                                                                                                                                               | Remove all complete and partial dentures, eyeglasses, and jewelry                                                                                                               |

TROUBLESHOOTING  
PROCEDURAL ERRORS IN  
PANORAMIC RADIOGRAPHY

Table 10-2 contains a summary of panoramic procedural errors.

ALTERING THE PANORAMIC MACHINE  
(FIG. 10-24)

Removing essential parts of a panoramic machine, such as the biteblock assembly, chin rest, or side guides, on a routine basis is an extremely poor practice and does not meet the normal standard of care for routine panoramic radiography. On the other hand, the addition of rare earth screen filtration at the collimator slit and/or conversion to

digital imaging can result in significant savings in radiation dose to the patient (see p. 279).

PROSTHESES, JEWELRY, ETC. (FIG. 10-25)

Intraoral: removable items such as complete and partial dentures should be removed before the procedure. Acrylic complete dentures and acrylic partial dentures involving anterior teeth may be left in to better position the patient in the machine, to effect the desired interocclusal gap between the upper and lower teeth, and to help stabilize an otherwise shaky patient. Extraoral: removable items, such as eyeglasses, earrings, nose jewelry, neck chains, and napkin chains, must be removed. Normally, eye prostheses, hearing aids, and wigs can be left on during the procedure, although these may also sometimes interfere with the image.

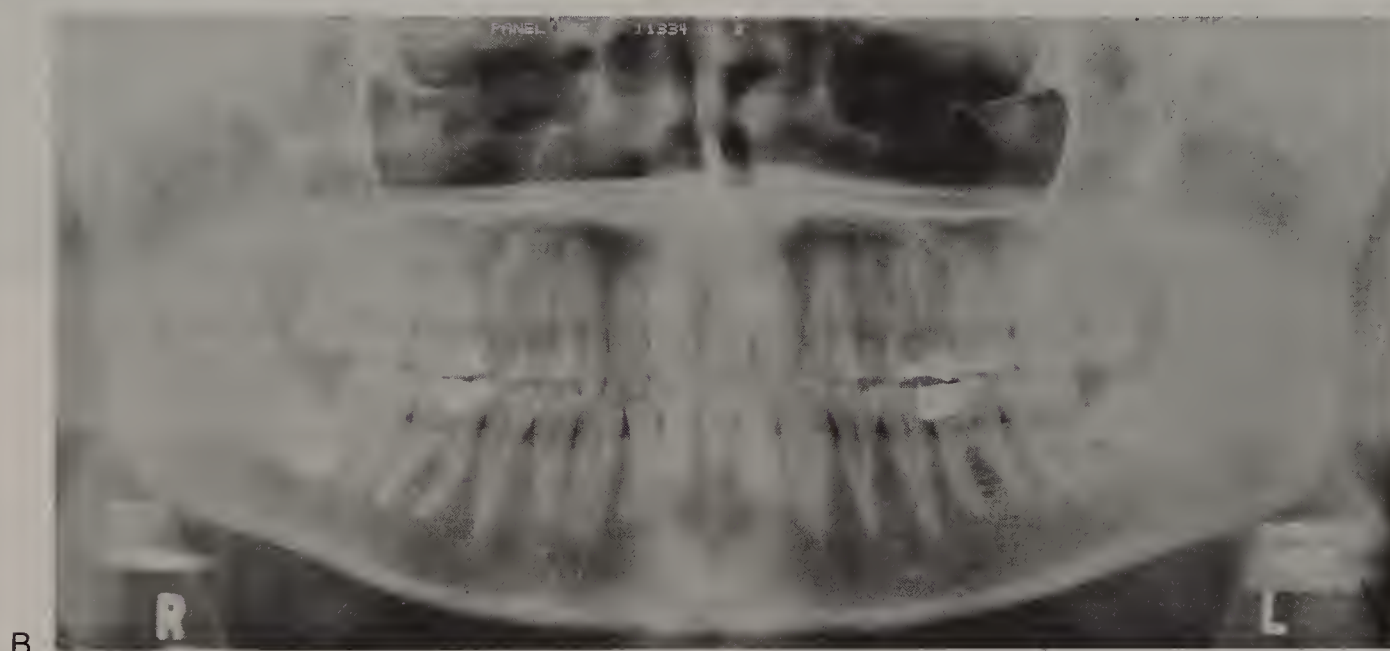
TABLE 10-2. Analysis of Panoramic Procedural Errors

| Error and Cause             | Identifying Features                                                                                                                                                               | Correction                                                                                                                                                             |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Not starting at “home base” | A portion of the film is blank<br>A portion of the anatomy is lost at the edge of the film                                                                                         | Align the machine and/or cassette with starting point                                                                                                                  |
| Cassette resistance         | One or several dark vertical bands on the film; these represent areas of overexposure as the cassette is stopped, but radiation continues to be emitted until the end of the cycle | Be certain to remove thickly padded items of clothing<br>In stocky patients with a short neck, the cassette may need to be raised slightly above the ideal position    |
| Paper or lint in screen     | Radiopacity of unusual shape and location<br>Foreign object prevents complete exposure of film by fluorescent screen                                                               | Periodic inspection and cleaning of the screens                                                                                                                        |
| “Fingernail” artifact       | Crescent-shaped radiolucency                                                                                                                                                       | Avoid rough handling of the film when removing from the box or cassette                                                                                                |
| Static electricity          | Lightning-like radiolucency; dot-like radiolucencies<br>Starburst and other patterns, such as tree-shaped objects                                                                  | Dry air in the darkroom can be humidified with a humidifier or large bowl of water.<br>Avoid rapidly pulling the film from envelope-type cassettes or full box of film |
| White-light exposure        | A portion of the film appears overexposed                                                                                                                                          | Avoid smoking near film<br>Check other sources of light leaks in the darkroom (i.e., unsafe safelight or radio)<br>Check integrity of cassette                         |
| Double exposure             | Two images on the same film                                                                                                                                                        | Always place exposed films in the same location and where they may not be mistaken for unexposed films                                                                 |
| Underexposed                | Film too light                                                                                                                                                                     | Increase kV and/or mA depending on the machine<br>Place film between screens, not to one side only<br>Check developer solution                                         |
| Overexposed                 | Film too dark                                                                                                                                                                      | Decrease kV and/or mA depending on the machine                                                                                                                         |
| No name                     | Patient’s name or identification number not on the film                                                                                                                            | Use film imprinter, special labeling tape, or special pen                                                                                                              |





**Figure 10.24 Machine Modifications.** (A) The biteblock has been removed; this should never be done on a routine basis (undesirable). A square piece of rare-earth filter removes 40% of the radiation dose to the patient (*arrow*) (desirable). (B) Radiograph with no biteblock. The teeth are not separated. The patient is too far back and twisted, and the chin is too high.



### LEADED APRON/THYROID SHIELD ARTIFACT

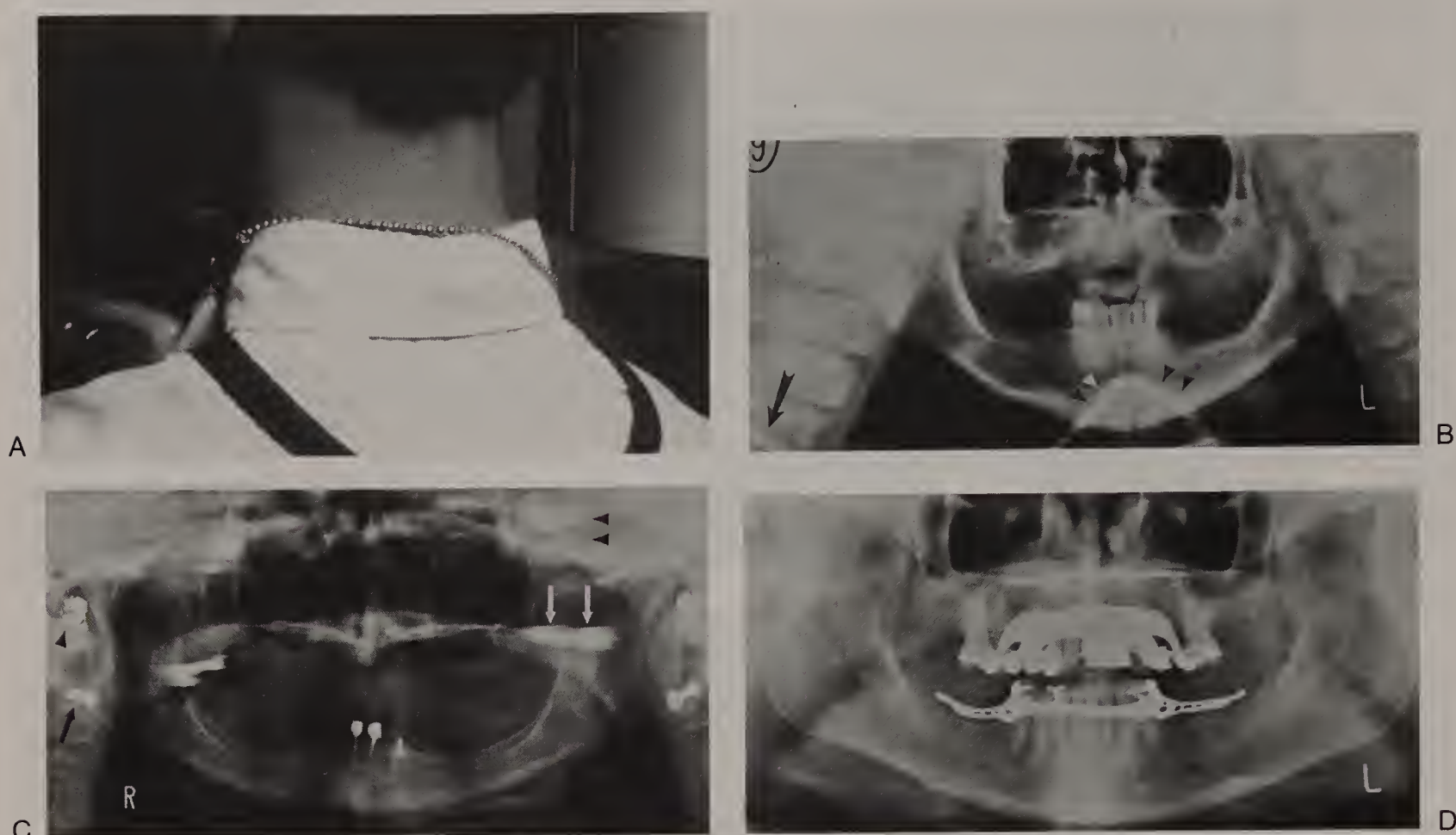
The proper type of leaded apron for panoramic radiography is the poncho style that offers particular protection to the back and front of the patient (Fig. 10-26); x-rays come from the sides and back of the patient to expose the film. The intraoral style of apron should not be used in panoramic radiography. When the apron parts extend onto the neck, especially at the sides and back, these are projected onto the film as blank or clear unexposed areas (Fig. 10-27). Thyroid shields are not recommended because they will project onto the film due to the negative projection angle of the beam. In panoramic radiography, there is about 10 times less dose to the thyroid gland without a thyroid shield than for the intraoral full-mouth survey with the long, round BID and E+ speed film with the thyroid shield.

### NOT STARTING AT “HOME BASE” (FIG. 10-28)

Most panoramic machine cassette holder assemblies need to be manually aligned with the correct starting point to expose the film fully. When this is not done, a panoramic cone-cut results. Only a part of the patient will be imaged, and the remainder of the film will be blank or clear because it remains unexposed.

### CASSETTE RESISTANCE (FIG. 10-29)

At times, the cassette will hang up on a person with large shoulders and/or a short neck, on an item of the patient's clothing, or on an improperly placed leaded apron. This causes the machine to slow down or stop and to overexpose a narrow band of the film over its full vertical breadth. Variants of this problem include several dark



**Figure 10.25 Jewelry, Prostheses, and Hearing Aids.** (A) Napkin and jewelry chain should be removed. (B) Jewelry chain; real image (arrow) and ghost image (arrowheads). (C) Bilateral earrings and hearing aids. Arrows indicate real and corresponding ghost images of earring. Arrowheads indicate real and corresponding ghost images of hearing aid. (D) Prostheses interfere with interpretation.

bands due to multiple interferences with the machine's progress, or a single dark band followed by an unexposed area where the exposure was aborted and the interfering item repositioned. In such cases, the entire exposure is re-

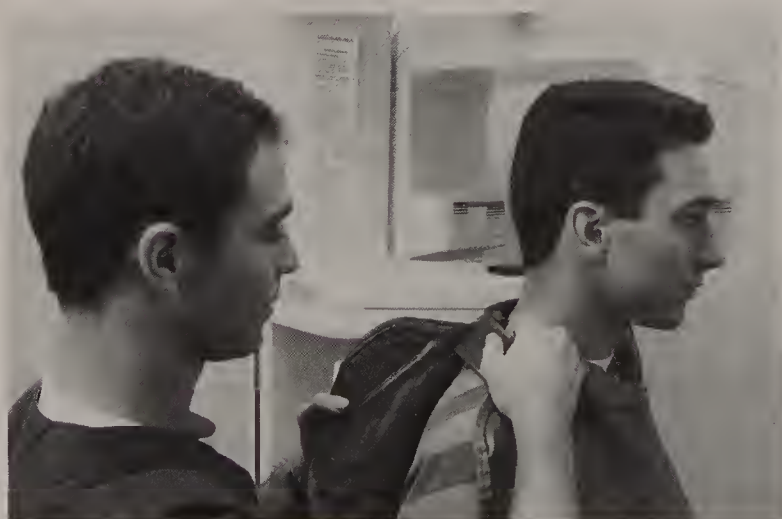
peated with a new film. Patient movement is sometimes seen in association with this error.

### FILM CRIMPING (FIG. 10-30)

At one time, the "fingernail artifact" was blamed on the mishandling of the film by persons with long fingernails. The reason for this is that the artifacts are usually curved and resemble fingernail marks. Actually, this artifact is the result of mishandling the film by causing the film to crimp as it is pressed firmly between the thumb and index finger, then bent as it is withdrawn from the box or cassette. The crimping causes emulsion damage and can occur anytime before processing. These marks are black in the image. However, the emulsion can still be damaged by scratching it with long fingernails.

### DAMAGED SCREEN (FIG. 10-31)

Screens are sometimes improperly manipulated by bending back a portion of the screen to insert or remove a film. Over many repetitions, this causes the screen to crack. This error occurs only with the soft, pliable cassettes for which the screen should be completely withdrawn, then



**Figure 10.26 Poncho-Style Led Apron for Panoramic Radiography.** The proper type of apron for panoramic radiography is the poncho-style lead apron shown here which offers radiation protection to the patient's front and back.





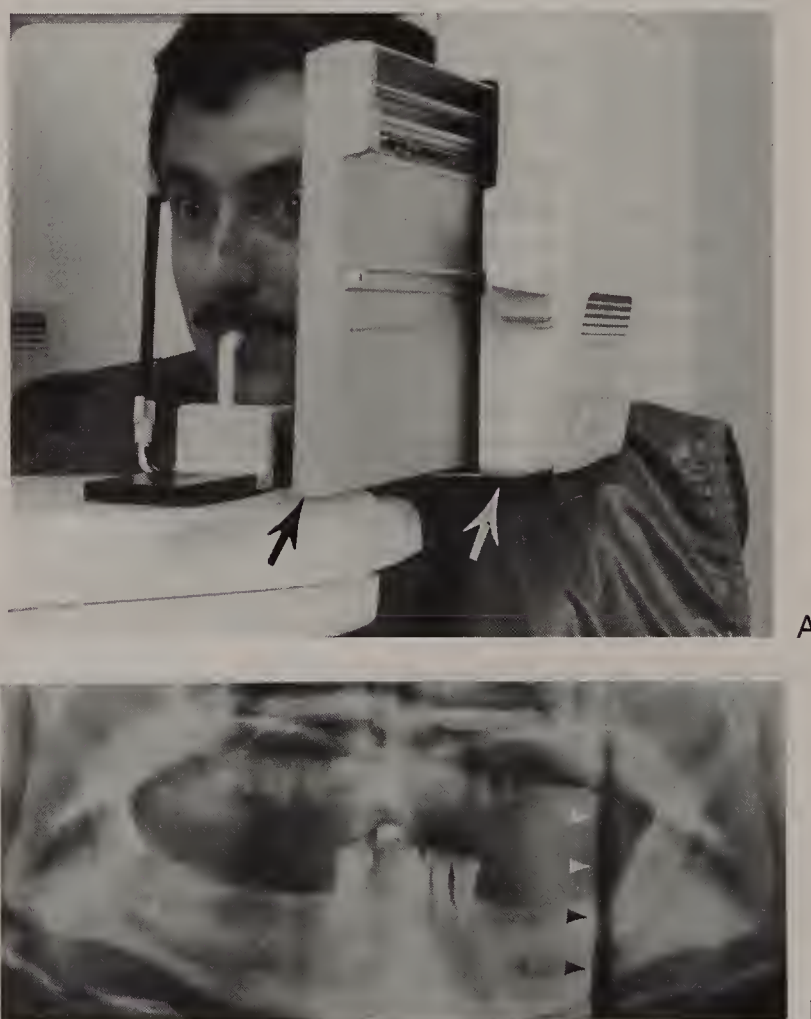
**Figure 10.27 Leaded Apron Artifact.** (A) Inappropriate placement of non-poncho-style leaded apron. (B) Leaded apron artifact on panoramic radiograph.

folded back to place film. Routine modifications of proper technique can often cause damage to the equipment and degradation of image quality. Another problem is a scratch on the screen that produces a white or clear line on the film, representing an area of nonexposure where the screen did not fluoresce. Dirty, dusty screens or **foreign objects on the screen** will develop small pits over time, which result in many small, white spots in the image at the site of each pit. These pits represent small pinpoint scratches on the screen surface and will no longer fluoresce; thus, clear unexposed areas in the image are produced.

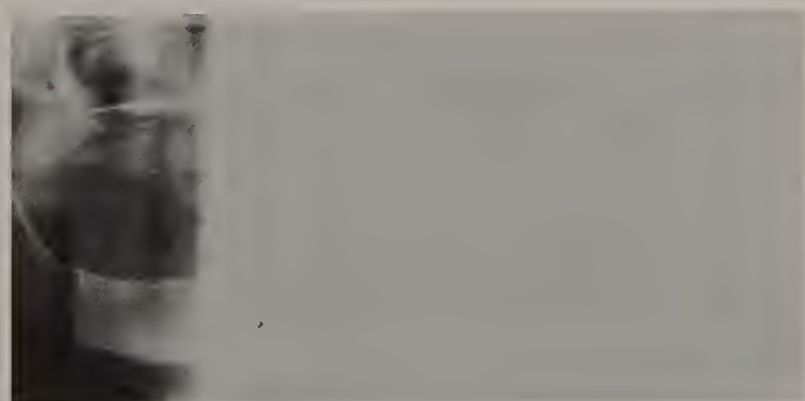
### SPLIT CASSETTE (FIG. 10-32)

Most flexible vinyl cassettes are so designed because they must be wrapped around a curved drum at the cassette rotation assembly. Over time, the heat-sealed margins of the vinyl material may split and allow light to enter into the cassette and expose the film. Rigid cassettes are not subject to this problem, although light leaks do occur over

time. This occurs as the felt wears away at the edges of the cassette back or cover, which ultimately allows light to leak in and expose the film. Exposure to light due to cassette leaks produces black streaks and marks around the edges of the film at the site(s) of the light leak(s). During



**Figure 10.29 Cassette Resistance.** (A) The cassette assembly (arrows) has struck the patient's shoulder, momentarily interrupting the exposure cycle. (B) Cassette resistance produces a dark, vertical band in the image representing an overexposed area (arrowheads).



**Figure 10.28 Not Starting at "Home Base."** Before initiating the exposure, the cassette-drum assembly must be manually aligned to the starting point in some machines; the result of this error is a "panoramic cone-cut."

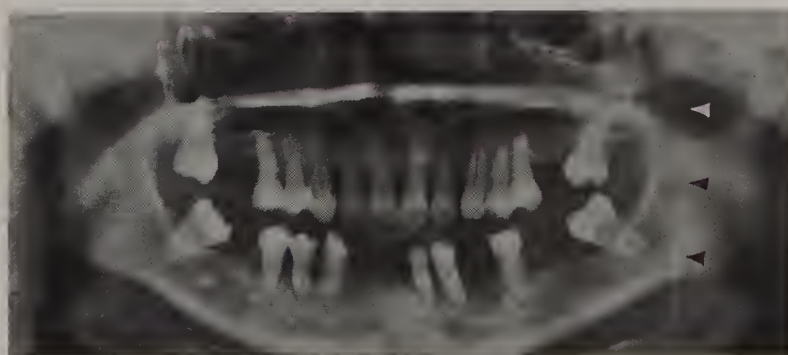


**Figure 10.30 Film Crimping.** The crimp mark (arrow) resembles a fingernail indentation in the film; long fingernails are not the cause.

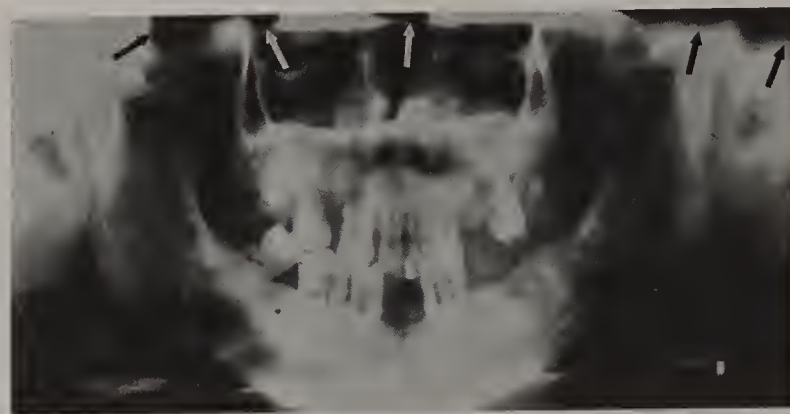
monthly maintenance inspections, the operator should make certain that the cassette(s) are light-tight by placing a blank film inside and exposing the cassette to a bright light.

### NO IDENTIFICATION

All panoramic machines must have the “R” and “L” markers to properly orient the right and left sides of the patient in the image. Some manufacturers place these markers on or in the cassette. If these markers are removed or lost, the film should be discarded. Legally, the patient’s anatomical features (such as a crown or missing tooth) must not be used to label the film after it has been exposed. It is also recommended that the operator label the patient information by first writing pertinent data—such as patient name, patient age, and date of procedure—on a card. The card is placed over one edge of the exposed film before processing and further exposed momentarily to light with a labeling machine. The processed film will now have unalterable patient information as part of the image.



**Figure 10.31 Damaged Screen.** A crack or scratch in the screen prevents the area from fluorescing, producing a white mark in the image corresponding to the damaged area of the screen (arrowheads).



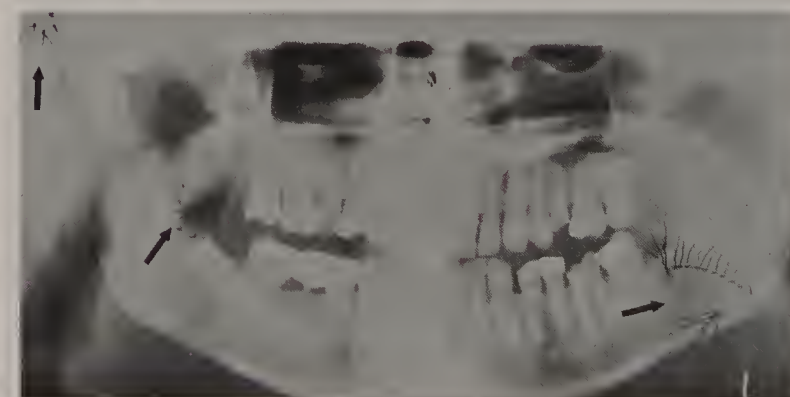
**Figure 10.32 Split Cassette.** Black, overexposed areas at the edges of a film caused by light leaking into a damaged cassette (arrows).

### STATIC ELECTRICITY (FIG. 10-33)

Static electricity will cause black lightning-like or starburst artifacts in the film emulsion when the following two circumstances coexist: dry air and friction on the surface of the film. The dry air occurs especially in winter, when heating systems dry out the air. The friction occurs when a film is withdrawn rapidly, especially from a new or full box of film or from a flexible cassette. The solution is to humidify the darkroom with a bowl of water, humidifier, or antistatic pad on the floor and to handle the film carefully when withdrawing it from the box or cassette. Static electricity can occur anytime before processing.

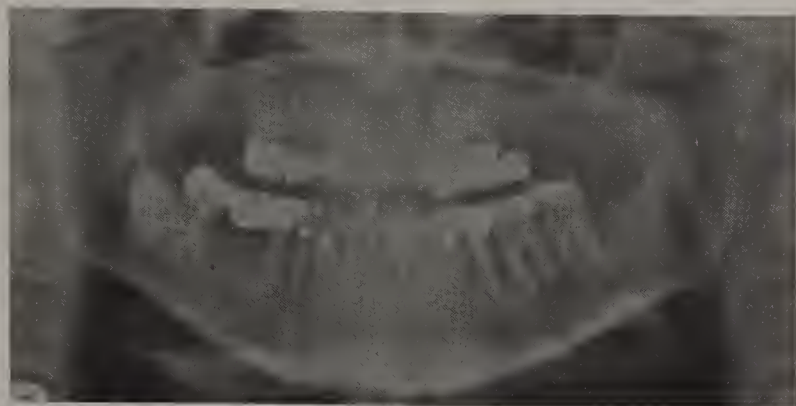
### FOG (FIG. 10-34)

Panoramic film is exposed by fluorescent light. Thus, the light-sensitive emulsion is subject to degradation by sources of fog in the darkroom such as white light leaks, improper safelight filter, improper safelight bulb wattage, distance from the counter top, and even the glow from a radio or cigarette, should smoking be permitted in the darkroom.



**Figure 10.33 Static Electricity.** Several patterns of static electricity (arrows).





**Figure 10.34 Fog.** Generalized gray appearance of unwanted density (fog).

## NOTE TO INSTRUCTORS

An optional workshop, entitled “Troubleshooting Panoramic Errors,” is possible if the instructor can make sets of films with panoramic errors for the students to share. Ask the students to identify the error(s) and state how to correct them.

A set of panoramic errors can be made available by the authors to instructors for duplication and student use. Multiple sets are available on a low cost-recovery basis. Please call (210) 567-3347 or fax (210) 567-3334.

## REVIEW QUESTIONS

- If the patient is positioned too far forward, a panoramic radiograph will have:
  - Incisors that appear too large.
  - Incisors that appear too small.
  - Incisors that appear too wide.
  - Incisors that appear too narrow.
- Which of the following structures can be projected as bilateral structures in continuous image panoramic machines?
  - Hard palate.
  - Epiglottis.
  - Hyoid bone.
  - Vertebral column.
  - 1, 2, and 4.
  - 1, 2, and 3.
  - 2 and 4.
  - 1 and 3.
  - 1, 2, 3, and 4.
- Which of the following are characteristics of ghost images on the panoramic x-ray film?
  - Located opposite side of film from real images.
  - Below the real image.
  - Larger than real image.
  - Smaller than real image.
  - Vertical component is blurred out, horizontal component is elongated and not blurred out.
  - 2 and 5.
  - 1 and 3.
  - 1, 4, and 5.
  - 1, 3, and 5.
  - 1, 2, and 4.
- In panoramic radiography, spreading-out of the nasal turbinate is seen when the patient is:
  - Too far forward.
  - Too far back.
  - Twisted.
  - Tilted.
  - 1 and 3.
  - 1 and 4.
  - 2 and 3.
  - 2 and 4.
- The ghost image of the spine, seen as a radiopaque band in the center of the panoramic image, is due to positioning the patient:
  - Too far forward.
  - Too far back.
  - In a twisted position.
  - In a slumped position.
- Ghost images of the contralateral rami occur due to which panoramic malpositioning problem?
  - Patient too far forward.
  - Patient too far back.
  - Chin tilted upward.
  - Chin tilted downward.
- When the double image of the palate in the panoramic radiograph becomes prominent and obscures the apices of the maxillary teeth, the patient is positioned:
  - Too far forward.
  - Too far back.
  - With the chin raised too high.
  - With the chin depressed too low.
- When an image of the hyoid bone is spread out across the mandibular midline, which malpositioning problem has occurred?
  - Patient is too far forward.
  - Patient is too far back.
  - Chin is tilted upward.
  - Chin is tilted downward.

9. When images of the nose and ears are seen, which malpositioning problem has occurred?
  - A. Patient is too far forward.
  - B. Patient is too far back.
  - C. Chin is tilted upward.
  - D. Chin is tilted downward.
10. When there is only a ghost image of the ramus on one side, not on the other side, this means the:
  - A. Patient is too far forward.
  - B. Patient is too far back.
  - C. Patient's head is twisted.
  - D. Patient's head is tilted.
11. Movement of the patient during an exposure is best noted:
  - A. In the midline of the image.
  - B. Along the cortex of the mandible.
  - C. When there is ghosting of the spin.
  - D. When there is overall unsharpness of the image.
12. An air space above the tongue obliterated the maxillary structures is due to:
  - A. Presence of maxillary denture.
  - B. Interference by maxillary torus.
  - C. Normal technique.
  - D. Tongue not positioned against the palate.
13. If the patient is positioned too far back, the panoramic radiograph will have:
  - A. Incisors that appear too large.
  - B. Incisors that appear too small.
  - C. Incisors that appear too wide.
  - D. Incisors that appear too narrow.
14. Static electricity is seen on the panoramic image as:
  - A. Lightning-like streaks.
  - B. A series of black dots.
  - C. A starburst effect.
  - D. Tree-shaped effect.
  - E. All of the above.
15. An underexposed panoramic radiograph will be due to:
  1. Low kVp.
  2. High mA.
  3. Improper exposure time.
  4. Depleted developer.
  - A. 2 and 3 only.
  - B. 1 and 4 only.
  - C. 2, 3, and 4 only.
  - D. 1, 2, 3, and 4.

## CASE-BASED QUESTIONS

**Special Note:** When assessing the panoramic image, remember that multiple positioning errors occur and combinations of positioning and technical errors may occur in the same image. Select the most correct choice(s).

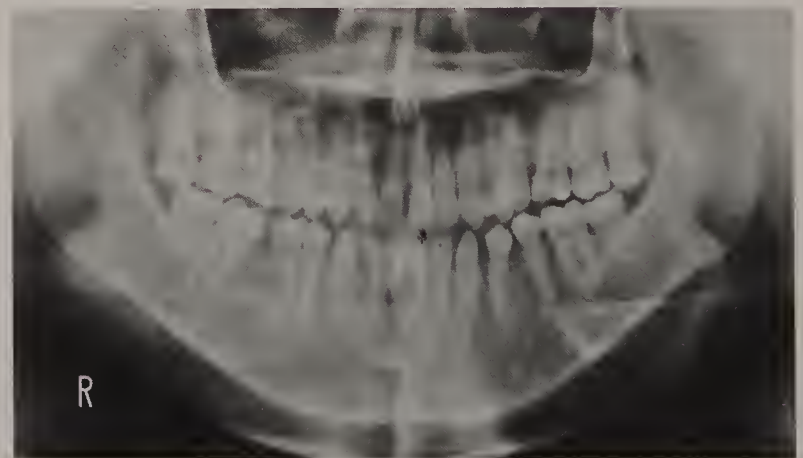
### CASE 10.1



## QUESTIONS

1. The positioning error(s) in this case is (are):
  - A. Slumped.
  - B. Slumped and twisted.
  - C. Too far forward.
  - D. Chin down too low.
2. The technical error in this case is:
  - A. A light leak.
  - B. Fog.
  - C. Static electricity.
  - D. Foreign object on screen.

### CASE 10.2

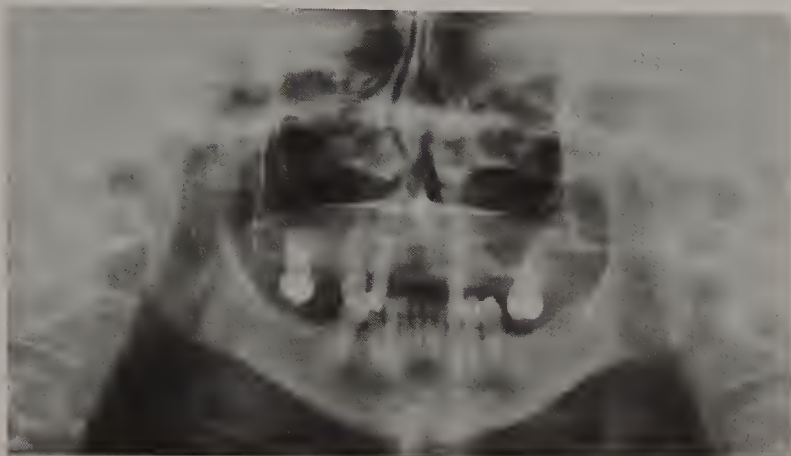


## QUESTION

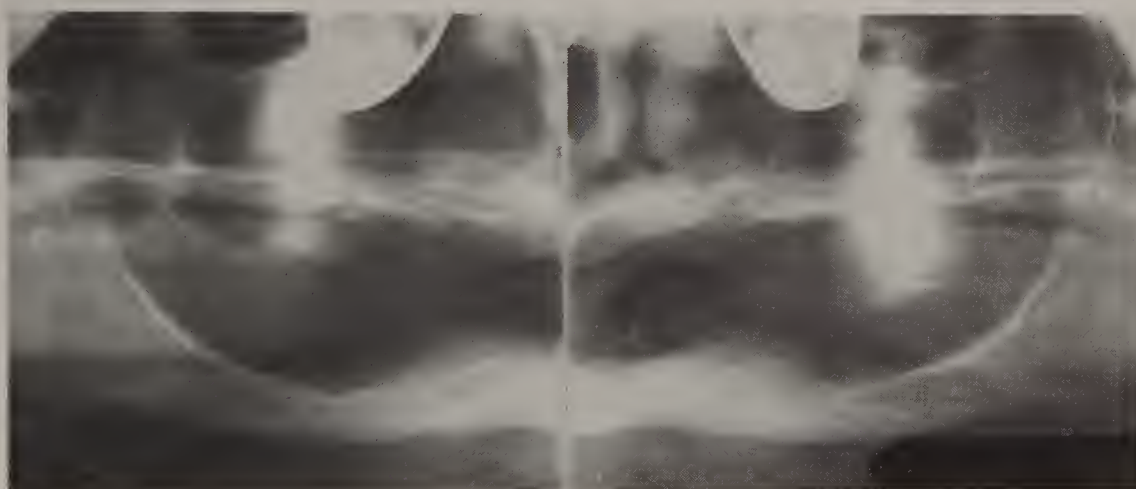
1. The positioning error in this case is:
 

|                     |                   |
|---------------------|-------------------|
| A. Too far forward. | C. Chin too low.  |
| B. Too far back.    | D. Chin too high. |

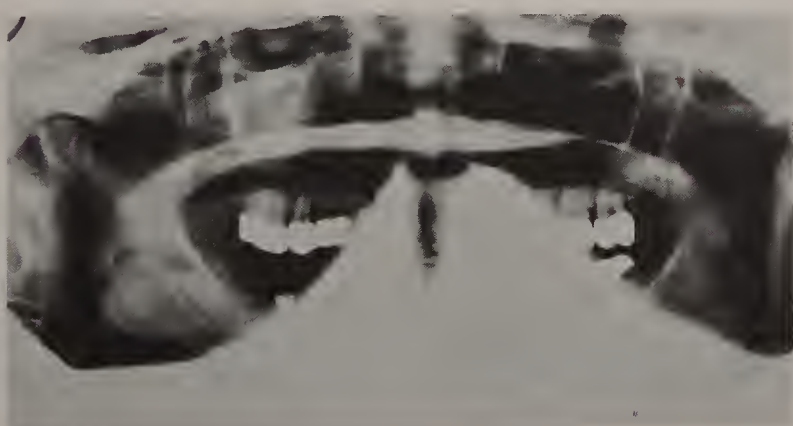


**CASE 10.3****QUESTION**

1. The positioning error(s) in this case is (are):
  - A. Too far forward.
  - B. Too far back.
  - C. Chin too low.
  - D. Too far forward and no biteblock.

**CASE 10.4****QUESTION**

1. The positioning error(s) in this case is (are):
  - A. Eyeglasses left on.
  - B. Foreign object on screen.
  - C. Damaged screen.
  - D. Earrings and eyeglasses left on.

**CASE 10.5****QUESTION**

1. The error(s) in this case is (are):
  - A. Patient slumped and tongue not on palate.
  - B. Vinyl cassette light leak.
  - C. Chin not on chin rest and patient too far back.
  - D. Foreign object in cassette and chin not on chin rest.
  - E. Leaded apron artifact and tongue not on palate.

**CASE 10.6****BIBLIOGRAPHY**

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**QUESTION**

1. The positioning error(s) in this case is (are):

1. Too far forward.
  2. Too far back.
  3. Lips open.
  4. Patient twisted.
  5. Patient tilted.
- A. 2 and 3.
  - B. 1 and 4.
  - C. 1 and 3.
  - D. 3 and 5.
  - E. 2



# Special Imaging Techniques

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *Explain special techniques for use in children and edentulous patients as well as in endodontics, implants, and digital imaging.*
2. *Describe the minimum standard of care in implant imaging.*
3. *List specific extraoral techniques for the imaging of the skull, paranasal sinuses, and temporomandibular joint.*
4. *List the advantages of digital imaging.*
5. *List the disadvantages of digital imaging.*
6. *Describe the characteristics of a digital image.*
7. *State the factors affecting computer and software selection.*
8. *Explain indirect and direct image acquisition.*
9. *Explain the three basic types of sensors.*
10. *Relate a general knowledge of panoramic and cephalometric detectors.*
11. *Explain the various considerations of x-ray equipment.*
12. *Understand the steps of acquiring a digital image.*
13. *Understand the various methods of processing the digital image.*
14. *Explain image storage, compression, archiving, and transmission.*
15. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                             |                                       |                                 |                                          |
|-----------------------------|---------------------------------------|---------------------------------|------------------------------------------|
| buccal-object rule          | Frankfort horizontal plane            | orbitale                        | Richards' technique                      |
| cassette                    | fluorescence                          | panoramic                       | sagittal tomography                      |
| cephalometric radiography   | hypocycloidal movement                | temporomandibular joint         | spectral sensitivity                     |
| Charge Coupled Device (CCD) | implant imaging                       | (TMJ) projection                | storage phosphor                         |
| Clark's rule                | intensifying screens                  | pediatric radiography           | T-Mat film                               |
| computed tomography         | linear tomography                     | photo stimuable phosphors (PSP) | temporomandibular joint (TMJ)            |
| cross-sectional tomography  | localization                          | porion                          | transcranial lateral                     |
| digital imaging             | magnetic resonance imaging (MRI)      | random access memory (RAM)      | temporomandibular joint (TMJ) projection |
| edentulous radiography      | minimum standard of care for implants | rare earth screens              | tube-shift method                        |
| endodontic radiography      |                                       |                                 |                                          |

## INTRODUCTION

There are several special radiographic examinations that can be used in the diagnosis and prevention of diseases and abnormalities of the head and neck region. These radiographic examinations include techniques for specific circumstances and extraoral radiography.

### PART I

#### TECHNIQUES FOR SPECIFIC CIRCUMSTANCES

#### PEDIATRIC RADIOGRAPHY

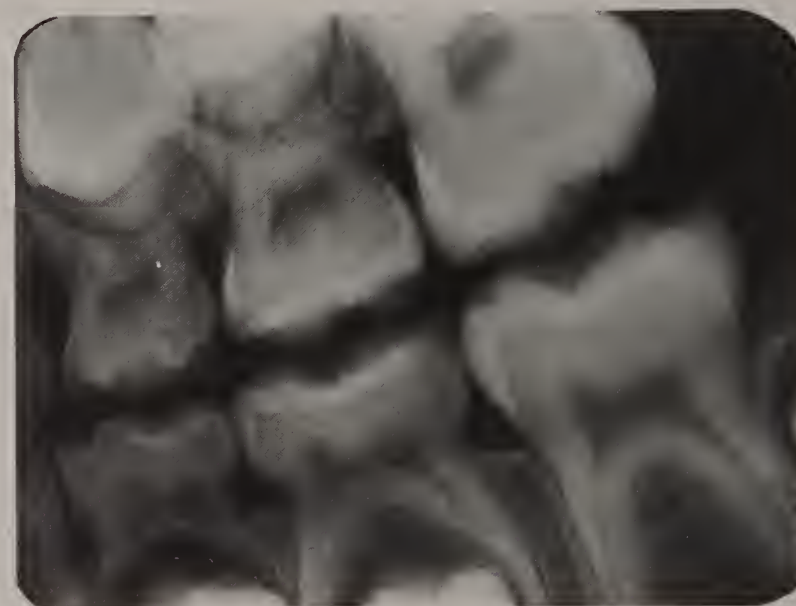
Radiographs of children reveal many conditions that cannot be discovered by any other method. Without radiographs, it is often impossible to identify dental disease and to plan appropriate treatment (Fig. 11-1). Congenital and pathologic disorders are often detected during childhood. Many of these disorders produce changes in the teeth. Most of the odontogenic tumors and cysts arise within the jaw bones during the period of tooth development. Additionally, some malignant disorders—such as histiocytosis X, Ewing's sarcoma, other sarcomas, Burkitt's lymphoma, and leukemia—all occur in children. The decision to take radiographs should be based on the expected benefit to the patient (Fig. 11-2). (See Table 8-1, "Guidelines for Prescribing Dental Radiographs," under the heading, "Child.")



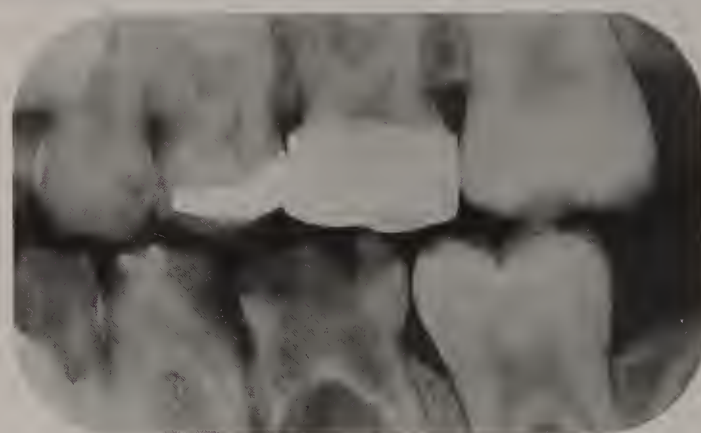
**Figure 11.1 Dentigerous Cyst.** Large dentigerous cyst surrounding a mandibular second premolar in a 9-year-old child.



A



B



C

**Figure 11.2 Selection Criteria (5 Years of Age and Younger).** (A) Children 5 years and younger often have spaces (white arrows) between their posterior teeth, and one should defer taking bitewing radiographs until all posterior spacing is closed. (Note the beginning of calcification of premolars.) (B) Posterior bitewing radiograph of child with no dental caries and tooth contact. (Note erupting premolars underneath the primary molars.) If indicated, bitewing radiographs for caries detection are usually taken every 12 to 18 months in the absence of dental caries with primary tooth contact as seen here, or every 24 months with permanent tooth contact. (C) Posterior bitewings of a child (6 years of age or younger) with a high risk for caries. A child with a high risk of dental caries should have bitewing radiographs made as soon as posterior primary teeth are in contact.



## RADIOGRAPHIC SURVEYS FOR CHILDREN

If it has been determined that a child requires a complete radiographic survey, the final factor to be considered is the number and size of films to be used in the survey. The age and behavior of the child may very well determine the type of radiographic survey to be made. However, irrespective of the size and number of films, the radiographic survey must be complete to be considered diagnostic. It must reveal all the present and developing dentition and oral conditions of the patient.

### PERIAPICAL COMPLETE-MOUTH SURVEY IN CHILDREN

If a panoramic x-ray machine is not available, the following complete periapical radiographic surveys are recom-

(1) the early eruptive stage (5 years and younger) (Fig. 11-

Of course, these are only guidelines; some children are large or more advanced dentally for their age. The important thing to remember is that radiography for children has to be **flexible** and **individualized**. The radiographic technique, film size, and the number of films to be ordered is unique for each child. It is recommended that to minimize exposure to children, radiographs should be taken with a long beam indicating device (BID) paralleling, high-kilovoltage technique using the fastest, most appropriate dental film (D, E+, or F), rectangular collimation (if possible), and film-holders with beam-aiming devices. The patient should be shielded with a torso lead apron (to protect the body and gonads) and a leaded cervical collar (to protect the thyroid) (Fig. 11-5). Children in the

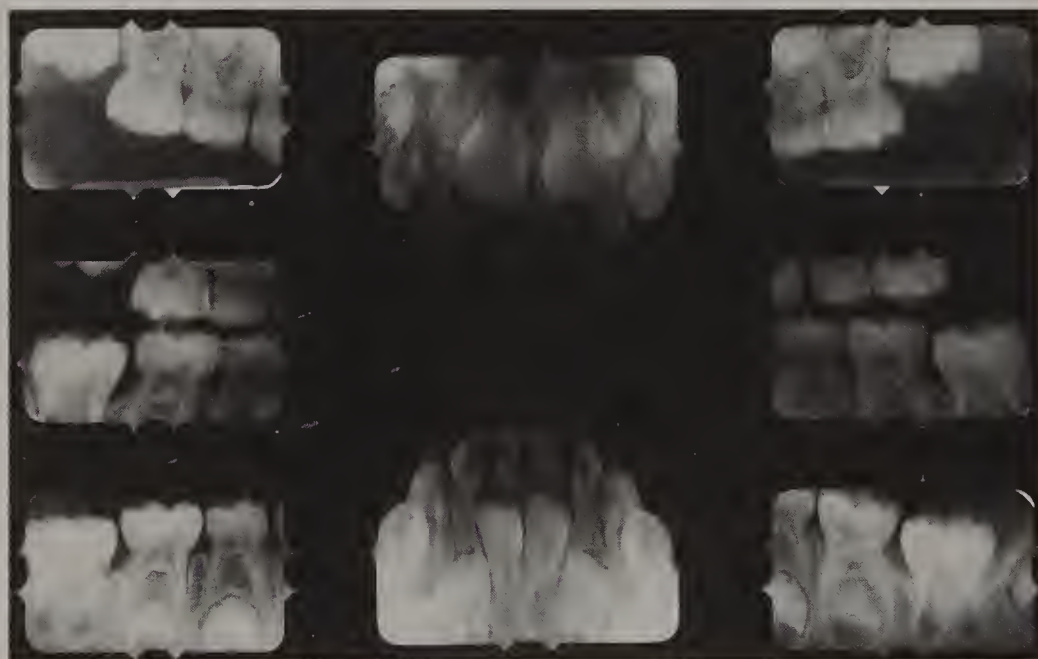
to the adult chair to take radiographs conveniently (Fig. 11-6). When complete surveys are used, there will always be more radiation dose to the child than with panoramic radiography.

### PANORAMIC RADIOGRAPHY IN CHILDREN

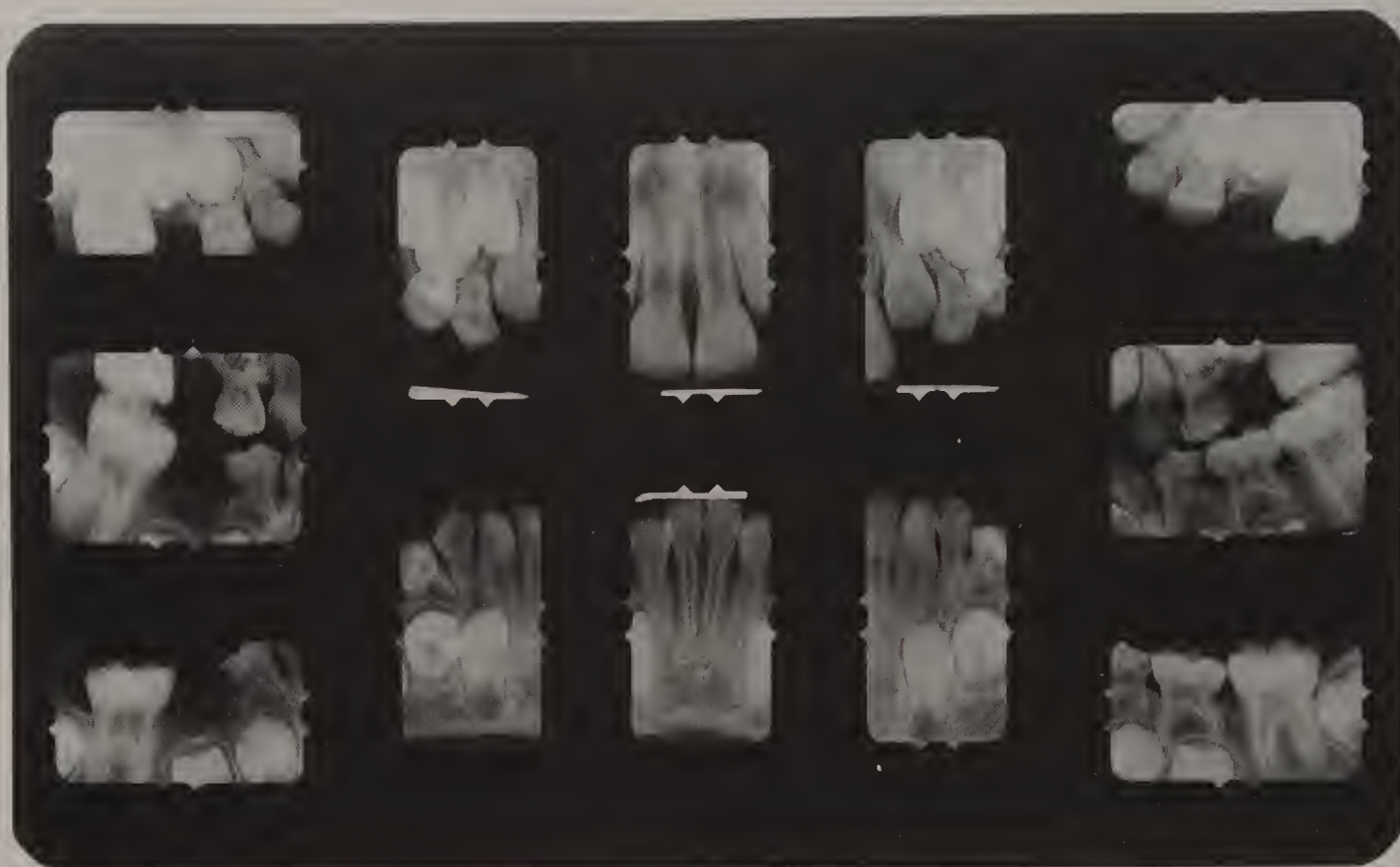
If a panoramic x-ray machine is available, the panoramic radiograph with or without posterior bitewings, as required, is the baseline radiographic survey of choice (Fig. 11-7). Panoramic radiography is unequalled in evaluating growth and developmental patterns in the young child, preadolescent, and adolescent. There is no simpler, quicker technique, nor is there an alternate method of examining the teeth and jaws with less radiation dose to the child.

### ENDODONTIC RADIOGRAPHY

The endodontic radiograph is much more difficult to take than the routine periapical radiograph. The major reason for this difficulty is that exposure of the film is made under adverse visual conditions, because the endodontic working radiographs are made with the rubber dam and endodontic instruments in place. Although the basic principles of dental radiography do not change, the problem is related to visualization of the tooth for proper film positioning and BID angulation due to the presence of endodontic instruments. Because the patient cannot close on a biteblock, it becomes necessary to stabilize the film by means of various film-holders (Figs. 11-8–11-10) used in endodontic procedures. The figures should be reviewed for hints in using the hemostat and the Dentsply/Rinn



**Figure 11.3 The Early Eruptive Stage (5 Years of Age and Younger).** A No. 2 regular periapical film is used as an occlusal film for maxillary and mandibular anterior teeth. No. 0 pedodontic film is used for the posterior periapical and bitewing films.



A



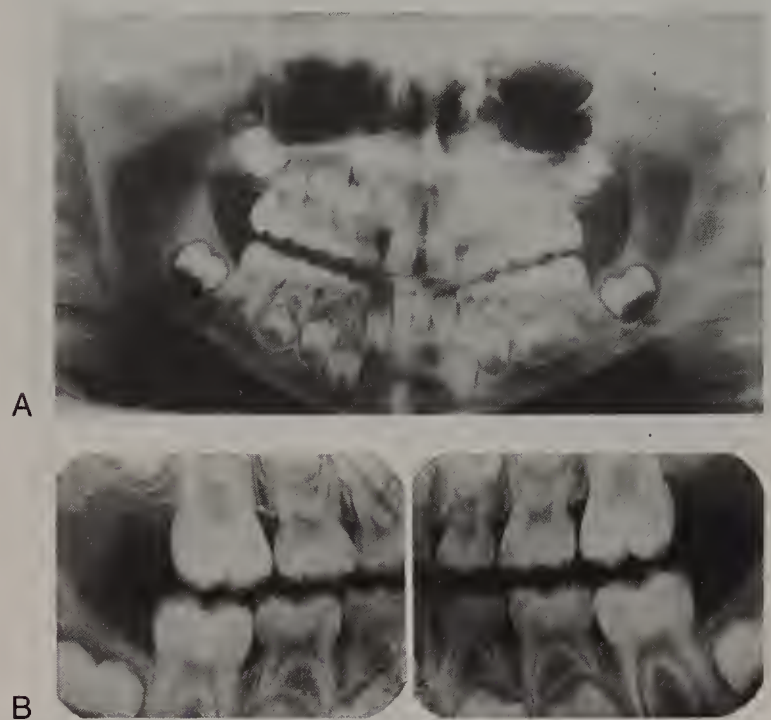
B

radiographic survey is completed with No. 1 narrow films. A No. 2 regular film is used for the posterior bitewings (as seen





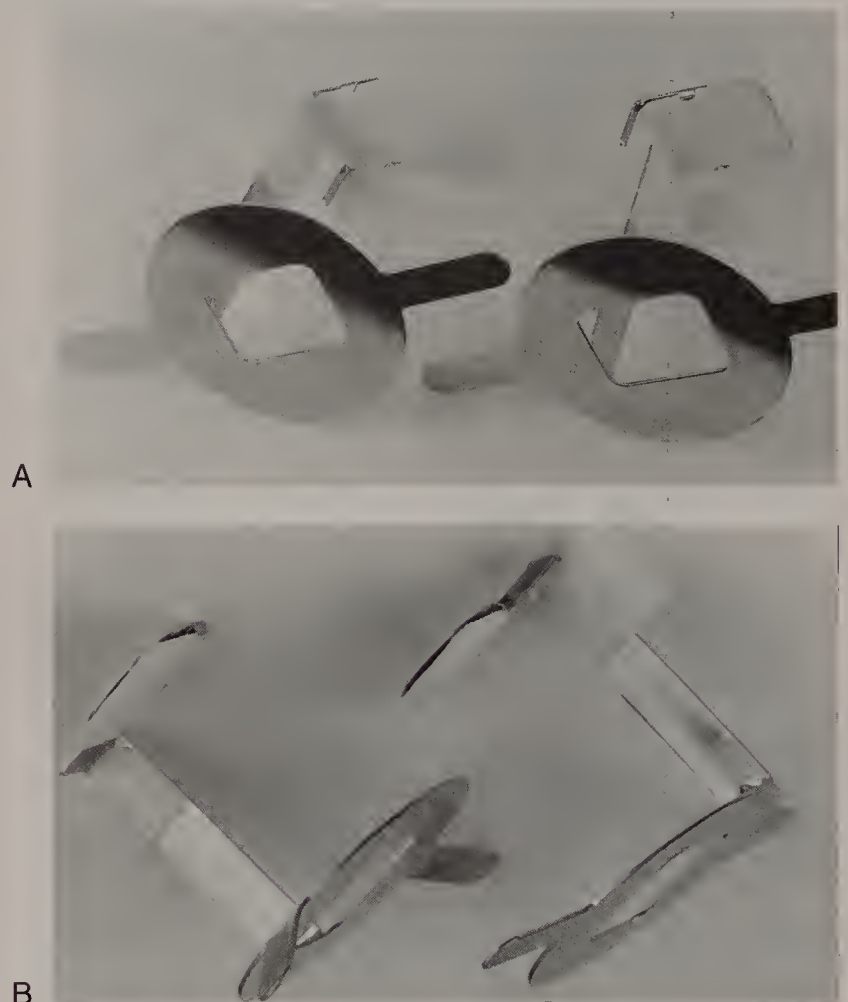
**Figure 11.5 Leaded Torso Apron and Thyroid Collar.** Torso and thyroid leaded shields for a child.



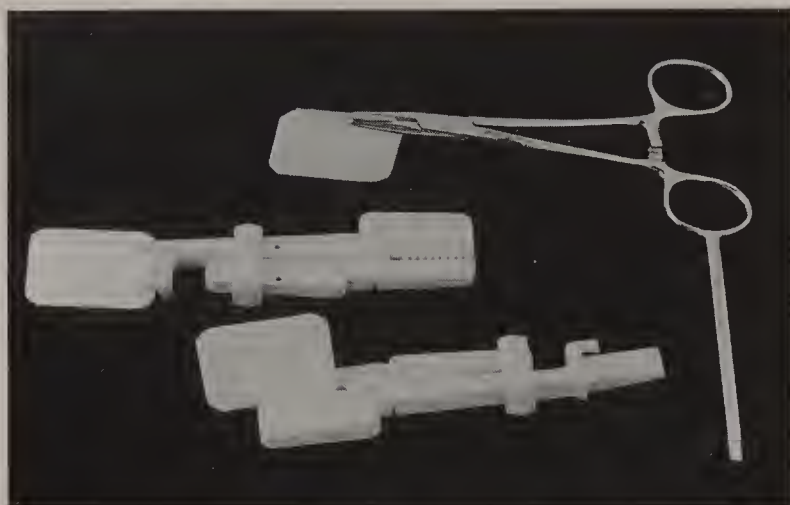
**Figure 11.7 Panoramic Radiographic Survey and Posterior Bite-wings.** Panoramic survey with posterior bite-wings of the same patient. Radiographs supplement each other and significantly reduce the radiation dose over intraoral surveys. (A) Panoramic radiograph. (B) Posterior bite-wings.



**Figure 11.6 Child Chair Used In Dental Radiography.** A commercial child's chair used in dental radiography.



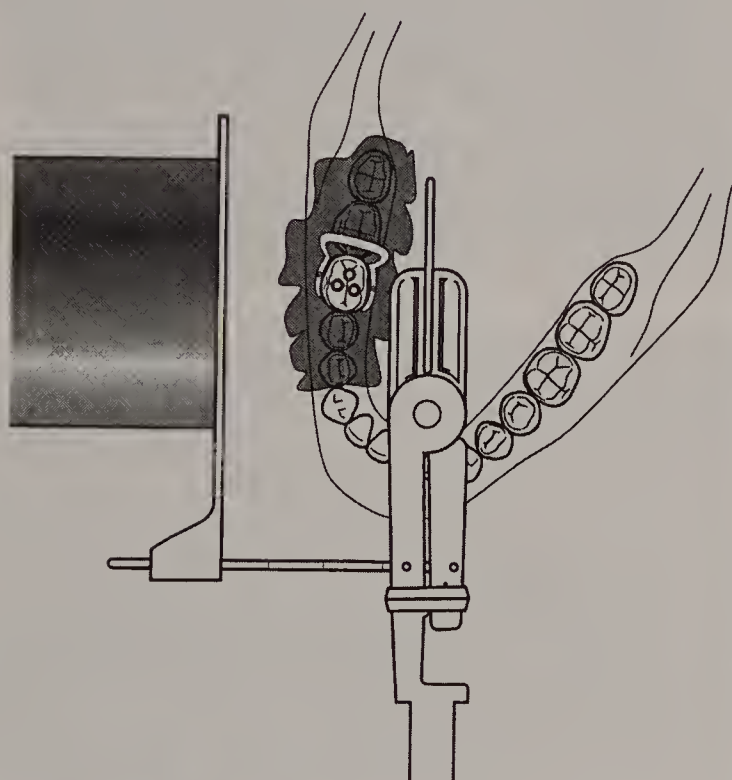
**Figure 11.8 Masel Precision Endodontics Instruments.** The arm is offset in these instruments so the radiograph may be taken without removing the files, reamers, or rubber dam clamp. (A) Anterior instruments. (B) Posterior instruments.



**Figure 11.9 Film-Holders That Can Be Used for Endodontic Radiography.** (Lower) Dentsply/Rinn film-holders. (Upper) Hemostat to hold film in patient's mouth.



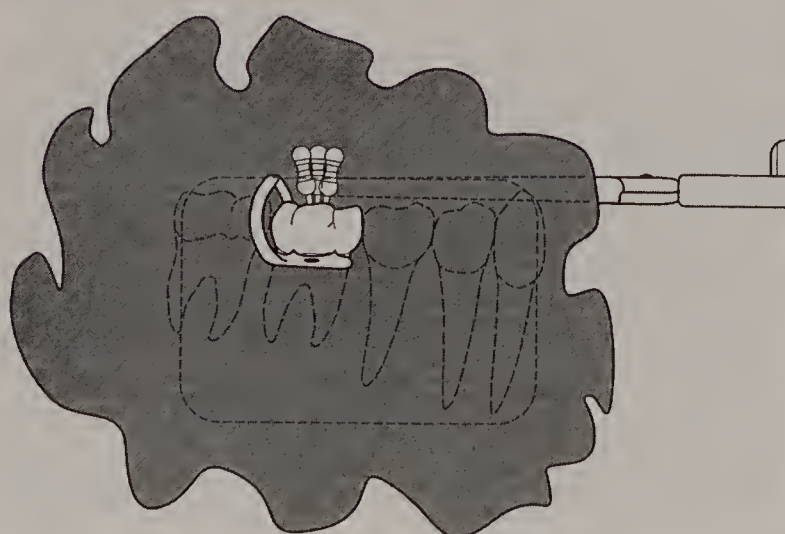
**Figure 11.10 Dentsply/Rinn Snapex Film-Holders.**



A



B



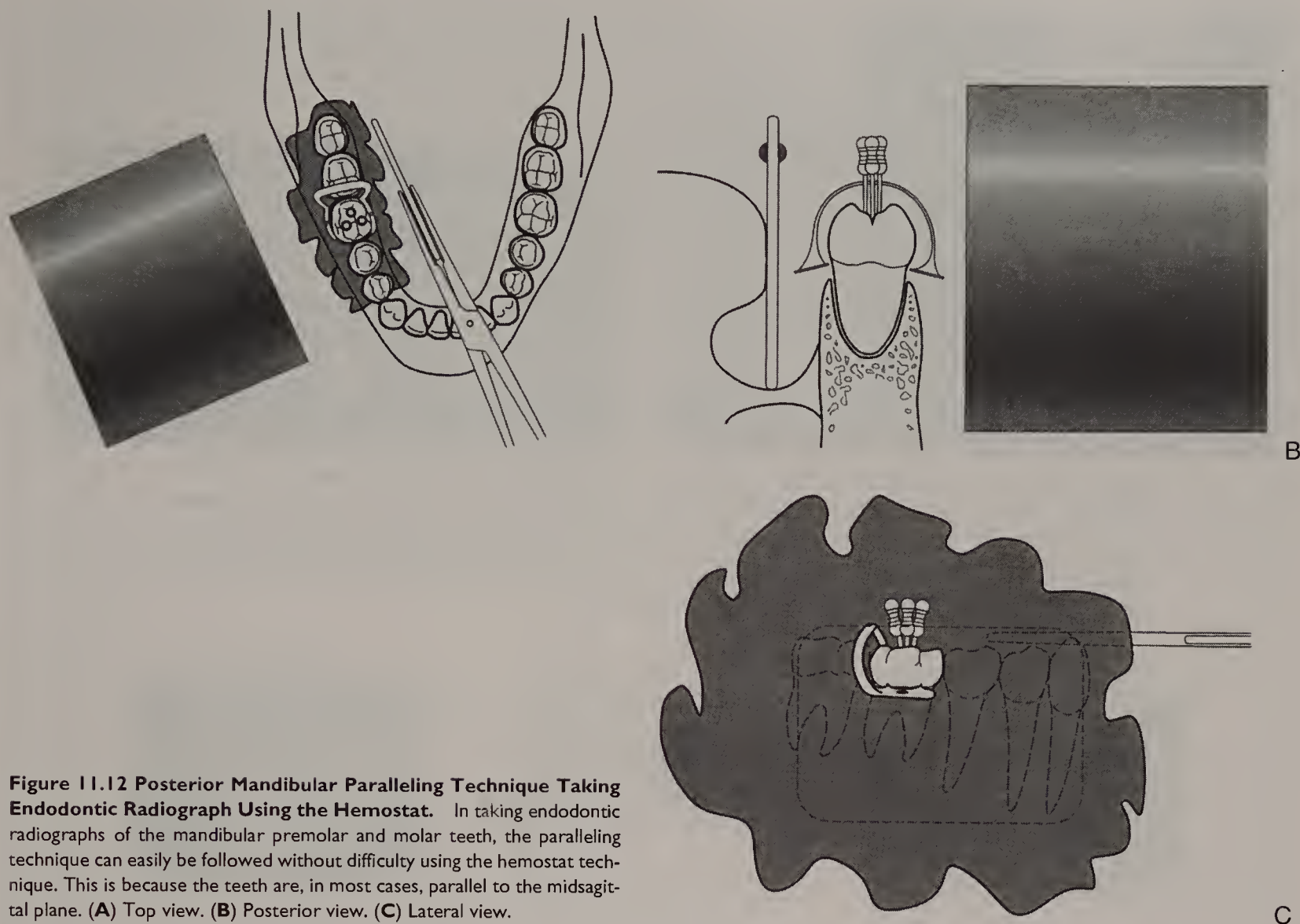
C



D

**Figure 11.11 Using Dentsply/Rinn Snapex Endodontic Film-Holder in Mandibular Posterior Region.** (A) Top view of the instrument in position to take working radiograph of mandibular first molar. (B) Patient with instrument in place for mandibular right first molar endodontic working radiograph. (C) Lateral view of instrument in position to take working radiograph of mandibular first molar. (D) Right first molar radiograph taken with Snapex Film-Holder.





**Figure 11.12 Posterior Mandibular Paralleling Technique Taking Endodontic Radiograph Using the Hemostat.** In taking endodontic radiographs of the mandibular premolar and molar teeth, the paralleling technique can easily be followed without difficulty using the hemostat technique. This is because the teeth are, in most cases, parallel to the midsagittal plane. (A) Top view. (B) Posterior view. (C) Lateral view.

Snapex (Elgin, IL) endodontic film-holders to make endodontic radiography simpler and more accurate (Figs. 11-11 and 11-12). Another endodontic film-holder used is the Dentsply/Rinn EndoRay II. Having the patient hold the film with a finger is **not** recommended.

A single radiograph taken from one direction only may not provide sufficient diagnostic information when multi-rooted teeth or teeth with curved roots are involved endodontically. Under these circumstances, at least two periapical radiographs should be taken to aid in gaining a three-dimensional perspective. One radiograph should be taken at a normal vertical and horizontal angulation, the other at a 20° horizontal angle either from the mesial or distal direction.

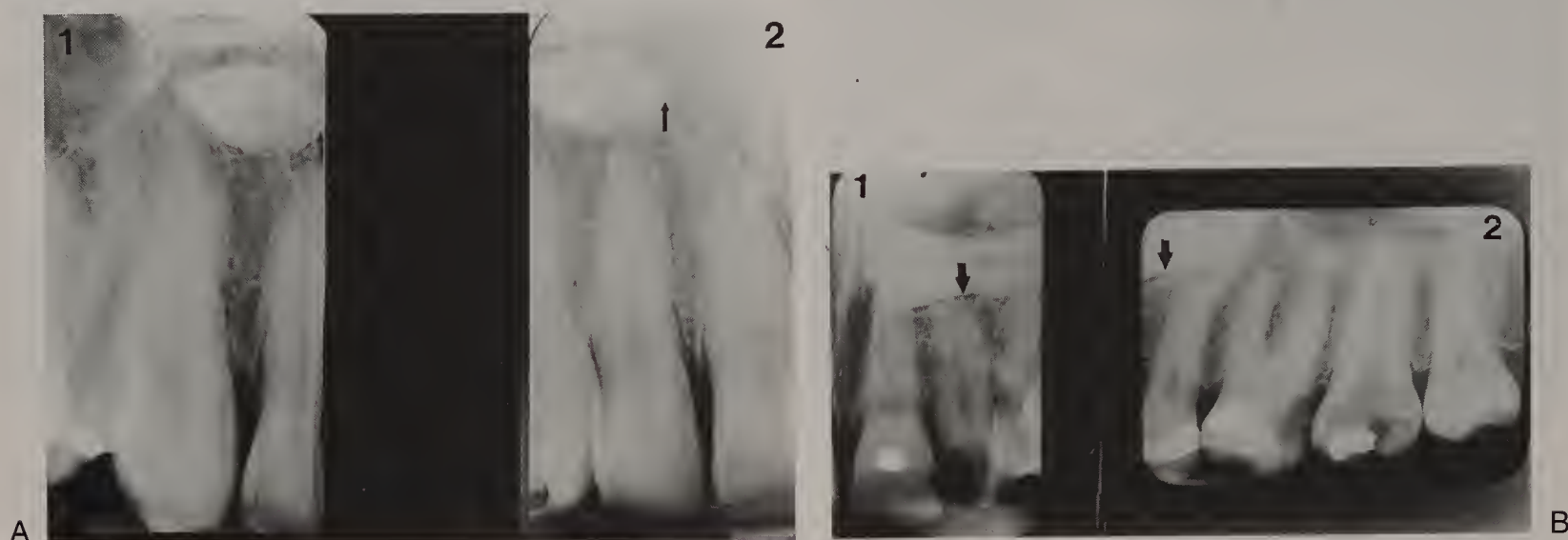
## LOCALIZATION TECHNIQUES

**Localization** is indicated in the following instances: endodontic treatment of some teeth, foreign bodies, broken needles, broken instruments, filling materials in the alveolar process, retained roots, impacted supernumerary and

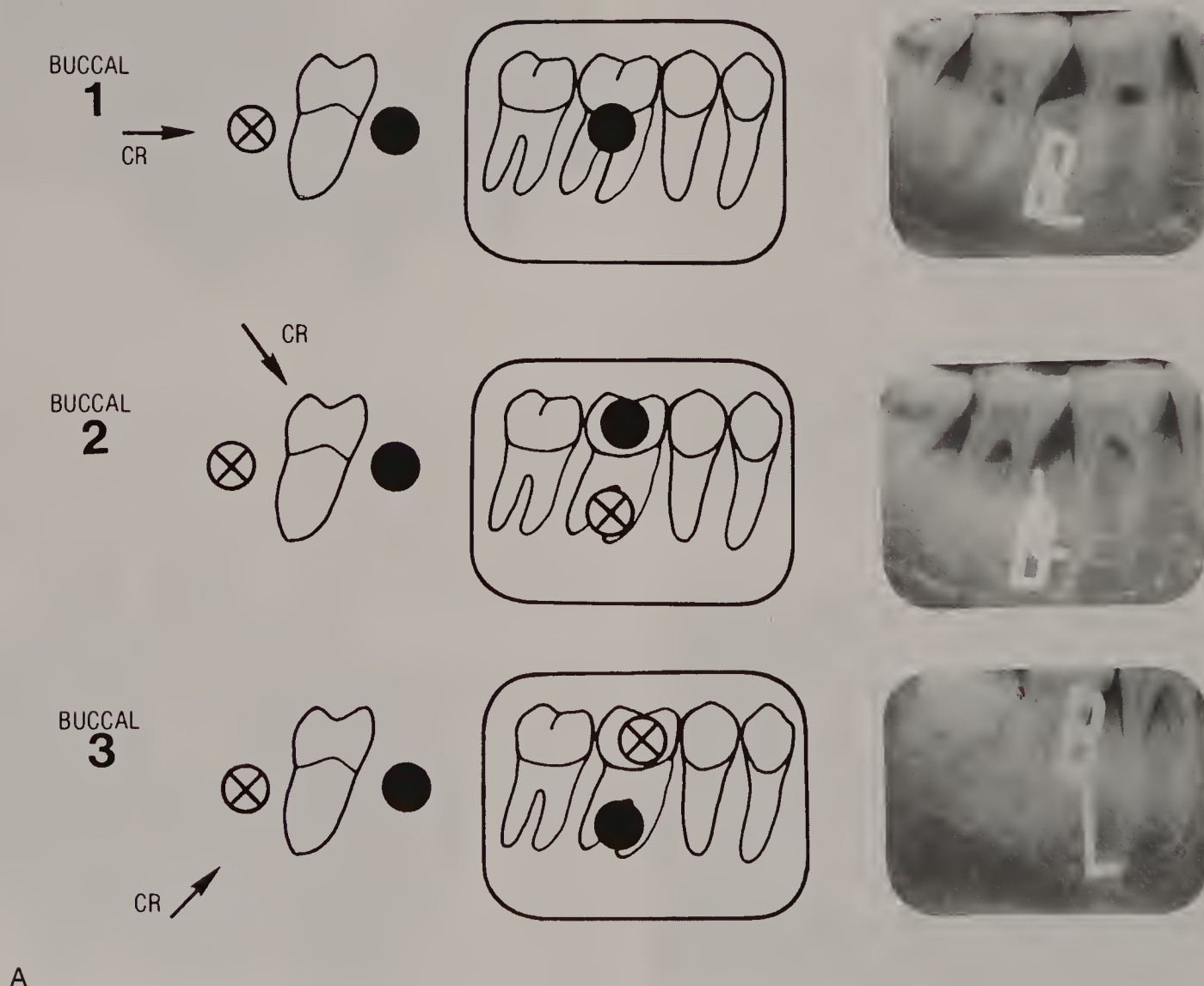
unerupted teeth, calculi in a gland or duct of salivary glands, fractures of the maxilla and mandible, fracture of condyles, and expansion of the alveolar process in cyst formation. The methods of localization are as follows: **tube-shift method** (Clark's rule), and the **buccal-object rule** (Richards' technique).

### TUBE-SHIFT METHOD OF LOCALIZATION

This method was first described by Clark in 1909. It is used to determine the buccolingual relationship of foreign objects and impacted or unerupted teeth within the jaws. The method requires two periapical radiographs of the area in question, shifting the tube horizontally between exposures. The rule governing the tube-shift method of localization is as follows. If the unerupted tooth or foreign body moves in the **same direction** as the tubehead (not the BID) when the tubehead is shifted horizontally, the unerupted tooth or foreign body is located on the **lingual** side. If the unerupted tooth or foreign object moves in the **opposite direction** as the tubehead (not the BID) when the



**Figure 11.13 Horizontal Tube-Shift Method Localization.** (A) (1) Note the position of mesiodens in canine periapical radiography (arrow). (2) In lateral incisor periapical, the mesiodens moves in the direction of tube-shift (arrow); therefore, mesiodens is lingual to other anterior teeth in the arch. (B) (1) Lateral incisor periapical radiograph of impacted canine. (2) Molar periapical radiograph. The impacted canine moves horizontally in the direction of the tube-shift to the posterior. The cemento-enamel junction of canine (arrows) moves from distal of lateral incisor to mesial of second premolar. Therefore, canine is lingual to other teeth in left maxillary arch.



**Figure 11.14 Buccal-Object Rule (Vertical and Horizontal Shift).** (A) Vertical shift. Buccal and lingual foreign bodies change position with vertical shift of x-ray beam. (1) The original radiograph. Buccal and lingual objects are superimposed. (2) The beam is directed inferiorly (positive vertical angulation). The buccal object (B) moves inferiorly while the lingual object (L) moves superiorly. (3) The beam is directed superiorly (negative vertical angulation). The buccal object (B) moves superiorly while the lingual object (L) moves inferiorly. (continued on next page)

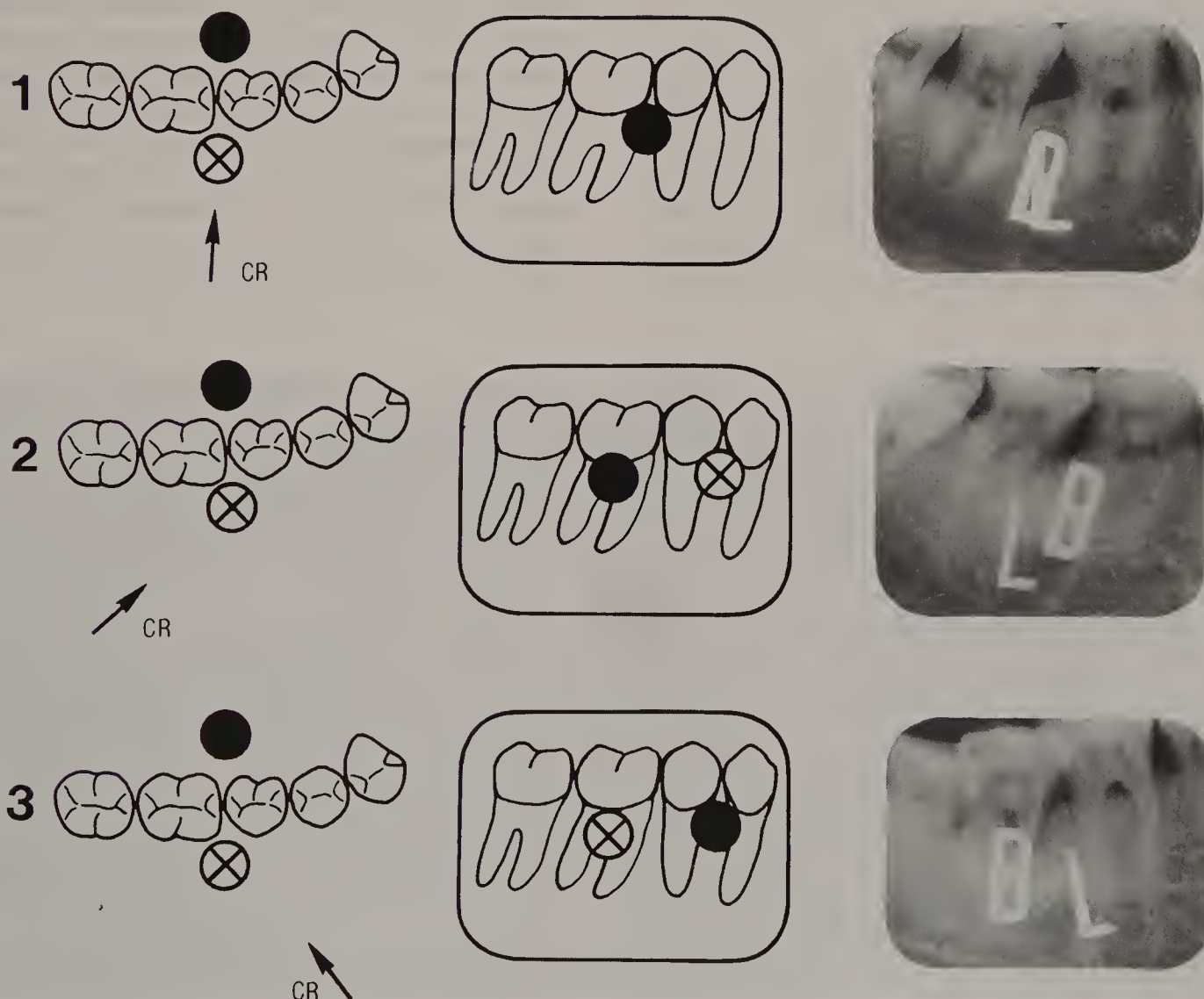


tubehead is shifted horizontally, the location of the unerupted tooth or foreign object is on the facial or buccal/labial. (SLOB rule: same on lingual/opposite on buccal.) If a full-mouth survey has been taken of a patient, an unerupted tooth or foreign object could be localized as facial or lingual to the erupted teeth by the simple application of the tube-shift rule (Fig. 11-13). This would negate the necessity of taking another film to locate the unerupted tooth, foreign object, anomalies, or pathosis.

### BUCCAL-OBJECT RULE METHOD OF LOCALIZATION

This method of localization of pathoses, supernumerary teeth, fractures, and foreign bodies was first suggested by Richards in 1952. The rule states that when two different radiographs are made of a pair of objects, the image of the most buccal (facial) object moves, relative to the image of the lingual object, in the same direction that the x-ray

beam (BID) is directed (Fig. 11-14). The horizontal (left and right) angulation of the x-ray beam (BID) should be changed when locating vertically aligned images on the radiograph, such as root canals; the vertical (up and down) angulation of the x-ray beam (BID) should be changed when locating a horizontally aligned image on the radiograph, such as the mandibular canal. The successful application of the buccal-object rule requires two different radiographs taken of the same region from different horizontal angles. These radiographs will reveal necessary clues to locate the position of the hidden object (such as an unerupted tooth) in relation to known objects (such as erupted teeth). If buccal and lingual objects are superimposed, the two may be separated and identified by applying the buccal-object rule. In making the second radiograph, the horizontal or vertical angulation of the beam should be changed. When the second radiograph is compared with the first (original), the buccal object will appear to have moved in the same direction as the beam.



B

**Figure 11.14 Buccal-Object Rule (Vertical and Horizontal Shift).** (continued) (B) Horizontal shift. (1) Original radiograph. Buccal and lingual objects are superimposed. (2) The beam is directed mesially. The buccal object (B) moves mesially while the lingual object (L) moves distally. (3) The beam is directed distally. The buccal object (B) moves distally while the lingual object (L) moves mesially.

## EDENTULOUS RADIOGRAPHY

Studies have shown that approximately one of four edentulous patients have pathologic conditions such as residual roots, unerupted and supernumerary teeth, cysts, residual areas of infection, and foreign bodies as well as other less frequently seen abnormalities. Clinical examination of the edentulous ridges alone is an insufficient basis on which to determine the health of the edentulous ridges and their surrounding tissues.

### PANORAMIC EDENTULOUS SURVEY

If a panoramic x-ray machine is available, the panoramic radiograph is the baseline radiographic survey of choice. The panoramic technique produces an image that provides exceptional coverage of both jaws on one radiograph and results in much less radiation dose than the edentulous complete mouth survey (Fig. 11-15).

### EDENTULOUS COMPLETE-MOUTH PERIAPICAL SURVEY

If no panoramic x-ray machine is available, the edentulous survey may be taken by either the paralleling or bisecting angle technique. As much of the ridge as possible should be covered with the film, and the central ray should be directed to the center of the film. The objective is to show as much of the bone as possible on the film. A 14-film survey using No. 2 film is recommended for the

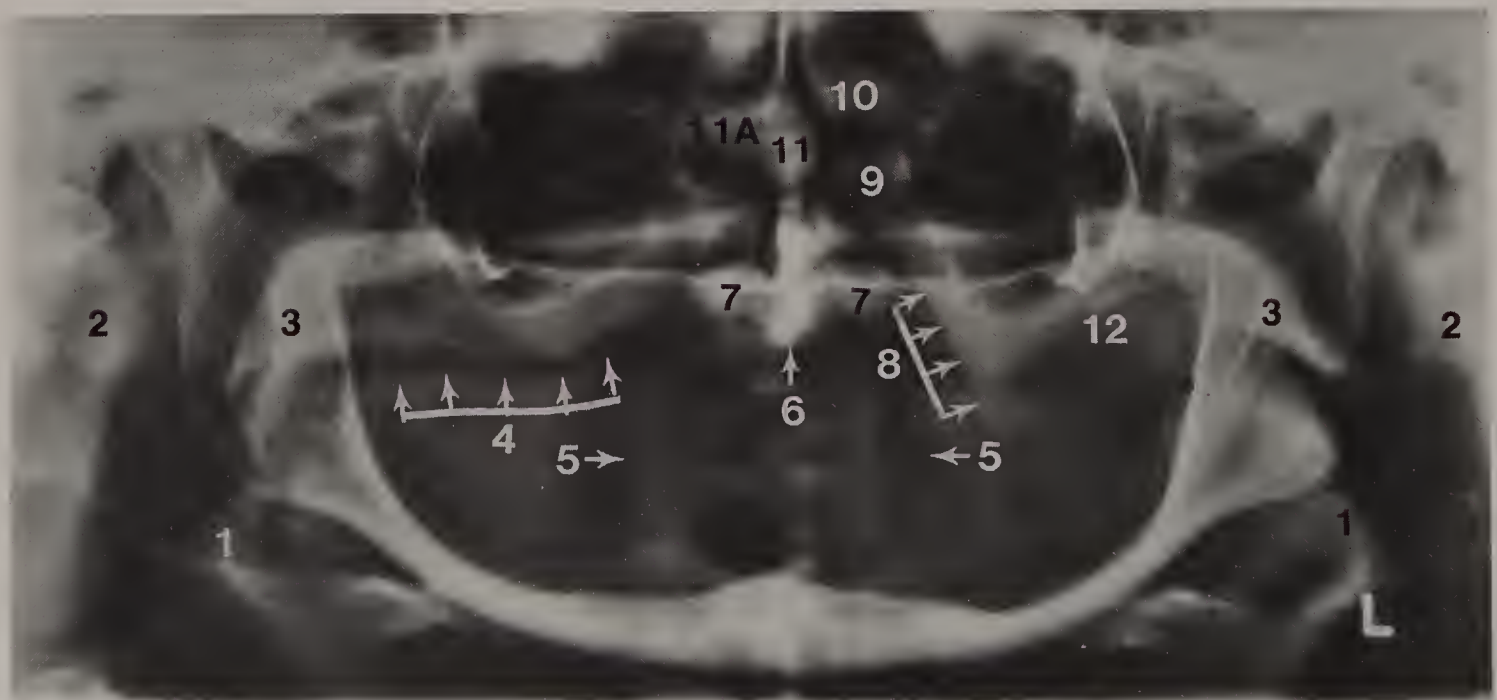
edentulous complete radiographic survey (Fig. 11-16). If there is minimal resorption of the edentulous ridge, the paralleling technique using film-holders can be used.

## IMPLANT IMAGING

Radiography offers the sole method of noninvasive analysis of bone required for implant therapy. It helps the clinician determine the quantity of bone present and available, and the location of critical anatomical structures. Generally, it is sound practice to obtain multiple views of the proposed site to assess it adequately.

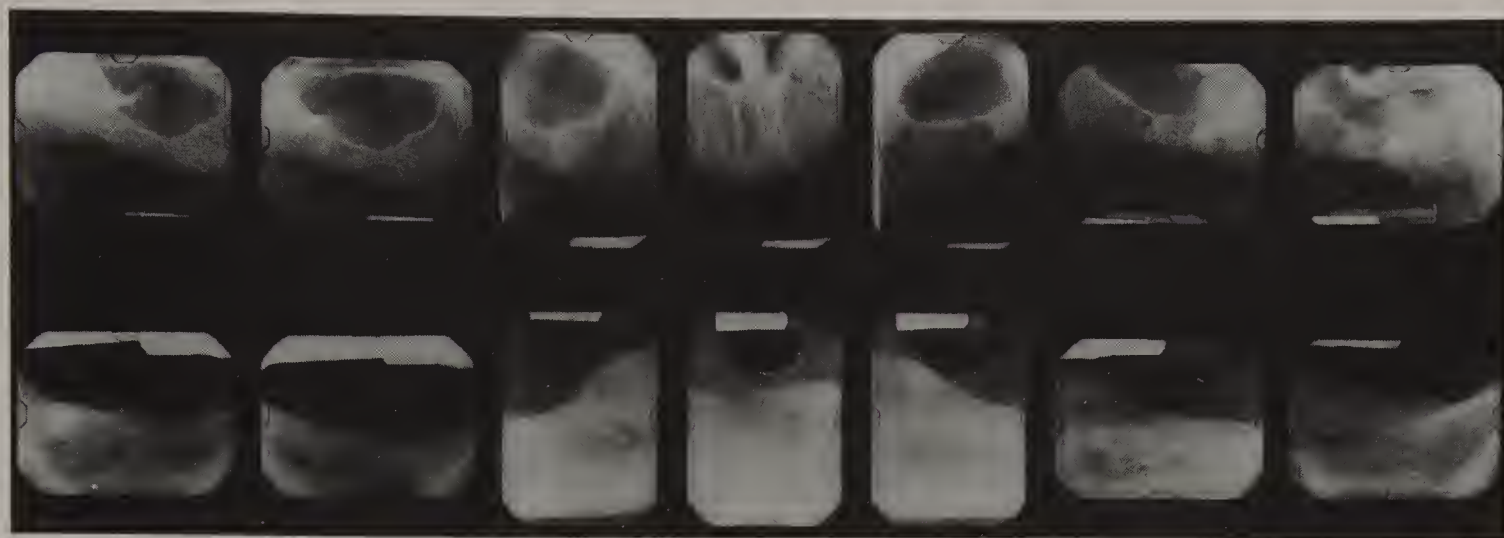
### MINIMUM STANDARD OF CARE IN IMPLANT IMAGING

Following the clinical examination, the minimum standard of care for the radiologic assessment before initiating implant therapy consists of sagittal and cross-sectional linear tomograms of each implant site. Periapical, occlusal, cephalometric, and sometimes panoramic radiography are commonly used instead of tomograms. Although these images may be used in conjunction with the minimum standard, such images or combination of images do not represent the minimum standard of care for implant imaging because of variations in projection geometry, and in the case of panoramic radiography unequal magnification in the vertical and horizontal directions throughout the panoramic radiograph.



**Figure 11.15 Panoramic Edentulous Survey.** Note severely resorbed edentulous ridges. (1) Epiglottis (bilateral), (2) ear lobe, (3) soft palate (bilateral), (4) dorsum of tongue, (5) upper and lower lips, (6) tip of nose, (7) ala of nose, (8) nasolabial fold, (9) inferior turbinate, (10) middle turbinate, (11) soft tissue of nasal septum, (11A) spreading out effect of nasal septum, and (12) gingiva at crest of maxillary left ridge.





**Figure 11.16 Edentulous Complete-Mouth Periapical Survey.** Fourteen-film survey using No. 2 periapical film.

### CROSS-SECTIONAL AND SAGITTAL TOMOGRAPHY FOR IMPLANTS (FIG. 11-17)

The minimum standard of care and the most cost-effective method of radiographic assessment of one to several implant sites are both cross-sectional (coronal) and sagittal (anteroposterior) tomography, either linear or multi-directional. These tomographic radiographs are made on special tomographic equipment. Use of both cross-sectional and sagittal tomograms is necessary to obtain a three-dimensional view of each implant site and to make accurate measurements. Vertical measurements should only be made on the sagittal tomogram.

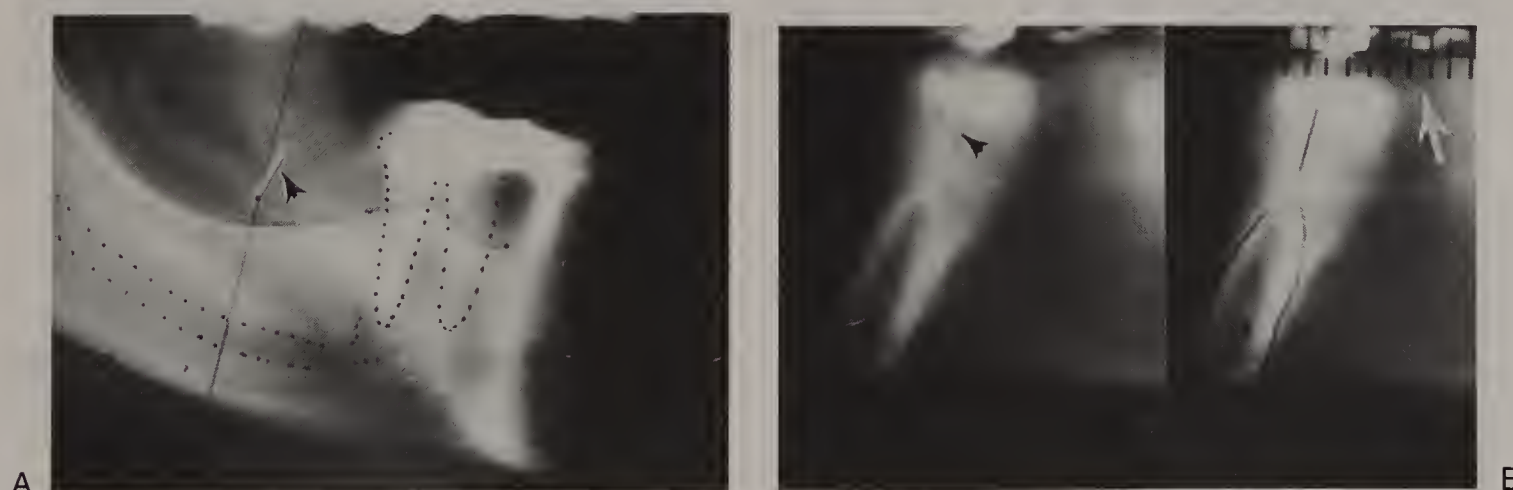
### COMPUTED TOMOGRAPHY FOR IMPLANTS (FIG. 11-18)

Computed tomography (CT) is probably the most useful imaging modality for presurgical implant assessment

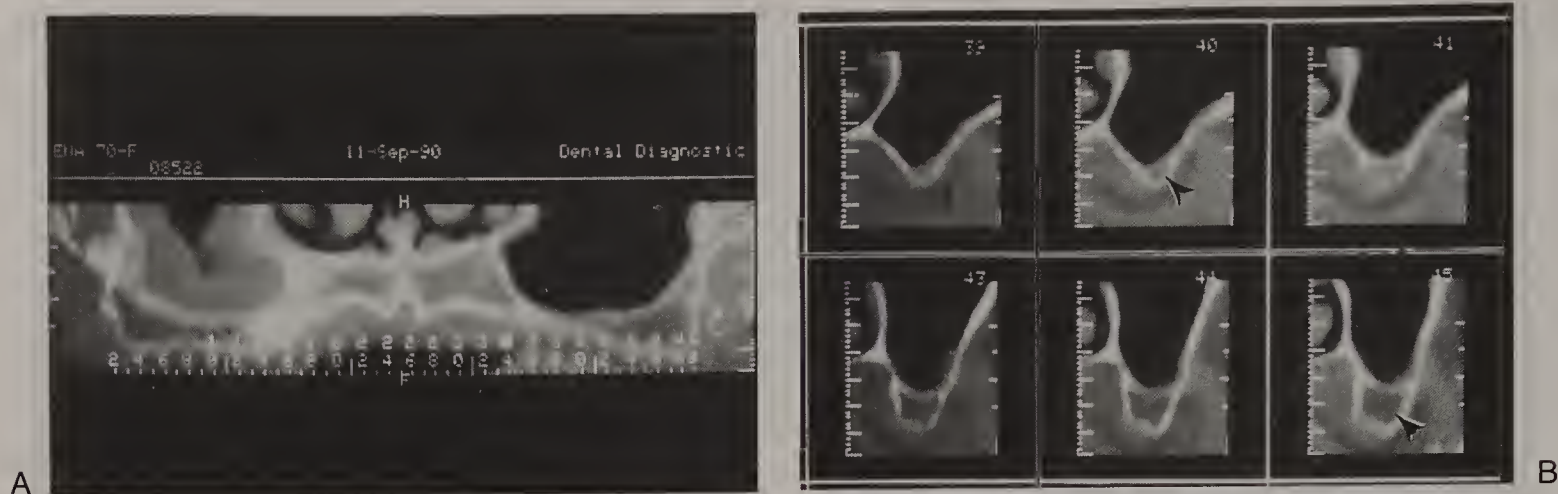
when multiple implant sites in multiple arches are involved. In addition, most contemporary work stations and the software used to process the CT image data are rapid, detailed, and allow visualization of the proposed sites on a 1:1 ratio, that is, life-sized. The disadvantages of CT for use in implant imaging are (1) the cost of a CT examination, (2) the significantly higher amounts of radiation exposure, (3) the artifacts from dental restorations can compromise the image at the selected site, and (4) common to all tomographic techniques, the CT images may not reveal with sufficient detail the important vital structures such as the mandibular canal.

### DIGITAL IMAGING (FIG. 11-19)

Digital radiography (see Part 3 in this chapter) is an image acquisition process that produces radiographic images in digital form. Digital radiographic images may be



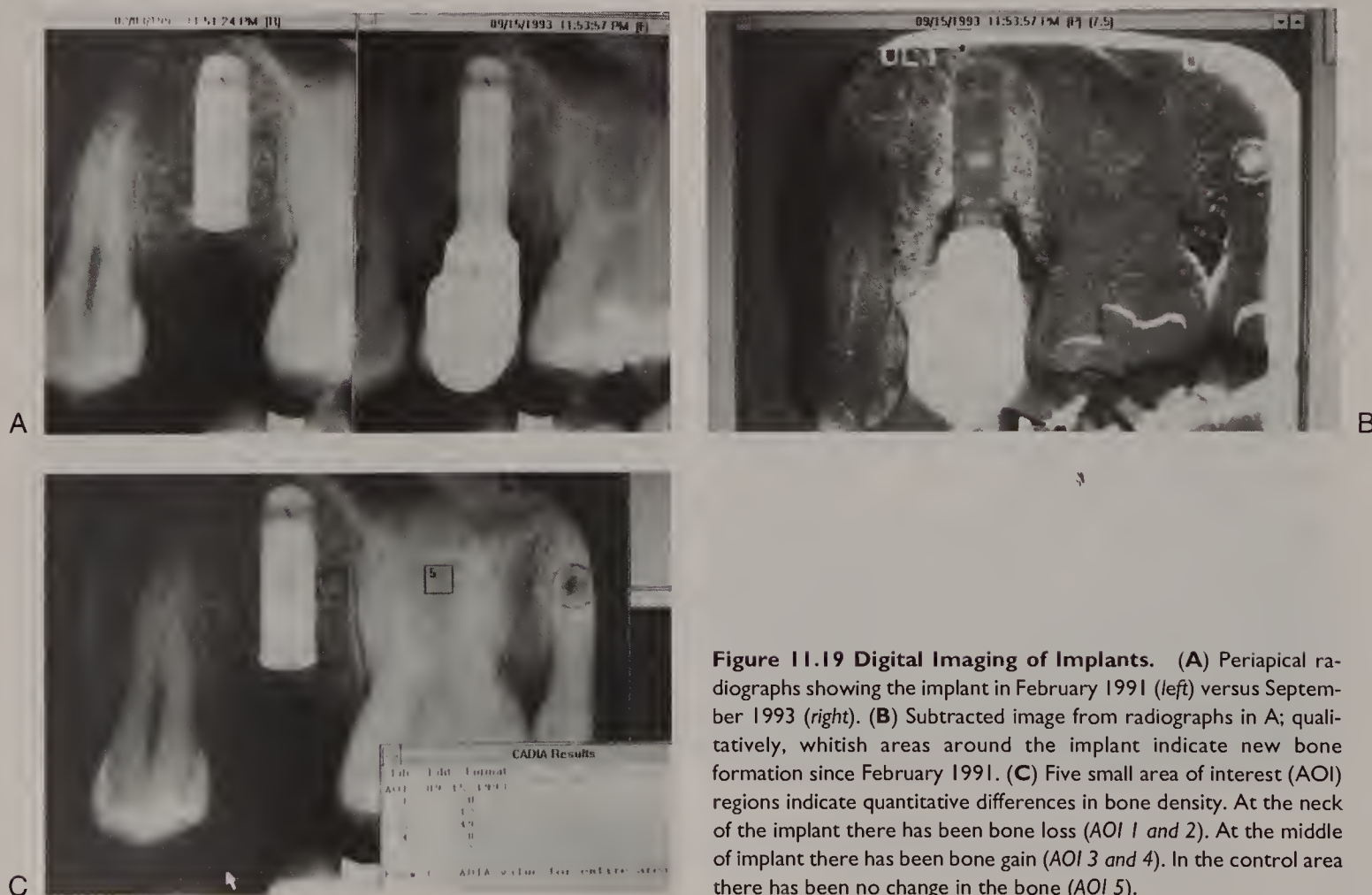
**Figure 11.17 Linear Tomography for Implants.** (A) Sagittal cut with tracings of structures of interest. (B) Cross-sectional cut. A magnified scale (arrow) is included with the tracing. (A radiopaque pin [arrowhead] identifies the desired placement of the implant as marked on the cast.)



**Figure 11.18 CT for Implants.** (A) Panoramic-like reformatted image of the maxilla. Note the one-to-one millimeter and centimeter measuring scales on the edges of the image. Numeric references along the bottom indicate the location of the numbered cross-sectional cuts. (B) Numbered cross-sectional cuts from the left maxilla with the one-to-one measuring scale on the edges. Note the difference in the available bone for implants between cuts 40 and 45 (arrowheads).

acquired by radiographic film (indirect digital radiography) or by detectors (direct digital radiography). The system categories: (1) The Charge Coupled Device (CCD) systems (Trophy RVG [Trophy Radiologie, Paris, France], and Schick CDR (Schick Technologies, Inc., Long Island, NY) all have a small, active image area with

wire connections from sensor to computer and an instantaneous image display. The Trophy, Gendex, and Schick systems are still available in 2002. (2) The image plate (photo stimulable phosphor) is utilized by the Soredex Digora System (Soredex Medical Systems, Soredex Orion Corp., Helsinki, Finland and Gendex DenOptix [Gendex Co., Des Plaines, IL]). The most common de-



**Figure 11.19 Digital Imaging of Implants.** (A) Periapical radiographs showing the implant in February 1991 (left) versus September 1993 (right). (B) Subtracted image from radiographs in A; qualitatively, whitish areas around the implant indicate new bone formation since February 1991. (C) Five small area of interest (AOI) regions indicate quantitative differences in bone density. At the neck of the implant there has been bone loss (AOI 1 and 2). At the middle of implant there has been bone gain (AOI 3 and 4). In the control area there has been no change in the bone (AOI 5).



detector is the Charge Coupled Device (CCD), which is a solid-state electronic device. In the Digora System, a fundamentally different concept for digital image acquisition is used. The Digora System does not use a CCD, but uses storage phosphors instead. With either direct digital system, the digital image may be stored for future use,

electronically to a remote site (teleradiography). Advantages of the digital techniques include immediate image display with no waiting for darkroom processing; the ability to manipulate the image by contrast enhancement or gray-scale reversal; reduction in patient radiation dose; elimination of film, darkroom, processors, processing chemicals, film mounts, and film mounting; and significantly less cost, including supplies (such as film, film mounts, processing chemicals, processor maintenance, repairs, and replacement) and the space required to accommodate a darkroom or processor with a daylight loader. For a detailed description of digital imaging, see Part 3 of this chapter.

## PART 2

### EXTRAORAL RADIOGRAPHY

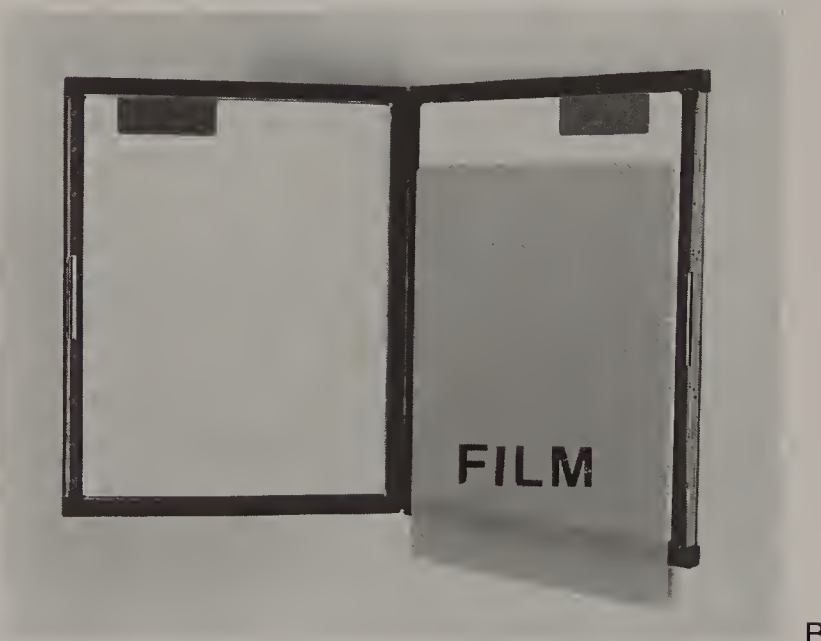
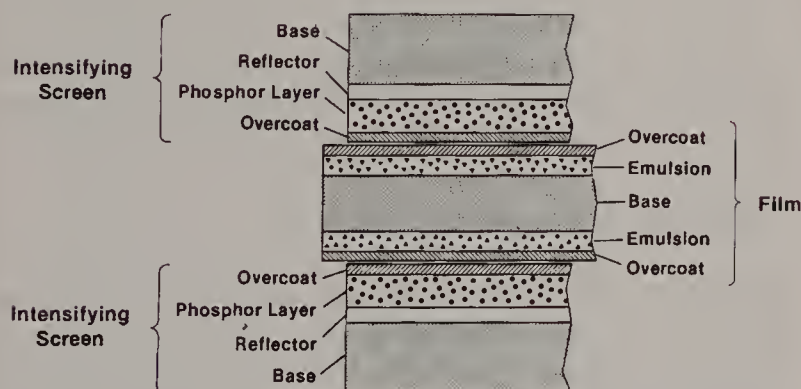
An extraoral radiograph is made by placing the film in a cassette against the side of the head or face and projecting the x-rays from the other side. Extraoral radiographs are taken using screen film and appropriate intensifying screens within a cassette. Intensifying screens are used be-

cause they decrease the x-ray dose (less mAs) to the patient, yet still produce a properly exposed radiograph. The x-ray film used with intensifying screens has a photosensitive (light-sensitive) emulsion on both sides of the film and is called screen film. The film is sandwiched between two intensifying screens in a cassette, so that the emulsion on each side of the film can be exposed to the light from the intensifying screen adjacent to it (Fig. 11-20). The intensifying screen functions to absorb the energy of the x-ray beam that has penetrated the patient. The screen then converts this energy into light to form a latent image on the x-ray film. The latent image is made visible by processing the film in chemical solutions under darkroom conditions.

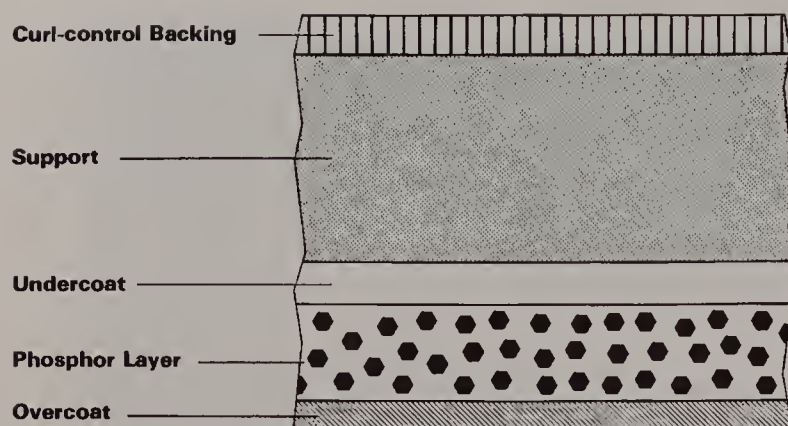
## FACTORS COMMON TO ALL EXTRAORAL RADIOGRAPHIC TECHNIQUES

### SCREEN/FILM SIZE AND SCREEN/FILM SYSTEMS

For dental use, the following screen film sizes are available: 5 × 7 inches, 5 × 12 inches (panoramic), 6 × 12 inches (panoramic), 8 × 10 inches, and 10 × 12 inches. A characteristic of x-rays is that they cause certain materials to fluoresce, that is, give off ultraviolet and/or visible light radiation. Such fluorescent materials are called phosphors. The ability of phosphors to fluoresce when excited by x-rays makes the intensifying screen possible



**Figure 11.20 Intensifying Screens and Cassette.** (A) Illustration shows the double-coated film sandwiched between two intensifying screens. All components of film-screen combination are shown, but not drawn to scale. For example, the thickness of the phosphor layer of the top screen may differ from that of the lower screen. (B) Photograph of 8 × 10-inch cassette with two white intensifying screens. The film is placed between them in the darkroom, and the cassette is closed tightly to hold the film between the two intensifying screens during exposure.



**Figure 11.21 Intensifying Screen, Physical Characteristics.** Curl-control backing prevents warping or distortion of screen. The support layer is made of paper, plastic, or cardboard to impart required stiffness to the screen. Undercoat may be light-reflective, light-absorptive, or simply transparent, depending on the desired performance characteristics of the screen. Using the desired undercoat as a reflector of light will increase the speed of the screen. The phosphor layer consists of tiny phosphor crystals embedded in the binder of the screen. Overcoat is a plastic protective coat.

(Fig. 11-21). **Fluorescence** is a form of luminescence, which refers to the emission of light by a substance caused by various kinds of stimuli such as chemical reactions, and ionizing radiation. The phosphor of the intensifying screen has one purpose: the conversion of the x-ray beam into visible light. This action of the phosphor can be viewed by opening a cassette in a darkened room and, while standing behind a protective barrier, exposing the intensifying screen to x-radiation. The screen will glow brightly. Depending on the phosphor selected and its treatment during manufacture, light of almost any desired color may be obtained.

Screen or photographic films are selective in their response to light of various wavelengths. When a certain type of film is exposed to light, its speed varies. Certain films are more sensitive to one part of the light spectrum than to another. A film's response to various wavelengths (color) is referred to as its **spectral sensitivity**. The speed of the screen/film combination is dependent on the matching of the spectral sensitivity of the film (whether it is blue, blue-green, ultraviolet, or green light) with the color emitted by the intensifying screen.

### RARE EARTH INTENSIFYING SCREENS AND T-MAT FILM

Some of the newer phosphor screens are the **rare earth** screens. The term rare earth is used because these elements are difficult and expensive to separate from the earth and each other, not because the elements are rare. Lanthanum (La) and gadolinium (Gd) are used as rare earth phosphors. The rare earth screens emit light in approximately 60% of the green portion of the light wave spectrum. Therefore, **green-sensitive** films were developed

that gave a greater sensitivity and speed to the rare earth screen-film combinations and, in turn, provided dramatic reduction in patient exposures. In 1983, T-grain film was introduced by Eastman Kodak (Rochester, NY). T-grain film contains silver halide grains that are tabular or flat, rather than pebble shaped. These flat grains have a greater cross-section, which increases their ability to absorb light from the intensifying screens. When green-sensitive T-grain film (T-Mat film) is used with rare earth green-light-emitting screens, it was found that this film-screen combination was twice as fast as conventional calcium tungstate screen film combinations. Also, screen/film systems are designed for various applications. For instance, Kodak T-Mat L film combined with Kodak Lanex regular screens (gadolinium rare earth) provides good soft tissue visualization with a wide range of densities (long-scale contrast), whereas Kodak T-Mat G film with the same screens gives higher-contrast (short-scale contrast) radiographic images.

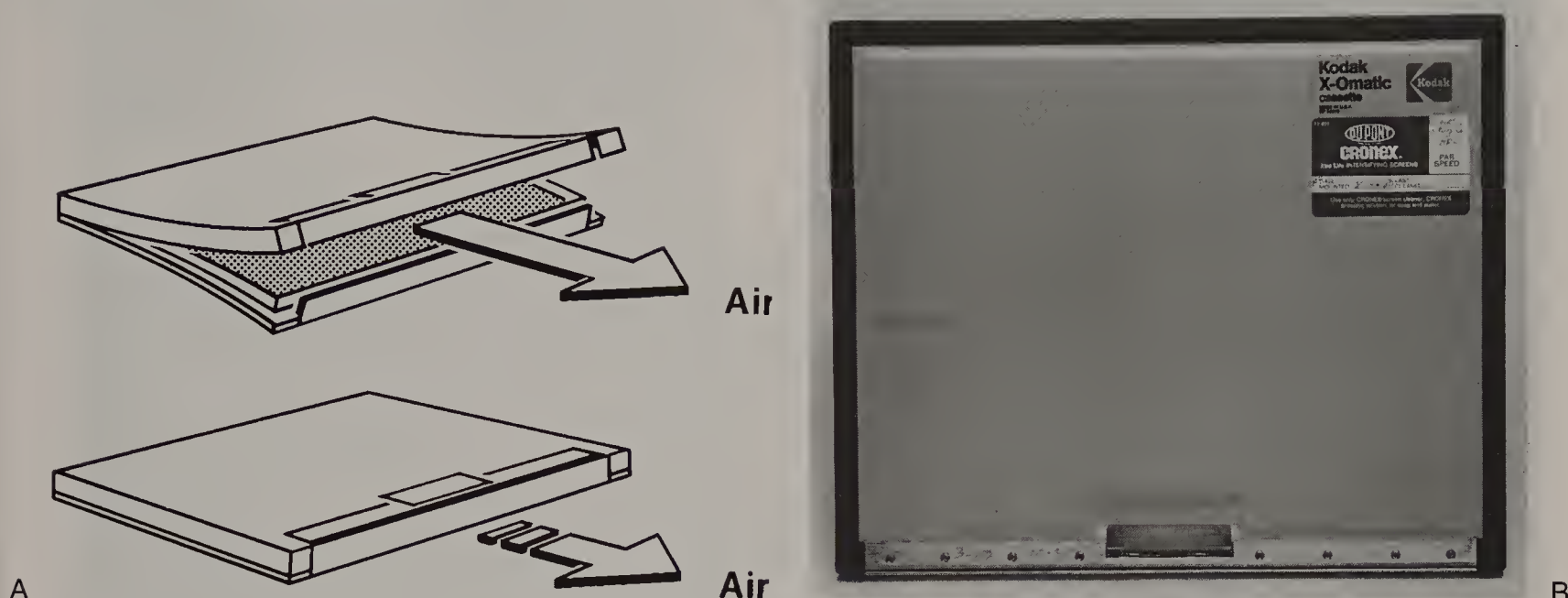
### CASSETTES

The **cassette** is the rigid holder that contains the screens and the film. The front surfaces or the side facing the tube should be made of material containing elements with low atomic numbers—such as in plastics, cardboard, or Bakelite—and should be as thin as practical to allow as much radiation through as possible. Attached to each cover is an intensifying screen, and the radiographic film is loaded between them. Between each screen and cover is a compression device, such as felt or rubber, which maintains close film contact with the screens when the cassette is closed and latched. The back cover is usually made of heavy metal (aluminum, lead lined) to minimize backscatter. The hinges and hold-down clamps are usually made of stainless steel. Some of the newer cassettes feature a curved construction for more efficient expulsion of trapped air (Fig. 11-22). Some of the panoramic units use flexible plastic cassettes that wrap around a drum that rotates during the exposure cycle. A high-quality screen film radiograph depends on intimate contact being maintained between the film and intensifying screen. If there is any space between the screen and the film, a loss of sharpness of the outline of the radiographic images will occur.

### IDENTIFICATION

It is important to identify the right and left sides of the patient on the extraoral radiograph. This can be done by placing “R” and “L” lead markers on the cassette. Extraoral radiographs can be produced in the dental office when using conventional dental and panoramic x-ray machines. Also, the patient can be identified by “burning-in” the information in the emulsion with the use of a simple identification photographic device before processing.





**Figure 11.22 Kodak X-Omatic Cassette.** (A) Curved construction for more efficient expulsion of trapped air and better maintenance of contact without springs. (B) Front of the cassette is in closed position.

## EXTRAORAL RADIOGRAPHIC UNITS USED IN DENTISTRY

Panoramic units are used to achieve better overall coverage of the maxillomandibular structures than conventional intraoral dental techniques can provide. Although the large medical x-ray units are specifically designed for extraoral radiography, smaller conventional dental x-ray units can be used in extraoral radiography.

## SKULL RADIOGRAPHY

The skull radiographic projections used by the dentist pertain mostly to cephalometric skull radiography and temporomandibular joint (TMJ) radiography.

### CEPHALOMETRIC RADIOGRAPHY

Cephalometric radiography is used by orthodontists and pediatric dentists for evaluation of the skull for prediction of growth. The technique is also used by oral surgeons for treatment planning purposes in orthognathic surgery. A head-holding device, called a cephalometer or cephalostat, is used in cephalometric radiography (Figs. 11-23 and 11-24). The cephalostat makes it possible to position and reposition the patient's head in a predetermined relationship to the x-ray beam and to the **Frankfort horizontal line**, which is a line connecting the superior border of the earpost of the cephalostat (**porion**) and the inferior border of orbit (**orbitale**). The most common view used in cephalometric radiography is the lateral or profile view. The lateral view is always made with the left side located

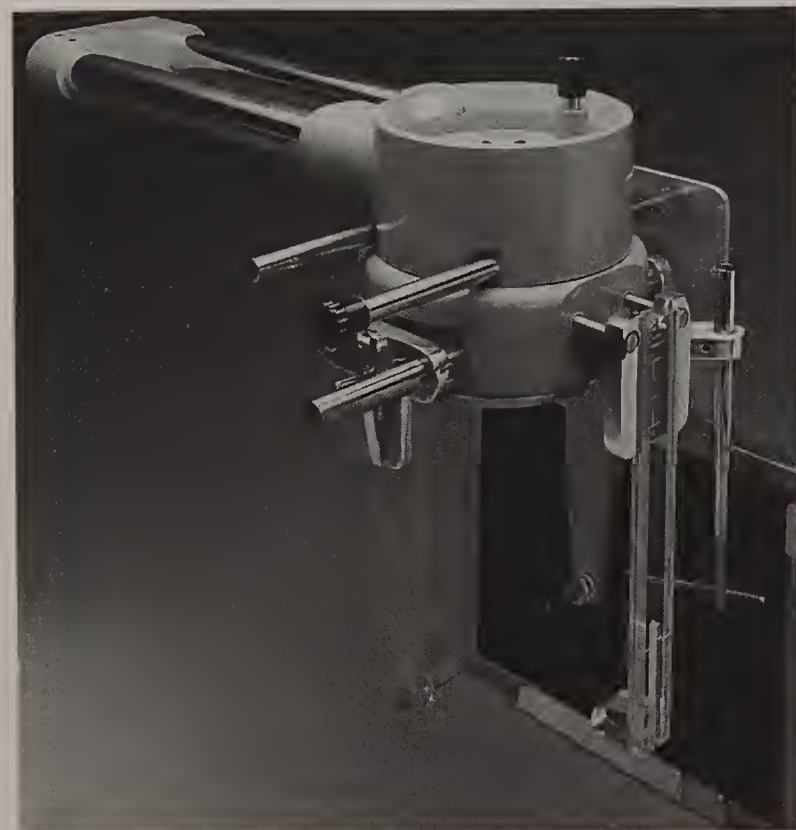
nearest the cassette. In cephalometrics, the accepted distance from x-ray source to patient is 5 feet or 152.4 cm. The patient location point is measured from the midsagittal plane, which is determined as the midpoint between the earposts. The cephalostat immobilizes the patient's head by means of the nasion positioning rod and the earpost plugs. The patient's head is aligned to the Frankfort plane by use of infraorbital marker. The midsagittal plane should be parallel to the horizontally placed film inside the cassette. A lateral (profile) skull cephalometric radiograph is shown in Figure 11-25. It is used to measure facial relationships and to predict or analyze growth patterns in orthodontic treatment. This is done by means of cephalometric (skull) tracings of key structures, which are then evaluated by measurements of angles and linear dimensions between the various parts.

### TMJ RADIOGRAPHY

There are two TMJ radiographic techniques that can be used in the dental office: the **transcranial lateral TMJ projection** and the **panoramic TMJ projection**. There are three TMJ radiographic techniques of such specialized character that they require equipment mostly found in hospitals, institutions, and specialty offices. These are linear or multidirectional tomography, computed tomography (CT), and magnetic resonance imaging (MRI).

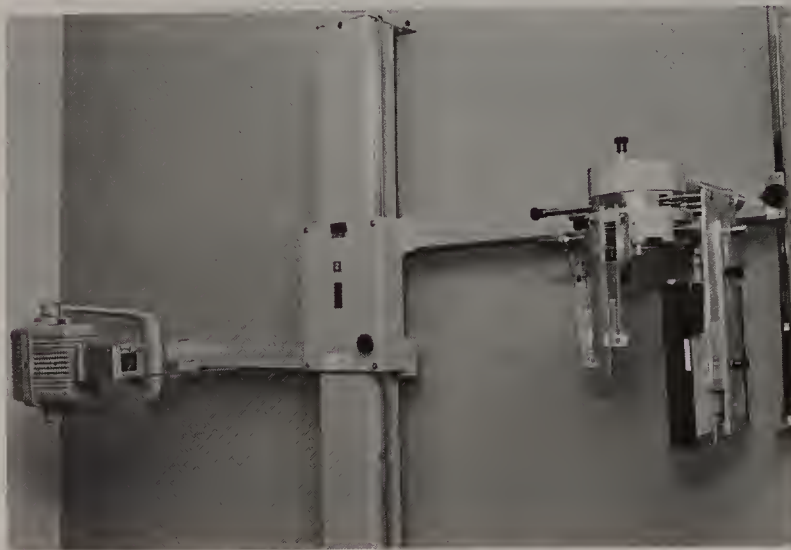
#### Transcranial Lateral TMJ Projection (Fig. 11-26)

In all transcranial techniques, the x-ray beam is directed down across the top of the **petrous portion** of the temporal



A

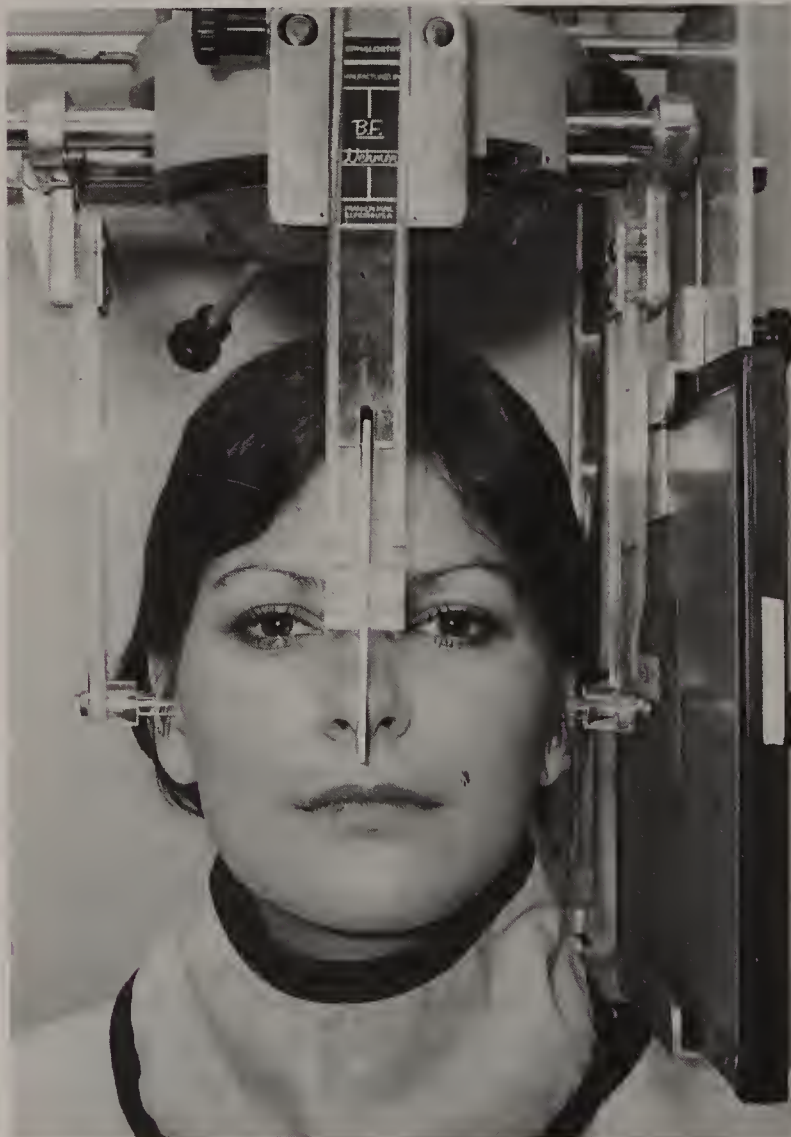
**Figure 11.23 Wehmer Cephalostat for Cephalometric Radiography.** (A) Cephalostat, close-up view. (B) Cephalostat and fixed dental x-ray tube-head. (C) Side view of lateral cephalometric projection. (D) Front view of lateral cephalometric projection.



B



C



D

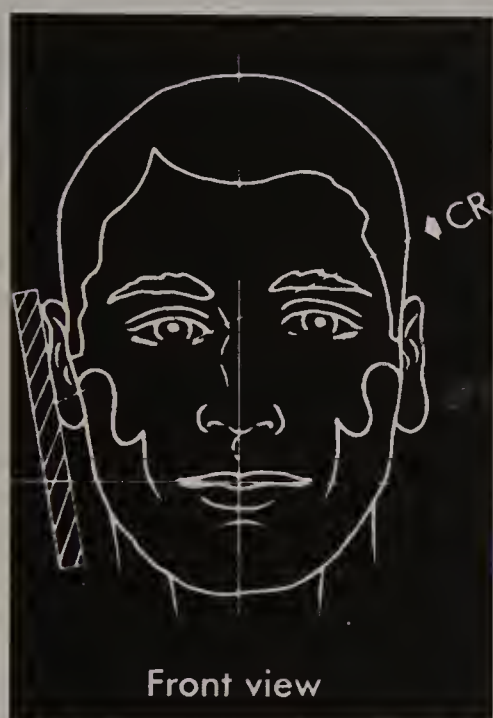




Figure 11.24 Panoramic Cephalometric Technique.



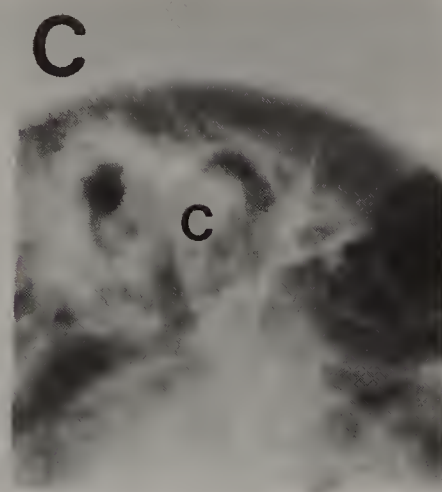
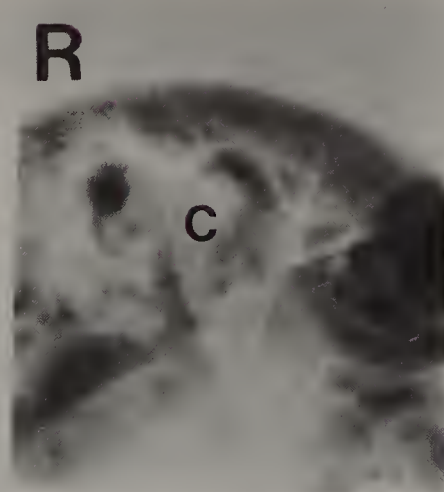
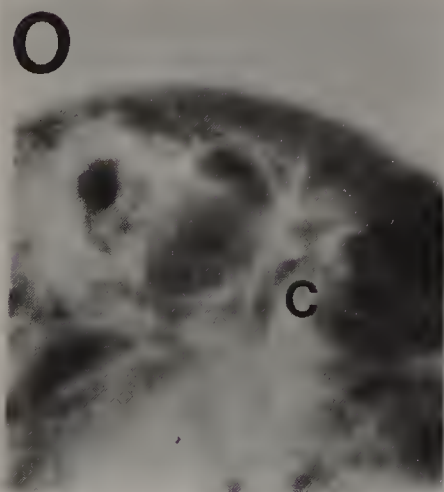
Figure 11.25 Lateral Cephalometric Radiograph. Lateral (profile) cephalometric radiograph of a child.



A

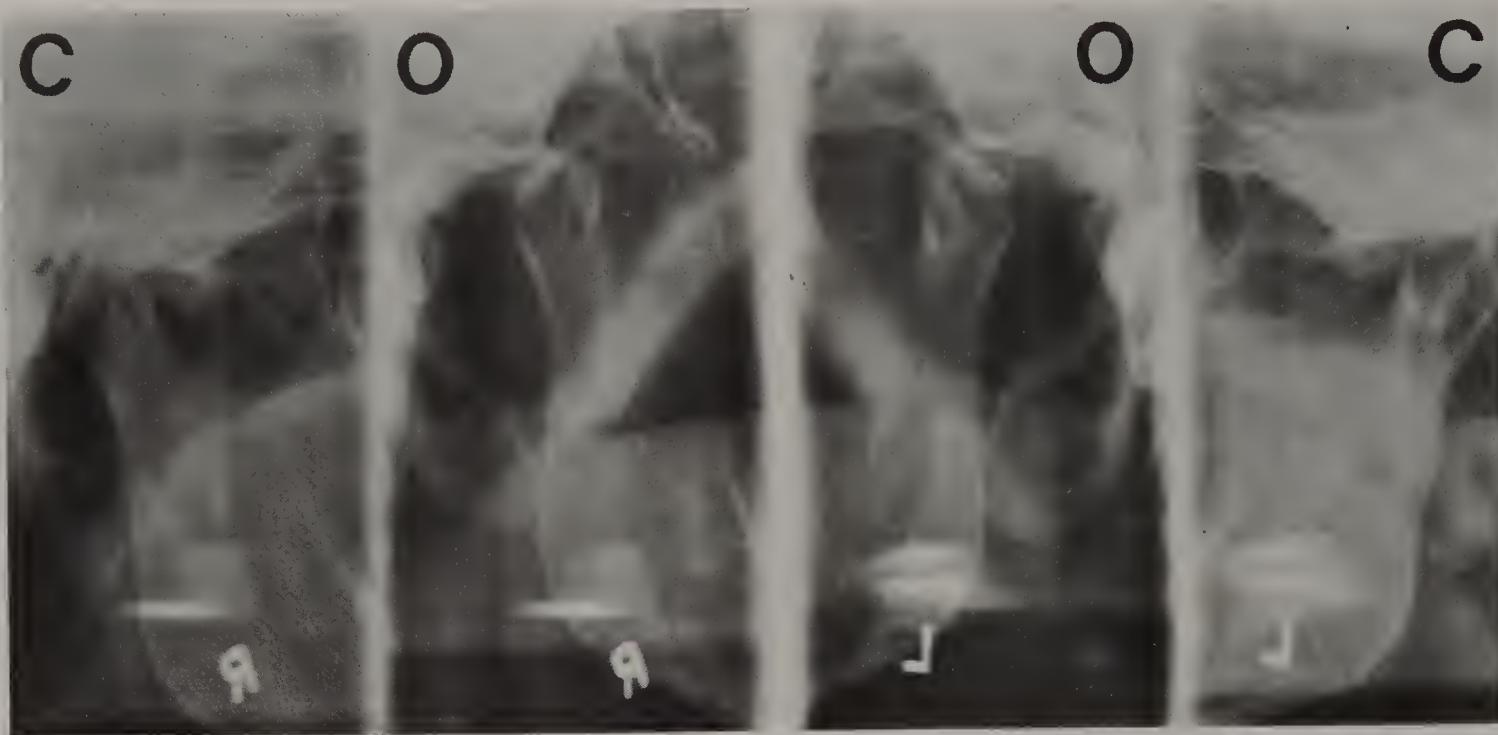


B



C

Figure 11.26 Transcranial Lateral TMJ Projection. (A) The point of entry of the central ray (CR) is 0.5 inches behind and 2 inches above the external auditory meatus on the opposite side. The CR is directed with a 25° downward vertical angulation at the condyle on the opposite side. The condylar head in the transcranial radiograph will reveal only the laterosuperior border of the condylar head because of the mandatory oblique angulation of the CR. (B) Position of the patient in transcranial lateral TMJ projection. (C) Transcranial lateral TMJ radiograph. O, open; R, rest; C, closed. ("C" indicates head of condyle in each radiograph.)



**Figure 11.27 Panoramic TMJ Projection.** Panoramic view of the TMJ. This is an anteroposterior oblique view of the condyles and can be used only to rule out gross pathology. C, closed; O, open.

bone to the condylar head on the opposite side of the skull. This is done to avoid superimposing the petrous portion of the temporal bone over the TMJ. This oblique projection of the x-ray beam causes distortions of the three-dimensional head of the condyle and the glenoid fossa. The most that can be accomplished by transcranial projections of the TMJ is to view the lateral border of the glenoid fossa and laterosuperior border of the head of the condyle. The superior border of the condyle between the lateral and medial poles of the condyle cannot be seen on the transcranial lateral TMJ. Unfortunately, this is where most of the changes occur in TMJ disorders.

#### Panoramic TMJ Projection

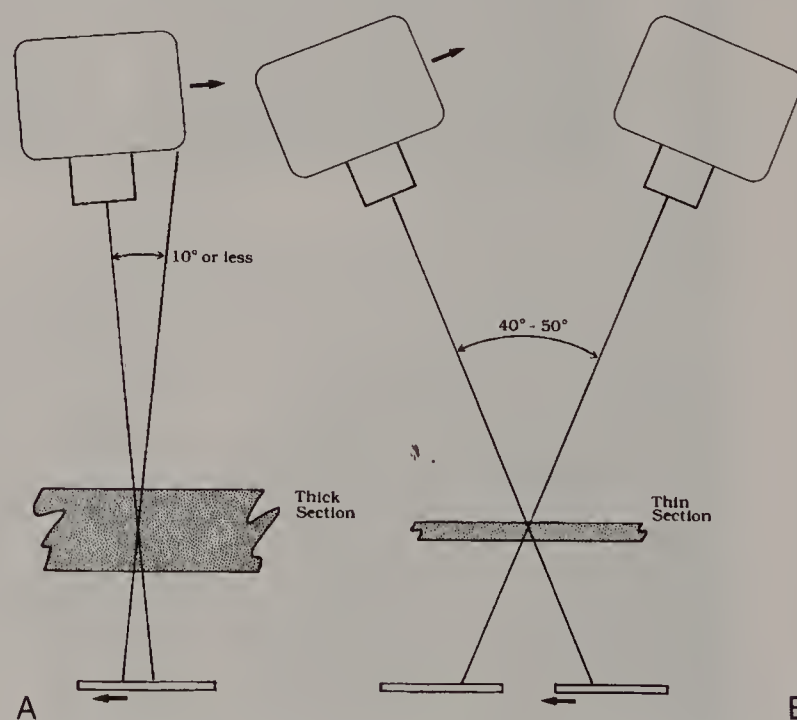
All rotational panoramic units have special TMJ projections. The panoramic TMJ views are usually of sufficient clarity to evaluate the condyles for gross osseous changes such as erosions, masses, or displaced fractures. This view is limited because the central ray is not directed through the long axis of the condyle. The TMJ area is usually revealed as an anteroposterior oblique view. This view is not generally accepted for close examination of the TMJ. It cannot be used to evaluate the disc or the position of the condyle in the fossa (Fig. 11-27).

#### TMJ Tomography

Tomography is a special x-ray technique that blurs out the shadows of superimposed anatomical structures that obscure information in the radiograph. It is not a method of improving sharpness of the radiographic image, but is a process of controlled blurring that leaves some parts of the image less blurred than others. The tomogram is made

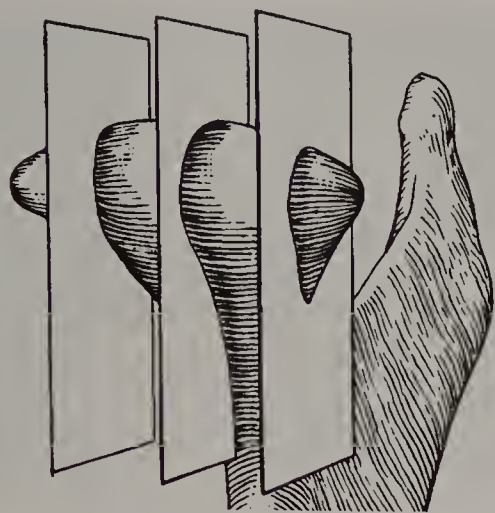
by a special mechanism in which the x-ray tube and the film cassette are attached to a rigid connecting rod that rotates around a fixed fulcrum.

When the tube moves in one direction, the film cassette moves in the opposite direction. Tomographic techniques blur all points that lay outside the focal plane (Fig. 11-28).



**Figure 11.28 Tomography.** When the tubehead moves in one direction, the film cassette moves in the opposite direction. Tomographic techniques blur all points outside the focal plane. The angles of exposure of tomography determine the thickness of the focal plane or the body section. (A) Zonography (narrow-angle tomography). (B) Wide-angle tomography is best for high-contrast tissues (bone).

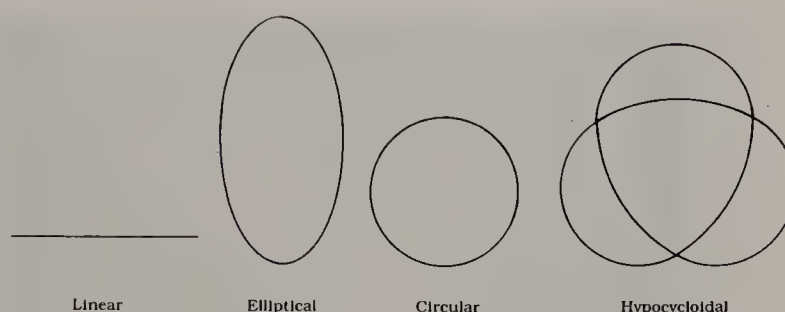




**Figure 11.29 TMJ Tomography.** The fulcrum of the TMJ tomographic system can be adjusted so that lateral condylar cuts or slices of the condylar head can be made.

The fulcrum around which the system rotates is adjustable, so that any desired image layer in an anatomical structure can be selected for radiographing (Fig. 11-29).

Another factor to consider in tomography is the type of motion or movement of the x-ray tube. If the x-ray tube and the film move in a straight line, it is called a **linear tomography**. It has an advantage in that this x-ray equipment is relatively inexpensive; however, it has a disadvantage in that linear structures aligned parallel to the direction of motion of the tube are not blurred as well as those lying at an angle to the tube. Therefore, tomographic equipment has been developed to produce complex types of motion that produce more effective blurring of unwanted structures (Fig. 11-30). The most complex trajectory or tube motion available is the **hypocycloidal movement**, which results in highly effective blurring; it is sometimes described as a **cloverleaf**. It has no dominant direction and is especially suitable for tomography of small bony structures of the head (e.g., the auditory ossicles and



**Four Varieties of Tomographic Trajectory**

**Figure 11.30 Types of Tube Motion in Tomography.** Four varieties of tomographic trajectory are shown. The hypocycloidal (cloverleaf) movement is the most complex and results in highly effective blurring of structures outside the focal plane.

the TMJs). Lateral tomographic slices provide a series of images that includes extensive viewing of the medial and lateral aspects of the joint (Fig. 11-31). Several tomographic units have been designed specifically for dentistry.

#### **CT of the TMJ (Fig. 11-32)**

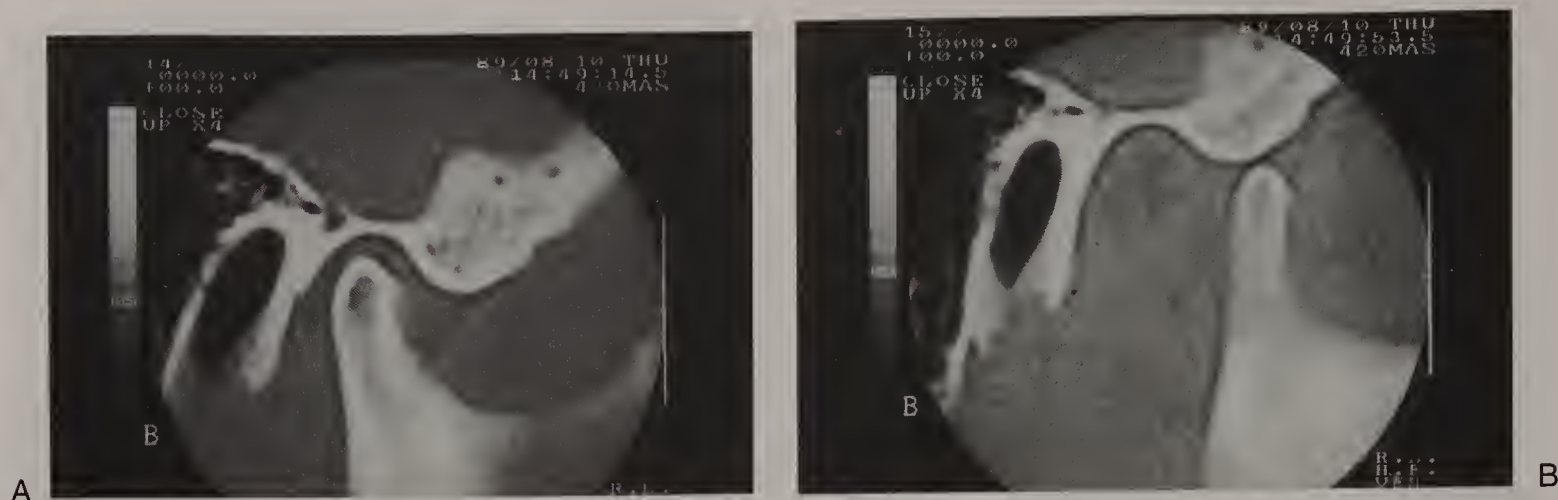
CT scanners create digital images by measuring the transmission of an x-ray beam through tissue as the x-ray tube rotates around the patient. CT imaging offers many diagnostic advantages, including the ability to produce reconstructed images in selected projections and low-contrast resolution (detail) far superior to that of all other x-ray imaging modalities. CT appears to reveal more bony detail of the TMJ than conventional tomography; however, in general, both imaging techniques appear to be comparable. Also, conventional tomography is less costly and delivers a smaller absorbed dose of radiation than CT.

#### **MRI of the TMJ (Fig. 11-33)**

Ionizing radiation is not used in magnetic resonance imaging (MRI). Instead, the patient is placed in a uniform magnetic field, and electromagnetic energy temporarily changes the alignment and orientation of the



**Figure 11.31 TMJ Tomographic Radiographs.** Linear tomographs taken of left normal TMJ. From left to right: closed, rest, and open.



**Figure 11.32 CT of TMJ.** Computed tomography is indicated when a greater amount of detail about the form and internal details of the osseous structures are required. (A) Closed. (B) Open.

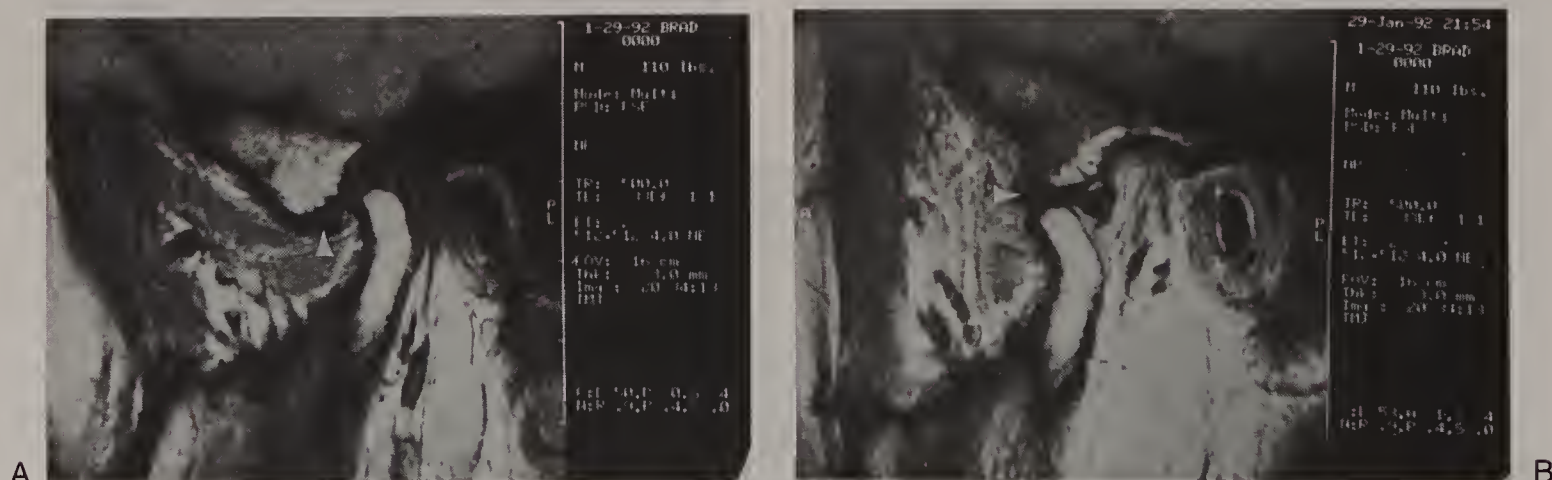
hydrogen protons within the body. The area being examined is then subjected to radio frequency waves that displace the equilibrium magnetization vector. As the magnetization vector returns to equilibrium, it gives off a signal that allows for indirect detection of the magnitude and molecular characteristics of the magnetized hydrogen protons. Using this information, a sophisticated mathematical operation, called a Fourier transformation, converts it into the final magnetic resonance image. MRI is the only imaging technique that can simultaneously image both the disc and posterior attachment as well as the condyle and mandibular fossae of both joints during a TMJ examination. Because of the high incidence of bilateral abnormalities in patients with TMJ dysfunction, this is a definite advantage. As in tomography, slices in the corrected lateral and frontal views are preferred. Both open and closed images are used to evaluate the position of the disc (Fig. 11-33).

## PART 3

### DIGITAL IMAGING

### INTRODUCTION TO DIGITAL IMAGING

The term radiography comes from the words “radiation” and “photography.” That is, making a photographic image using radiation. Today, we can create images within a computer using digital sensors, phosphor plates, or ultrasound and no longer need the photographic process. Hence, the term imaging has come to replace radiography when referring to all the different ways we can create images of a patient. The difference between digital images and radiographs is that digital images have no physical form. They exist only as numbers in a computer file (digital comes from the word “digits” or numbers) that tell the computer how



**Figure 11.33 MRI of TMJ.** MRI is the only imaging technique of TMJ that can simultaneously image both the disc and posterior attachment as well as the condyle and mandibular fossae of both points during a TMJ examination. (A) Closed anterior disc displacement (arrowhead). (B) Open. Disc has reduced to normal position (arrowhead). Disc and cortical bone appear black because of low water content.



to reconstruct the image so that it can be displayed on a monitor, laptop screen, printer, or other viewing device.

The advantages of digital imaging are many. Most are based on the elimination of the photographic process.

**Advantages of Digital Imaging**

- 1. Elimination of darkroom and automatic processing equipment.
- 2. No chemical processing or chemical wastes.
- 3. Elimination of x-ray film.
- 4. Instant viewing of the image.
- 5. Less radiation dose to the patient.
- 6. Lower cost per image.
- 7. Ability to perform image-processing techniques, such as darken or lighten.
- 8. Remote electronic consultation and sending of images by email.
- 9. Remote access to images from the home or outside the office.

No system is perfect. Although digital imaging systems are being improved rapidly, they currently have some disadvantages:

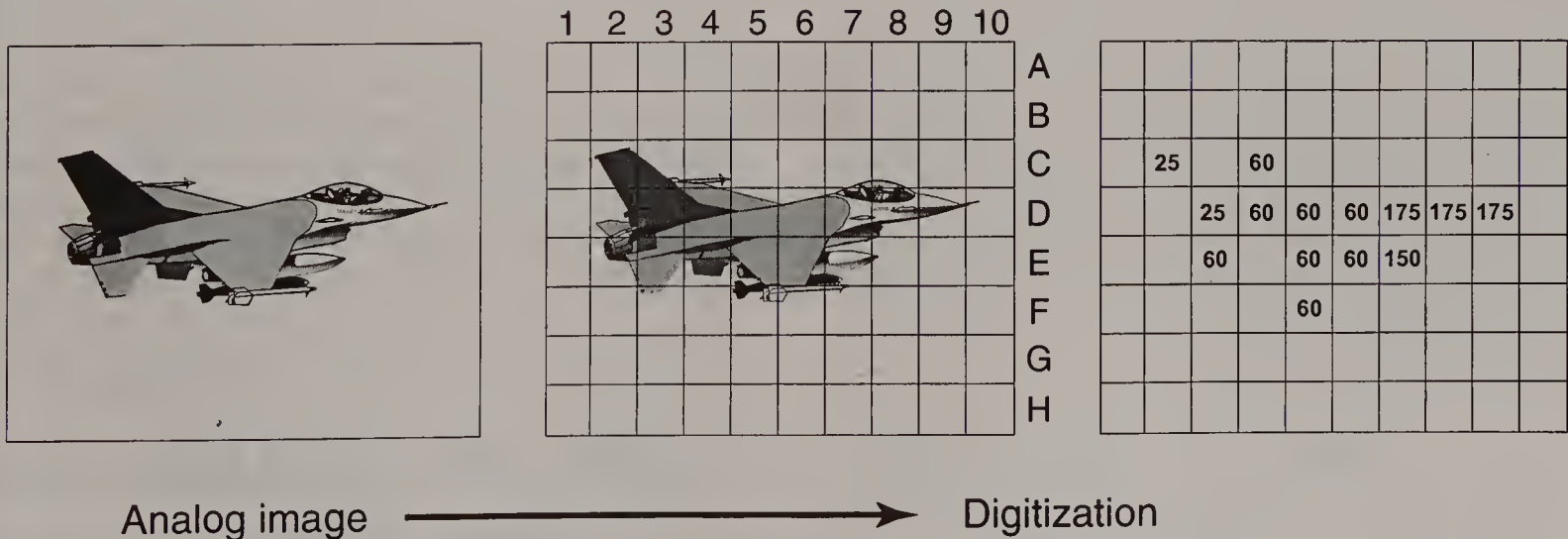
**Disadvantages of Digital Imaging**

- 1. High initial cost \$6000 to \$16,000.
- 2. Image quality is not quite as good as film.
- 3. Sensor size is sometimes bulky.
- 4. Need a computer and/or computer network.
- 5. [Redacted]
- 6. Panoramic and cephalometric units are more expensive and not as common.
- 7. Legal acceptance issues persist.
- 8. Acceptance by third party carriers is variable.
- 9. Integration of radiographic software into practice software is sometimes difficult.

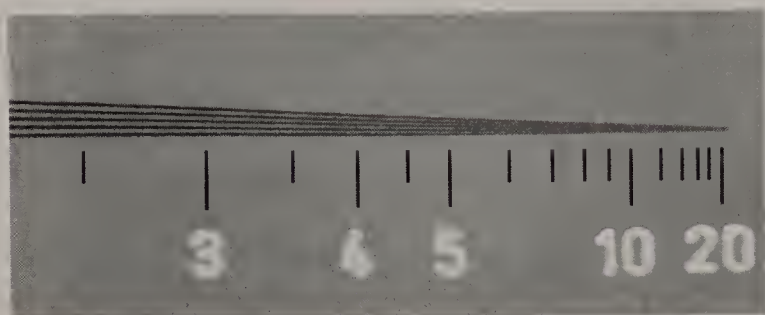
Despite the disadvantages, digital imaging represents the new age of imaging in dentistry. The disadvantages are disappearing as technology advances. The contemporary dental office will have not only digital radiographic devices, but also digital still and video cameras, surgical microscopes, and electronic patient records; it will also be in electronic communication with referral centers. Digital imaging will integrate into and be an essential part of a modern paperless dental office.

**WHAT IS A DIGITAL IMAGE?**

The term **digital image** is used to distinguish it from an ordinary or analog image. An analog image is traditionally described as being like a painting in which colors blend smoothly with one another, with no smaller parts making up the image. Examples of analog images are traditional radiographs, photographs, and television. A digital image, on the other hand, is like a mosaic, made up of many small pieces put together to make a whole. Imagine if we took a painting and put a grid on top of it. For every square in the grid we would record two numbers. The first number would indicate the location on the grid and the second would record the brightness value at that location. This process is called digitization (Fig. 11-34). It breaks up an analog image into discrete points of brightness which when reconstructed in the proper order will form a visible analog image. The grid used is referred to as the image matrix, and each individual square in the matrix is known as a pixel. The more pixels that are present in an image of a fixed size, the greater the resolution and better the visual appearance of the final image. This is one of the fundamental characteristics of a digital image.



**Figure 11.34 The Digitization Process.** From left to right: The analog image represents an ordinary image. In the digitization process, the analog image is superimposed on the image matrix and converted to numeric values using an analog to digital converter board in the computer and appropriate software.



**Figure 11.35 A Line-Pair Test Target to Measure Resolution.** In this particular example, the resolution appears to be between six and seven line pairs per millimeter where separation between individual lines cannot be seen.

## CHARACTERISTICS OF A DIGITAL IMAGE

### PIXEL OR SPATIAL RESOLUTION

The number of pixels and their size determine the spatial resolution of an image. When the number of pixels is low, the image appears pixilated or “blocky,” with jagged edges on diagonal lines and small objects being difficult to see. This property is measured in terms of line pairs. A line pair refers to the largest number of paired lines visible in a space of 1 mm in an image (Fig. 11-35). For example, a resolution of 12 line pairs (lp)/mm would mean that you could squeeze 12 ruled lines into 1 mm of an image and still be able to see the individual lines. The greater the resolution in an image, the sharper and “cleaner” it looks and the smaller the objects that can be accurately visualized on the image. Currently, the resolution of dental film is about 8 to 16 lp/mm and 6 to 9 lp/mm for panoramic film. The human eye can only resolve about 12 to 14 lp/mm. Spatial resolution is determined by the number of pixels and by their size. The more pixels in an image, the greater the spatial resolution. This is why digital cameras are advertised based on the number of pixels in their sensors. A megapixel camera has 1,000,000 pixels in its sensor. Also, spatial resolution is determined by pixel size. Since sensors can only be so big and still fit in the mouth, the closer you can fit pixels together, the more pixels you can squeeze into the same area (Fig. 11-36). Thus, manufacturers have been working to decrease pixel size. Older sensors had 70  $\mu$  size pixels; modern sensors have pixels as small as 25  $\mu$ . Current systems have pixel resolutions

**GRAY SCALE**  
**400 DPI**

**GRAY SCALE**  
**100 DPI**

**Figure 11.36 Pixel Number and Image Quality.** The left image has more pixels per inch and higher resolution. In the right image, pixelization has occurred and is a sign of poor image quality.



**Figure 11.37 Image Quality and Gray Scale.** (Top) A 3-bit image has  $2 \times 2 \times 2$  or 8 shades of gray. (Bottom) A 4-bit image has  $2 \times 2 \times 2 \times 2$  or 16 shades of gray (bottom diagram). Increasing bit depth yields more shades of gray. The human eye can see approximately 16 to 25 shades of gray.

of up to 20 lp/mm for intraoral sensors, which is greater than the eye can detect.

### GRAY SCALE RESOLUTION

The other property of digital images that determines how they look is gray scale resolution. Gray scale resolution refers to the total number of shades of gray visible in an image. A number stored for each pixel determines the number of shades of gray visible. For example, a pixel may have a number from 0 to 255, representing pure black at 0 to pure white at 255. These numbers represent powers of 2, the way computers store information. Each power of 2 requires 1 bit of computer storage. A 1-bit image can only store  $2^1$  shades or black and white. A 2-bit image can store  $2^2$  or 4 shades of gray. The standard image is  $2^8$  or 256 shades of gray. Figure 11-37 shows the effect of increasing bit depth or gray levels. At 256 shades of gray, the individual shades blend together to form a continuous tone image that appears to the eye as an analog image would. Modern digital imaging systems can store even more shades of gray, up to 10 or 12 bits or higher. However, only 8 bits are usually capable of being displayed on the monitor or used for image processing. Most people can only see 16 to 25 shades of gray, and the



maximum visible in laboratory conditions is only 64 shades of gray. However, higher gray scale resolutions are desirable because they are useful for reducing noise in the image. Noise is extraneous information generated by the imaging system, much like fog in a radiograph. Software called filters removes the noise and provides the best 8 bits for viewing.

The combination of pixel or spatial resolution and gray scale resolution determines the quality of the final image and how it appears to us. These two essential characteristics should be maximized in an imaging system up to the 12 to 14 lp/mm our eyes can see.

## COMPUTER AND SOFTWARE SELECTION

### COMPUTER

All digital images require a computer and a display device to capture and view an image. There are a wide variety of computer configurations possible, and specially designed computer systems are not required. Any commercial computer can be used, with some exceptions, as outlined below.

### PC VERSUS MACINTOSH

At this time all dental digital radiography systems are designed to work with PC-based computers (Intel-Windows) and are not compatible with the Macintosh system. Many newer Macintosh systems have Universal Serial Bus (USB) or Firewire connections. These systems are technically hardware compatible with dental digital radiology systems. However, Macintosh computers are still not software compatible.

### PROCESSOR SPEED

Dental digital radiography systems can work well with any current microprocessor speeds. A Pentium system running at 266 mHz or higher should be adequate for most systems. The computer operating system used will determine processor speed more than the digital radiology hardware. The Windows 2000 operating system, for example, requires a faster processor than Windows 95. Faster processors will speed up image processing significantly, and current 600 mHz or greater processors provide exceptional performance at a reasonable cost.

### RANDOM ACCESS MEMORY

Digital systems work with large amounts of data. These data must be stored in the computer's random access memory (RAM) during image capture and processing. If enough RAM is not available, parts of the image will have

to be stored on the hard disk, which will slow performance. The more RAM available in the computer, the better the performance will be. A recommended minimum amount of RAM for digital imaging is 64 to 128 megabytes (MB). More memory is better, especially if video will be incorporated. Insufficient memory can cause slow performance and system crashes.

### HARD DISK DRIVE STORAGE

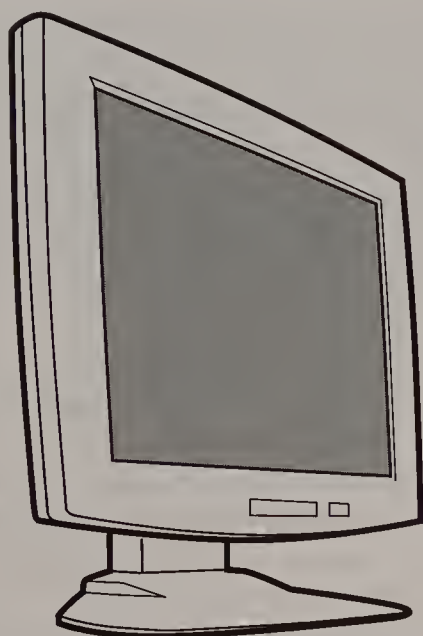
The hard disk drive is where the images are stored between uses. As digital image files can be quite large, the more hard disk drive space available, the more patient records can be kept on the computer at one time. An average periapical image requires 0.5 to 1 MB of storage. A panoramic image may be anywhere from 1.5 to 8 MB. A full-mouth series may require up to 20 MB of storage (1000 KB = 1 MB, 1000 MB = 1 GB). Modern drives of 15 to 30 gigabytes (GB) are perfect for digital imaging. They allow hundreds of patient records to be stored before the hard disk fills up and images must be moved to back-up media.

### MONITOR

A good display is essential for digital imaging. Some of the choices available are (1) a conventional cathode ray tube (CRT), which is similar to a TV set; (2) a flat panel display; or (3) a laptop computer screen. There are advantages and disadvantages to each. A conventional CRT display that comes with most desktop computers offers excellent image quality and the lowest cost. However, they are large and bulky and generate considerable heat. This makes them difficult to place in an operator. They are not portable and are difficult to disinfect for infection control. A laptop computer screen offers excellent portability and size and can be wrapped for infection control; however, due to power supply limitations, it does not offer the brightness or contrast of a CRT display. These screens are very directional and must be viewed from directly in front of the display. The best option may be the flat panel display, which is similar to a laptop computer display but works from the normal electrical supply (Fig. 11-38). These screens are thin and space-efficient, offer better contrast than a CRT, wider viewing angle than a laptop display, and can be wrapped for infection control. Currently, their biggest disadvantage is cost, but in the future they will probably be the display of choice for medicine and dentistry.

### LAPTOP OR DESKTOP?

Many dental digital radiography systems are being sold for use with laptop portable computers (Fig. 11-39). These systems offer great flexibility in that they can be



**Figure 11.38 A Flat Panel Display Device.** The device provides excellent image quality, even when viewing the screen at an angle, and requires minimal counter top space.

moved from operator to operator easily and avoid the need for a computer network. They are also small and take up relatively little space. The only real disadvantage of these systems is in the display as discussed previously, and they normally have slightly smaller hard drives. This should be evaluated before purchase.

## SOFTWARE

Dental digital imaging systems all provide software to acquire an image, find a patient's images, and perform various image-enhancing techniques such as brightness and contrast adjustment. Most products are compatible with dental practice software and can be integrated to form a complete electronic or "paperless" dental record. The interface or "look and feel" of these products varies considerably and should be evaluated before purchase. Currently, an effort is underway to allow all imaging software to be compatible with one another through the Digital Imaging and Communication in Medicine (DICOM) standard. Being DICOM-compliant is a highly desirable feature if images are going to be exchanged electronically.



**Figure 11.39 Clinical Use of a Laptop Computer.** A laptop CMOS system being used in the clinic. Note the clear plastic wrap being used for infection control. When treating a patient, long sleeves are recommended if spatter is being generated.



## ACQUIRING A DIGITAL IMAGE (SENSORS)

In radiography we “take a radiograph.” In digital imaging to “acquire an image” means exactly the same thing. There are many different ways to acquire a digital image. They can be broken down into two different types: indirect and direct.

### INDIRECT METHOD

Indirect methods of making digital images were the first to be used in the 1970s. In indirect imaging, an actual film-based radiograph is still required. Then an imaging device is used to scan or photograph the film-based radiograph (Fig. 11-40). This can be used for converting existing radiographs into digital images that can be stored and manipulated in the computer or e-mailed to insurance companies.

#### Cameras

Video or digital cameras can be used to photograph existing radiographs placed on a viewbox. With video cameras, which are analog devices, a digitizing board will need to be used in the computer to transform the analog image into a digital one. With digital cameras, a digital image is created directly in the camera itself. Problems with this technique are associated with the camera being hand-held and the resulting shaky or poor-quality images.

stand or tripod-mounted camera.

#### Scanners

Modern scanners offer a quick and convenient way to convert radiographs to digital images. Scanners pass a light beam through the radiograph to an imaging chip called a charge coupled device (CCD). The CCD converts the light passed through into a digital image. This process is essentially the same as the CCD sensors that will be discussed in the direct imaging section below. When using a scanner, it is important to remember that radiographs are viewed by transmitted light (which is passed through the radiograph), whereas most scanners are designed to deal

with reflected light off the page of a book. To scan radiographs requires a device called a transparency adaptor that mounts in the lid of the scanner and passes light through the radiograph to be read by the scanner. Transparency adaptors are available as options on most high-end flatbed scanners.

### DIRECT METHOD

In direct digital imaging, no film is used. The digital image is acquired directly by means of a sensor. A sensor is an electronic or specially coated plate that is sensitive to x-rays. When exposed to x-rays, the sensor converts the x-rays into electronic data that can be read and used by a computer. There are currently three types of sensors in common use.

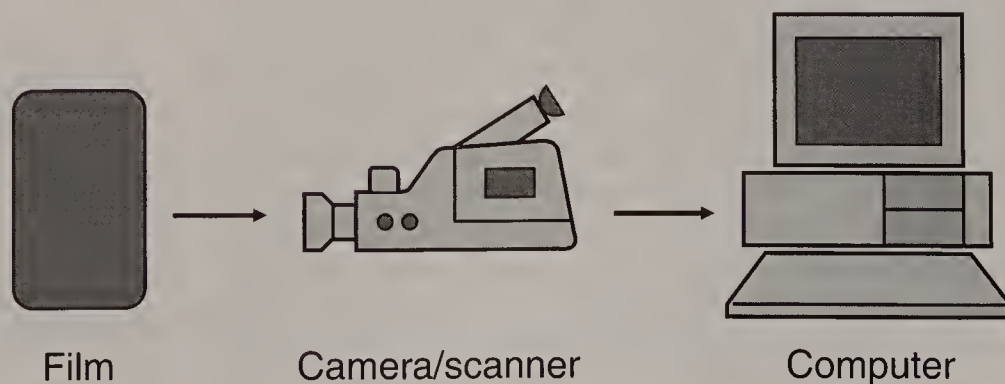
#### Three Basic Types of Sensors

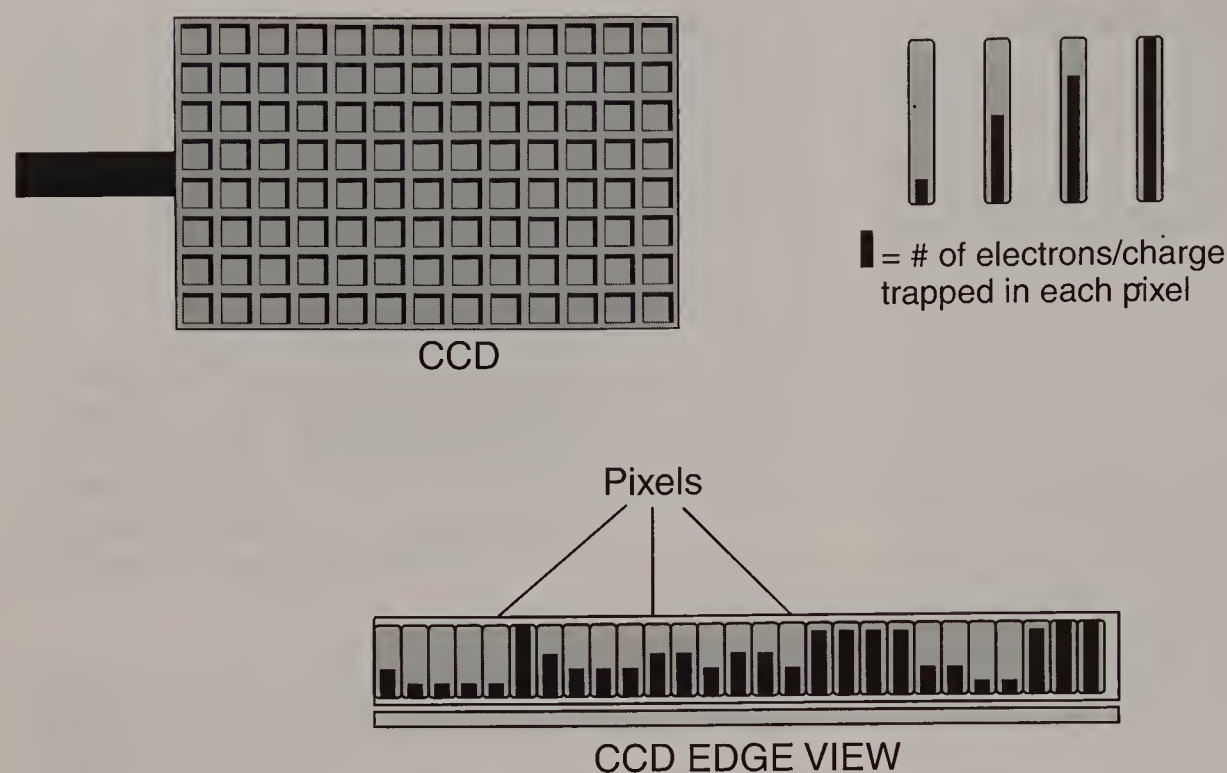
**Charge Coupled Device (CCD).** CCDs were first utilized in video cameras and can be found today in virtually all camcorders. They convert visible light images into a form that can be stored on tape. The first direct digital sensor to be used in dental radiology was the Trophy radiology system introduced in 1987 in France.

CCDs are a type of integrated circuit made up of a grid of small transistor elements that convert x-rays to electrons. These elements are sometimes called electron wells because they store the electrons. When x-ray photons strike these small transistor elements, electrons are trapped in the wells in proportion to the number of x-ray photons striking the element (Fig. 11-41). The individual transistor elements are arranged in a grid formation. Each element represents one pixel in the final image. After the exposure is complete, the elements are read and the amount of stored electron charge is converted to brightness values and locations to form a digital image. This information is then passed through a wire to a circuit board inside the computer for processing into an analog image for display on the monitor.

CCDs were designed for exposure by visible light. Exposure to x-radiation would cause early catastrophic failure of the device. To prevent this, CCD sensors are designed with a scintillation screen that intercepts the x-rays

**Figure 11.40 Indirect Digitization.** In this method, a radiograph is placed on a viewbox and the image is captured with an ordinary video camera, or it is placed on a scanner with a transparency adapter in the cover and captured. In either case, the captured analog x-ray image is transferred to the computer and is converted to a digital image. If the x-ray is captured with a digital still or video camera, the x-ray is digitized in the camera itself and stored there. The stored digital image can then be downloaded to the computer via USB or more rapidly with a Firewire connection or interface.





**Figure 11.41 A Charge Coupled Device (CCD) Sensor.** The pixels are arranged in an array of horizontal lines and vertical columns. For example, a  $1200 \times 1000$  (1.2 million or 1.2 megapixel) array would yield a high-quality rectangular image. Each pixel acts as a well within which a certain number of charged electrons are stored after the CCD has been exposed to x-rays. Each pixel has a brightness value and location, which can be converted to an image.

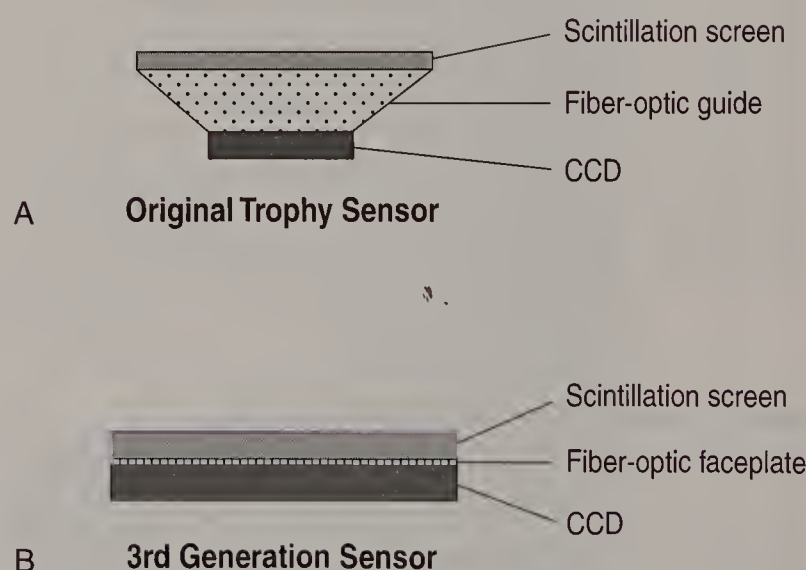
and fluoresces with visible light to expose the CCD. In addition, CCD sensors utilize a fiber-optic plate between the scintillation screen and the active sensor. The fiber-optic plate provides additional blockage of x-radiation from destroying the active part of the sensor and also acts to focus the light from the screen onto the sensor and increase image sharpness.

The addition of the scintillation screen and fiber-optic plate made early CCD sensors very thick and bulky. They were also very small so that often only one tooth could be imaged with each exposure. Patients had a hard time tolerating the thick plastic sensor, which was up to 14 mm thick as opposed to less than 1 mm thick for intraoral film. Today, CCD sensors have improved greatly with the use of thin but delicate leaded glass fiber-optic plates and larger CCDs (Fig. 11-42). Modern CCDs can be acquired in sizes similar to normal No. 2 periapical film and thickness as low as 3 to 5 mm.

**CMOS/APS.** CMOS stands for Complementary Metal Oxide Semiconductor, a type of integrated circuit like CCDs. The advantages of CMOS sensors include (1) the individual pixels can be made smaller, (2) power requirements are much less, and (3) the manufacturing cost is much lower than with CCDs (Table 11-1). However, until recently the image quality was inferior to that of CCDs. Technology developed by Jet Propulsion Laboratories and NASA in 1993 has changed that. By adding an active amplifying transistor to each pixel in the CMOS sensor, manufacturers have been able to overcome the inherent noise and low signal output (Fig. 11-43). This new technology is known as the CMOS/APS sensor, where APS stands for Active Pixel Sensor. These sensors offer the ca-

pability of embedding microprocessors and other circuitry right on the sensor chip itself. CMOS sensors can be connected to a computer using low-power external connections such as Universal Serial Bus (USB). They do

the computer as with a CCD sensor. This makes off-the-shelf laptop computer systems very feasible. Other aspects of CMOS sensor design are similar to the CCD sensor. They still use a wire connection to the computer and in-



**Figure 11.42 Older and Newer CCD Sensor Designs.** (A) This sensor was not delicate, but was thick and had distortion at the edges of the image. (B) Newer sensors are thinner but delicate due to the thin glass fiber-optic faceplate; however, the images are of excellent quality. A broken sensor can cost \$3500 to \$5000 to replace (year 2002 figure).



**TABLE 11-1. CCD Versus CMOS (APS) Digital Sensors**

|                      | CCD       | CMOS      |
|----------------------|-----------|-----------|
| When introduced      | 1987      | 1997      |
| Power consumption    | 400 mW    | 40 mW     |
| Sensitivity to light | Excellent | Excellent |
| Sensitivity to x-ray | High      | Unknown   |
| Pixel size           | 40 $\mu$  | 25 $\mu$  |
| Cost                 | High      | Medium    |
| Manufacture          | Expensive | Cheap     |
| Breakage resistance  | Low       | Medium    |
| Dynamic range        | Excellent | Excellent |
| Noise                | Low       | High      |
| Readout              | Complex   | Simple    |
| Efficiency           | Excellent | Fair      |
| Dark current         | Less      | More      |

ternal scintillation screen. Because of their ability to incorporate additional circuitry, in the future such sensors could offer “on chip” auto exposure, image processing, or wireless transmission of the image to a computer.

**Photo Stimuable Phosphors (PSP).** The photo stimuable phosphor sensor (PSP), or storage phosphor, is a completely different approach to digital imaging. It uses an imaging plate instead of an active detector like the CCD. Imaging plates were first developed during the 1980s for medical use. Soredex (Finland) introduced the

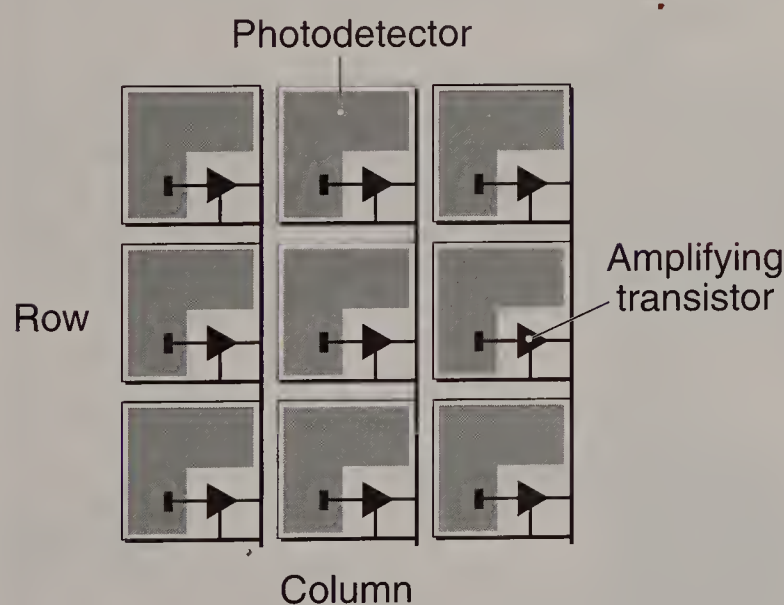
first commercial dental PSP unit in 1994. The PSP process is a two-step procedure. In step one, the plates which look and handle like film, are exposed by x-rays. In step two, they are “developed” using a special scanning device that converts the stored image on the plate into digital form for transfer into the computer. As with intraoral CCDs, PSPs require at least 50% less radiation dose than films, need no chemical processing, and can be re-used potentially thousands of times. An advantage of PSPs compared with intraoral CCDs is that the response of PSPs to x-rays is linear over a wide exposure range, from 5 microroentgens to 50 milliroentgens. This represents exposure differences of 10,000:1. The result of this linear response is that it is virtually impossible to overexpose or underexpose an image. This is known as “wide latitude.” A final advantage of PSPs over intraoral CCDs is that they are almost identical in size to standard dental films and need no cords connected to a computer. They are sometimes called wireless systems because of this.

Storage phosphor systems utilize a completely different technology than CCDs. They use rare earth phosphor (barium europium fluorohalide) coated plates that are exposed to x-rays. Storage phosphors do not fluoresce immediately on exposure, but “store” the x-ray energy until stimulated by a laser beam. This is done in a separate scanning device in which a laser beam is passed over the imaging plate and the resulting fluorescent “signal” is read and converted into a digital image (Fig. 11-44). This system is similar to film in that multiple image plates can be taken in one sitting and the plates “developed” later. The plates are reusable indefinitely and are erased by exposing them to bright light.

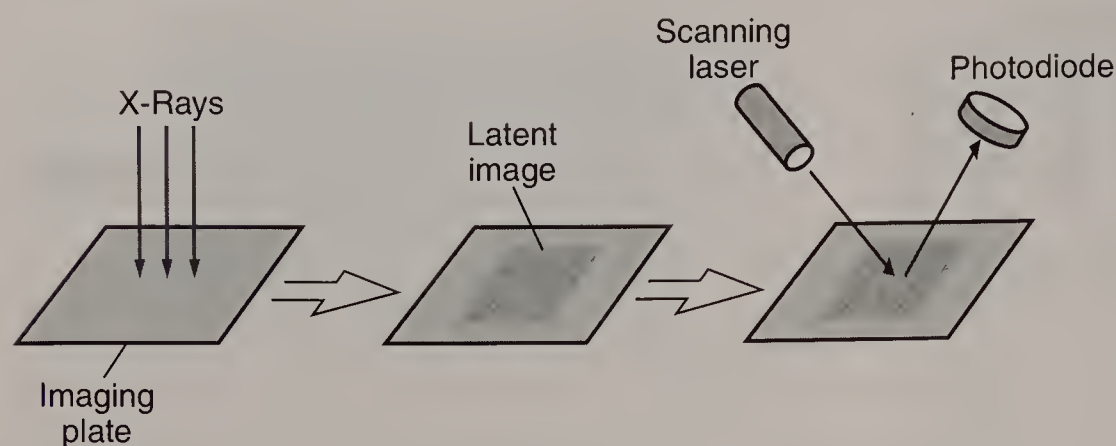
### Functional and Design Properties of the Detectors

The functional differences in the detectors have a great effect on how they are used.

**Size and Thickness of the Detectors.** The original CCD sensors were very thick (thicknesses approaching 14 mm). They were also very small. The original Trophy sensor only had an active area of  $19 \times 28$  mm, enough coverage for only a single molar tooth. When using CCD sensors it is important to remember that the “active” area of the sensor that is sensitive to x-rays is normally much smaller than the actual sensor itself (Table 11-2). It may take extra care in CCD sensor positioning, and more exposures may be necessary than with conventional film to image techniques in the same area. Newer sensors are much closer in size to regular dental film. PSP imaging plates, on the other hand, are normally sized exactly the same as regular dental film and do not have this limitation. Modern CCD and CMOS sensors are much thinner, ranging from 3.2 to 7 mm (Table 11-3). This is still thick when compared to PSP plates at 1 mm, or dental film at 0.77 mm thickness. Most manufacturers do not consider



**Figure 11.43 The Complementary Metal Oxide Semiconductor/Active Pixel Sensor Imaging Process (CMOS/APS).** The advantages of this sensor include excellent image quality, about 50% less replacement cost than CCD, greater durability, and about 10 times less power required than the CCD type; thus, it can be readily adopted for use with laptop computers.



**Figure 11.44 The Photostimulable Phosphor (PSP) Imaging Process.** From left to right: The plate is exposed; a latent image forms; and the latent image fluoresces when scanned with a laser and the fluorescent signal is read with a photodiode, which transmits the image information to a computer.

the additional bulk of the junction where the wire attaches to the sensor when quoting thickness. This junction, depending on location, may add considerable bulk to the sensor. Because of their increased thickness, CCD and CMOS sensors require special holding and beam indicating devices with thicker slots than normal. These are usually available from both the sensor manufacturer and third-party suppliers.

sors are sensitive electronic devices. A hard plastic outer

if dropped onto a hard surface. CMOS sensors are more rugged but can still break if abused. For this reason, CCD sensors should be used in carpeted areas. As an alternative, it is suggested that the cords be tied to the dental unit, so that a dropped sensor cannot reach the floor. PSP imaging plates are made from a rigid hard plastic sheet and are very difficult to break. The sensitive coating, however, can be prone to scratching if not handled properly.

## HOW EACH FUNCTIONS AND TRANSFERS THE DIGITAL DATA TO THE COMPUTER

A CCD or CMOS sensor must be connected to a computer by a wire connection and through an interface that connects the external sensor to the data input of the computer (Fig. 11-45). This wire connection can make sensor placement a little less convenient and may require extra

training. The PSP plates require no connection to the computer and are handled exactly like film. Exposed PSP plates must be protected from prolonged exposure to light, so they are placed in a small plastic pouch that is opaque and also provides infection control. The time required to bag the plates adds considerably to the total time needed to take a radiographic series. Originally, CCD sensors required an interface card within the computer itself. This required opening the computer and inserting a circuit board. Newer systems utilize a USB or Firewire interface. These systems do not require a card within the computer itself, but use an external module about the size of a pack of cigarettes (Fig. 11-46). They still require a wire connection to the computer, however. PSP systems do not require that the plate be connected to the computer. The plate reader or scanner must be connected to the computer instead, usually by a Small Computer System Interface (SCSI) (Fig. 11-47). This interface is very fast but can be difficult to install. It is usually not available on laptop computers, as it requires installation

## Processing Speed

CCD or CMOS sensors provide near instant imaging, with the time between exposure and viewing of the image as low as 10 to 15 seconds. Some digital panoramic machines even allow the image to be viewed as it is being taken! This has made CCD and CMOS systems very

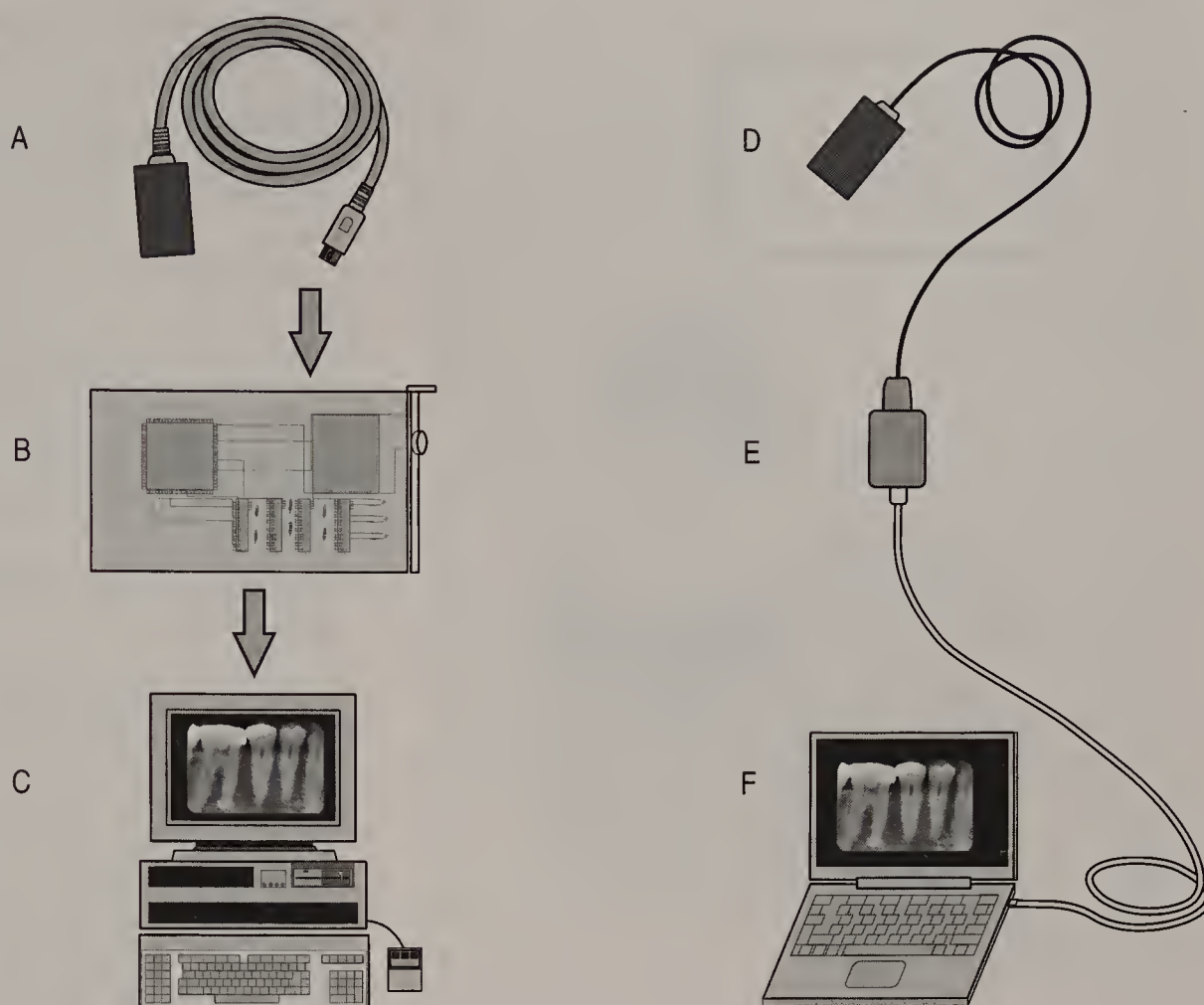
**TABLE 11-2. Active Area Versus Passive Area**

| Sensor   | Actual Size (mm <sup>2</sup> ) | Active Area (mm <sup>2</sup> ) | Difference |
|----------|--------------------------------|--------------------------------|------------|
| Film     | 1271                           | 1271                           | 0 %        |
| Schick   | 1290                           | 929                            | 73 %       |
| Cygnus   | 1275                           | 949                            | 75 %       |
| Trophy   | 1440                           | 951                            | 66 %       |
| Denoptix | 1271                           | 1271                           | 0 %        |

**TABLE 11-3. Sensor Thickness**

| Sensor                                       | Thickness (mm) |
|----------------------------------------------|----------------|
| Schick (Schick Technology, Long Island, NY)  | 5              |
| Cygnus (Cygnus Technologies, Scottsdale, AZ) | 7              |
| Trophy (Trophy Radiology, Danbury, CT)       | 5              |
| Denoptix (Gendex X-ray, Des Plaines, IL)     | 1              |

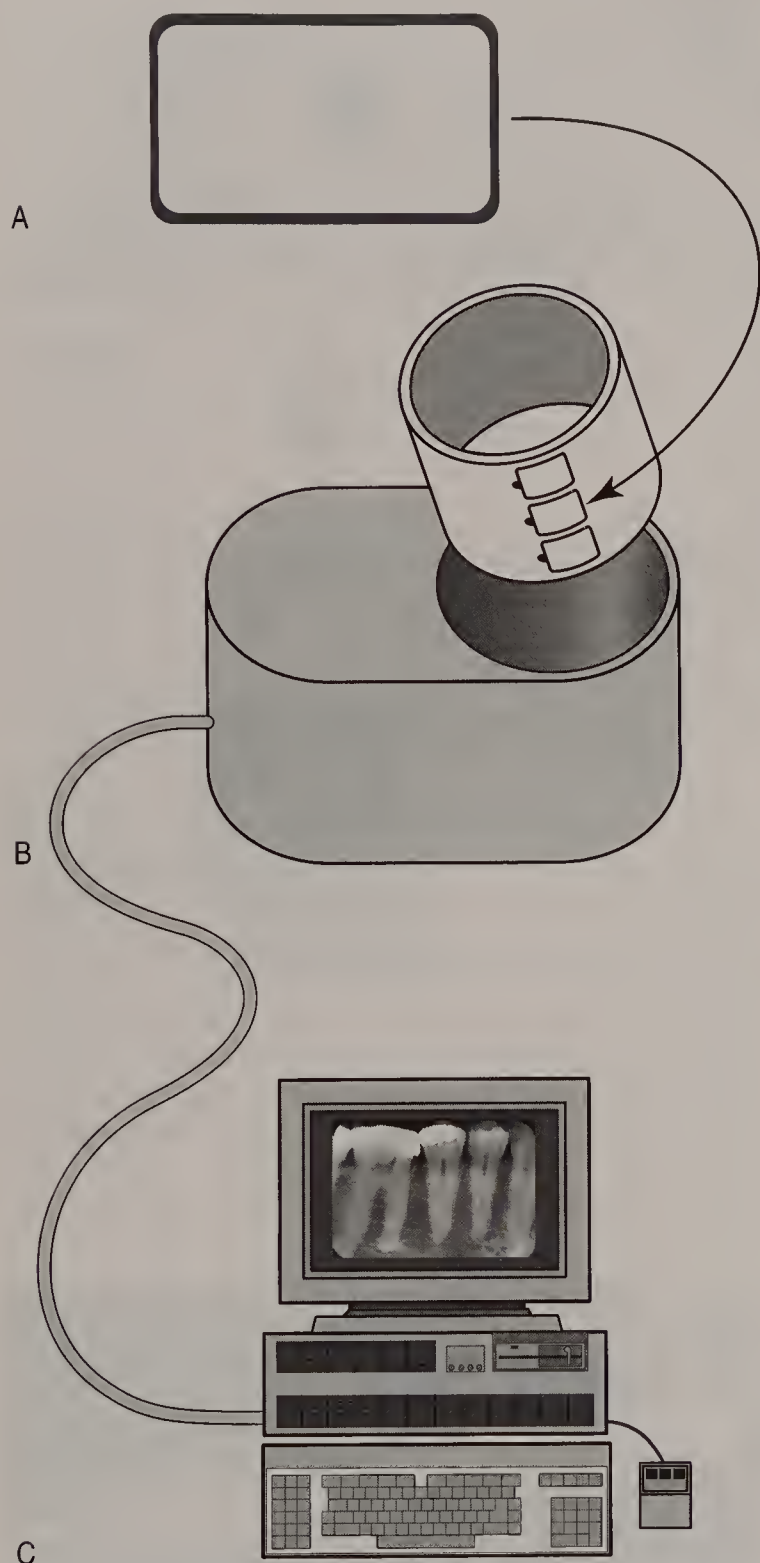




**Figure 11.45 CCD and CMOS Imaging Systems.** Currently, the CCD and CMOS systems are connected to a computer by a wire. (A) CCD sensor is connected to an external card. (B) Image processing board. (C) Computer. (D) CMOS sensor is connected to a USB (E) and laptop computer (F).



**Figure 11.46 A Universal Serial Bus (USB) Connector.** One major advantage of a USB connector is the low power requirement and possibility of connecting to a battery-operated laptop computer.



**Figure 11.47 A PSP Imaging System.** (A) The PSP wireless sensor is about the same size as ordinary film. (B) The "breadbox" or laser scanner. (C) The full-size computer. The major advantages of this system include the "wireless" sensors, low sensor price (about \$25 per intraoral sensor), and excellent durability.

popular with endodontists and surgeons who need immediate feedback. PSP systems are much slower. The plates must be erased, bagged, exposed, and then scanned. Scanning can take anywhere from 2 to 12 minutes, depending on the size and number of plates to be read. Although this is not faster than traditional film processing, you still gain

all the advantages of working with digital images with PSP systems.

### Latitude

As stated previously, PSP imaging plates offer great exposure latitude, making them very hard to overexpose or underexpose. CCD and CMOS sensors, on the other hand, are more difficult to underexpose than film but are not as good as the PSP plates at handling overexposures. CCD sensors tend to bloom or saturate (go black) suddenly when overexposed. For this reason, it is better to underexpose a CCD type sensor. This can lead to problems with older x-ray machines that have timers without short exposure times in 1/100 second graduations.

## PANORAMIC AND CEPHALOMETRIC DETECTORS

### Photo Stimulable Phosphor

Adapting PSP detectors to existing panoramic or cephalometric equipment is a simple matter of obtaining a larger plate to fit within a normal panoramic or cephalometric film cassette. The plate scanner, however, must be made correspondingly larger to accommodate the larger plates. These scanners are more expensive and require longer scanning times. Panoramic images are usually scanned at lower resolutions than the intraoral plates to keep scan times and image file sizes reasonable. Many systems also use a higher resolution coating on the intraoral plates as opposed to the panoramic plates. Resolutions are typically only 3 to 4 lp/mm with PSP panoramic systems as opposed to 6 to 8 lp/mm for film-based systems. Otherwise, use of these systems is completely similar to the intraoral equivalents.

### CCD

It is possible to acquire a panoramic or cephalometric image using a type of CCD detector called a linear array. In a linear array, a series of CCD detectors are stacked to form a grid, which is as tall as the panoramic or cephalometric film and several pixels wide. This CCD array is then moved around or across the patient in conjunction with the tube-head to acquire the image one vertical line at a time. This is

document, in which a sensor is moved across the document to scan it one line at a time. Several commercial systems are now available using this technique. These systems offer resolutions comparable to their film-based counterparts of 6 to 8 lp/mm. In addition, they offer the immediate image acquisition of intraoral systems, with some allowing the operator to actually see the image being formed in real time as the machine is making the exposure. This gives immediate feedback to the operator, and problem exposures can be stopped before the patient receives any more radiation. In combination cephalometric/panoramic systems, the detector (which is the most expensive part of the system) is moved from the panoramic position to the cephalometric



attachment so that only one sensor is required for both types of images. Like all CCD systems, these sensors are delicate and expensive. Most CCD digital panoramic machines are dedicated units and do not use film. However, conversion kits for older equipment are available for some models.

## X-RAY EQUIPMENT

### Converting Existing Equipment

In many cases dental digital radiology can be added to an office without replacing any existing radiographic equipment. This is especially true of the storage phosphor (PSP)-based systems. Many of the newer CCD-based systems require extremely short exposure times, which offer great benefits to patients in the form of lower radiation doses. These systems require an x-ray machine capable of very short exposure times. Older machines using impulse timers (60 impulses/second) may not be capable of generating these short exposures and will need to be replaced. Newer x-ray machines with electronic digital timers should work fine with digital systems. Most panoramic and cephalometric x-ray machines can accommodate PSP plates with only minor modification to the cassette. In addition, one manufacturer is now offering modification kits to convert some existing panoramic machines to use a CCD sensor. There is currently no way to modify an existing panoramic-cephalometric machine to take CCD-based cephalometric images.

### New Equipment

If purchasing new equipment, consideration should be given to the type of intraoral x-ray machine and the timing capabilities. The latest direct current (DC or constant potential) based x-ray machines use digital timers and are capable of providing very consistent short exposure times (1/100 of a second steps) that work well with CCD and CMOS systems. Consideration should also be given when evaluating new x-ray or video equipment to make sure it will all work well together. Currently, most digital imag-

tems from other manufacturers. Therefore, it is desirable to have intraoral, panoramic, and video systems from the same manufacturer to allow seamless integration of the images into an electronic record. It is much more expensive and inconvenient to maintain separate systems for each type of imaging.

## STEPS IN TAKING AN IMAGE

### CCD and CMOS Sensors

CCD and CMOS sensors are straightforward to use. First, the sensor must be properly prepared for infection control. A double barrier of a plastic sleeve and overlying finger cot works well. Infection control procedures are different for PSP plates, but both are not heat-sterilizable

and difficult to cold-sterilize by soaking in chemical solution. Therefore, the normal method of infection control is to use barrier devices. CCD sensors are very delicate and must be handled carefully. Dropping or banging the sensor against a hard object can break it. Care must also be taken with the junction of sensor and cord. This connection is subject to breakdown, especially if cords are bent or stretched excessively. It is recommended that the sensor not be allowed to dangle freely when not in use, but rather be secured by a rubber band or placed in a holder between uses.

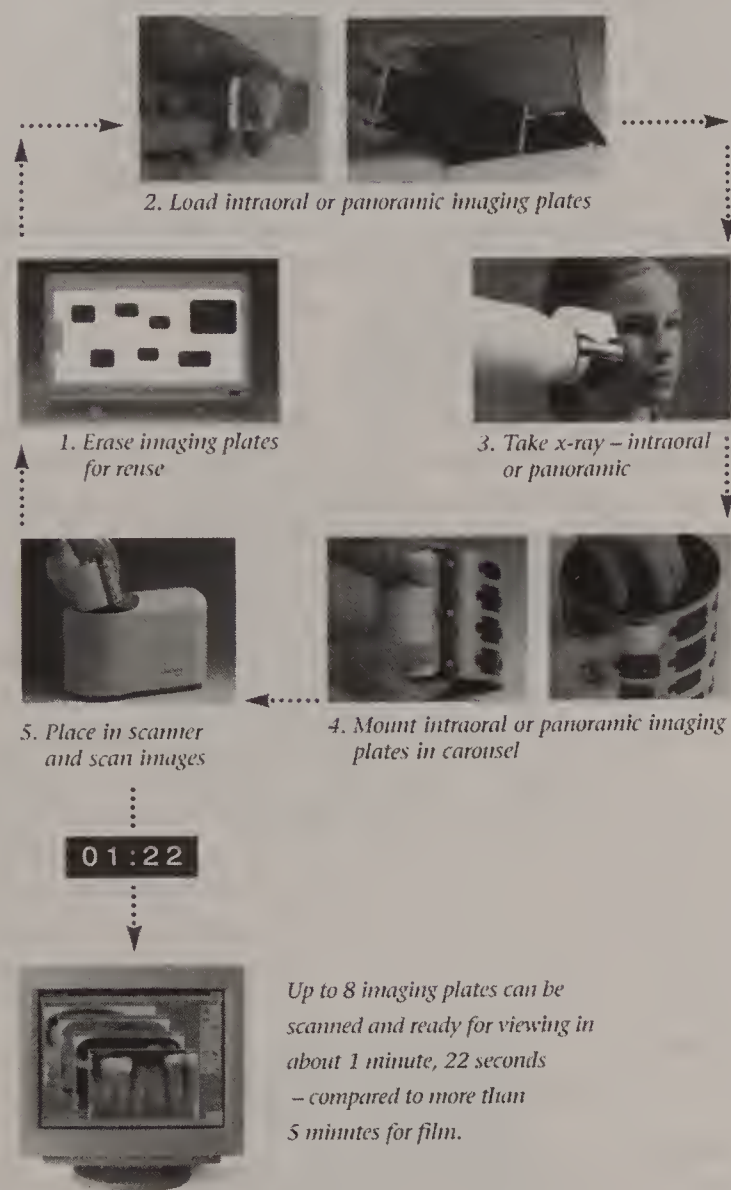
Because the thickness of digital sensors is much greater than film, modified positioning devices must be used to hold and align the sensor during exposure. Different solutions to this problem include modified Dentsply/Rinn film-holders, modified Snap-A-Ray devices, and third-party sensor-holders. Using these sensor-holding devices, the sensor is positioned in the patient's mouth as for a normal film-based radiographic exposure. The computer software supplied by the manufacturer is then used to set the sensor to take an image. When the software indicates it is ready (usually by a message window stating it is now ready to take an x-ray), the exposure is then made in the normal manner by pressing the exposure button on the x-ray machine. The image will appear on the screen within 10 to 30 seconds. At this point the image is saved and the software is made ready to take another exposure. Images may have to be flipped or rotated by the software to be viewed in the same aspect as film-based images. Some software packages will do this automatically.

### Storage Phosphor (PSP) Systems

The PSP imaging cycle is more time-consuming, with more steps than CCD or CMOS sensors (Fig. 11-48). First the plates must be erased to remove any residual image from prior exposures. This is normally done by placing the plates, sensitive side down, onto a viewbox for 1 to 2 minutes. Larger plates, such as a panoramic, may take longer to erase fully. The x-ray-sensitive surface is quite prone to scratching, and care should be taken not to rub the surface or move plates around while face down on the viewbox.

Exposed PSP plates require a light, tight pouch to protect against accidental erasure. The next step in the imaging cycle is to place each plate into a pouch. This pouch is similar to a Kodak Clin-A-Sept barrier envelope and also acts as a barrier against microorganisms in oral fluids. The pouched imaging plate is then placed in the patient's mouth for exposure very similar to film. Because the plates are very thin, special holding devices are not normally required and standard Dentsply/Rinn instruments can be used.

Before scanning, the barrier is peeled open and the plate placed onto a drum that holds them in the scanner. These drums can hold multiple intraoral and other film sizes at one time. This part of the process does not require a darkroom, but should be done under dim lighting, as the

**The DenOptix Imaging Cycle**

**Figure 11.48 The Photostimuable Phosphor (PSP) Imaging Cycle.** (1) Erase used imaging plates on a viewbox. (2) Place the imaging plate in the sealed plastic barrier envelope (intraoral) or in the panoramic cassette. (3) Expose the PSP sensor. (4) Mount the PSPs on the scanner drum. (5) Scan the PSPs. (6) Read the images in the computer

plates are sensitive to light at this point. The drum is then placed in the scanner and the images are scanned into the computer for display. Depending on the number of plates and their size, it can take from 2 to 12 minutes to scan the plates. After scanning, the plates are removed, placed on the viewbox for erasure, and the cycle is repeated.

## PROCESSING THE DIGITAL IMAGE

### IMAGE PROCESSING

One of the advantages of having digital images is that they are in a form that computers can act on and manipulate.

This allows the use of various image-processing tools that can enhance and improve images for better diagnosis and patient education. Some of the most common types of processing that can be applied to an image are as follows.

#### Mirror

In digital imaging, newly acquired images do not always match the orientation of a conventional film mount. The flip and rotate commands allow images to be manipulated for viewing in the same orientation as a conventional radiograph. Some software packages will do this automatically if images are acquired in a specific sequence.

#### Lighten/Darken

Also known as brightness, this control allows the user to make a dark radiograph lighter and a light radiograph darker. It acts as an exposure compensation tool.

#### Contrast Modification

Sometimes called "equalize," it is actually a "histogram stretch" or optimization. The histogram is a graphical representation of the gray scale distribution within an image. This command ensures that the gray scale in an image utilizes the best range possible from 0 to 255. This gives optimum contrast in an image.

#### Reverse Gray Scale (Invert or Inverse)

This tool converts a black-on-white image to a white-on-black image by reversing all the whites and blacks in the image. This can be useful for visualizing structures that are on a dark background or emphasizing objects, such as endodontic files, by making them a dark black instead of white.

#### Noise Reduction/Sharpen/Smooth

Filters enhance an image by removing noise and sharpening edges. They can induce blurring or artifacting, however.

#### Zoom

The zoom control allows you to magnify an image for close inspection. It can bring out small details in an image. The normal digital image is already magnified by approximately 4×, so this is a true "close-up" tool.

#### Colorize

Also known as "pseudocolor," this tool assigns a random color to each gray value in an image. As the human eye is much more sensitive to changes in color than gray contrast changes, this tool can enhance perception of an image.

#### Measure

This tool allows you to make accurate measurements directly on a digital image. It is even possible to measure along a curve (such as a curved molar root) while performing endodontic procedures.

#### Subtraction

In subtraction radiography two images taken at different times are combined digitally, then subtracted so that only



the changes between them are made visible. This allows for serial comparisons over time. This technique can be used to follow-up implants, periodontal surgery, incipient caries, subtle changes in bone loss, and caries progression.

## LEGAL IMPLICATIONS

There has been much concern expressed about the legal implications of digital image processing. Using these techniques it is possible to modify an image to create caries where none exists and extract a tooth where no extraction has been done. How can we tell when an image has been altered? Companies today have addressed these concerns, and they are being rapidly solved. Most software today will not permit an altered image to be saved, except as a

ded into the image, should make fraudulent modification of images too difficult to be practical. Recently, the digital capture of patients' signatures for inclusion in the electronic record has been legalized. Most insurance companies are not concerned about accepting digital images, as the cost-savings to them greatly exceed the potential for fraud. Currently, images are accepted as paper printouts only until file types can be standardized.

## IMAGE STORAGE

Digital images are stored in computer files. One of the problems with digital images is that as the resolution improves, so does the file size and space required to store

with images if some type of image compression and back-up is not used. The average file sizes for common dental digital images are listed below:

| <i>Image Size</i> | <i>File Size</i>  |
|-------------------|-------------------|
| Periapical        | 300 to 1000 kbyte |
| Full-mouth series | 8 to 20 mbyte     |
| Panoramic         | 1.5 to 8 mbyte    |
| Cephalometric     | 8 to 20 mbyte     |

1 mbyte = 1 million bytes

Even with today's large hard drives of 20 to 40 gigabytes, a system is needed to reduce file sizes. This is done through image compression software.

## IMAGE COMPRESSION

Image compression can be divided into two types: "lossless" and "lossy." In lossless compression, the size of the image is compressed, but no information is discarded. In

lossy compression, the image is compressed by discarding redundant information. Thus, the image is altered forever. This raises serious concerns about whether images that have been compressed with lossy compression are diagnostic and whether they are legally adequate. Recent studies have shown that with compression ratios of less than 12 to 1, no decrease in diagnostic ability seems to occur. Common lossless file formats are the TIFF format. However, it only offers 1.5:1 compression ratios. The most common lossy format is the JPEG format. It offers compression ratios as high as 100:1. However, the JPEG format can introduce digital artifacts into an image and degrade its quality. A new advance in file compression is "wavelet compression" that will form the basis of the new recently released JPEG2000 format. It offers the high compression of JPEG without the image degradation.

## IMAGE ARCHIVING

### MAKING BACK-UP COPIES

Just as paper and film must be protected against loss and damage, digital images must also be protected against computer and hard drive failure. For this reason, regular back-up of digital images is critical. A back-up program must be instituted and performed daily to minimize potential data loss. There are several common types of back-up media currently available for use.

### TYPES OF BACK-UP STORAGE MEDIA

The oldest and still most common form of back-up media is tape. Modern digital audio tape (DAT) drives offer high speeds and relative ease of use. Their biggest limitation is that they are a magnetic form of storage. Magnetism can fade over time, and the estimated lifespan of tape back-ups is only 10 years. Zip<sup>®</sup> and Jazz<sup>®</sup> drives are another convenient form of back-up, but are also magnetic media. The most stable forms of back-up are optical discs, CD-ROMs, and DVD-ROMs. The storage capacity of CD-ROMs is only 650 MB, but they are inexpensive and easy to use. In the future, the larger storage capacity of DVD-ROMs (5 to 17 gigabytes) will probably make them the medium of choice for large-scale data back-up.

## IMAGE TRANSMISSION

One of the advantages of digital images is that they can be sent across the room or across the nation/world electronically, even from a hand-held computer. Most digital imaging systems allow images to be compressed and packaged for e-mailing to colleagues. This opens up new vistas in remote consultations and even examination of patients. With integration into dental practice

software, digital images allow for the completely paperless office. Many new practitioners are setting up paperless offices today.

## SUMMARY

Digital images offer tremendous advantages to dentistry in terms of lower radiation exposure for patients, no darkroom or processing problems, convenient image enhancement techniques, and remote teledentistry possibilities. Digital systems are now able to acquire all types of images including panoramic and cephalometric. As technology continues to improve, they will ultimately replace film as the medium of choice for dental imaging.

## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 11.1 LOCALIZATION

#### Materials and Equipment Needed

1. Manikin, skull, animal jaw.
2. Four No. 2 periapical films.
3. One BB (small metal ball or other metal object such as a screw).
4. X-ray machine and processing facility.

#### Instructions

- Step 1:** Obtain a manikin, skull, or animal jaw and place a radiopaque object (BB) on the buccal or lingual side. Do not mark the film packet. Take a standard periapical view of this object and then vary the horizontal angle by approximately 20° and expose a second film.
- Step 2:** Now leave the BB in the same spot on the buccal or lingual side as in Step 1. Do not mark the film packet. Take a standard periapical view of the object and then vary the vertical angle by approximately 20° and expose a second film.
- Step 3:** Process all four films and mount the films in a bitewing mount. Place the two images with the horizontal movement on one side and the two images with the vertical movement on the other side.
- Step 4:** Place your name on the bitewing mount and, because you know where the BB was, exchange your mount with a classmate and take your classmate's mount.
- Step 5:** Working in pairs, try to figure out the location of your classmate's BB.

## CASE-BASED PROBLEM-SOLVING

In the future, you will become aware of the hassles of keeping track of inventories of x-ray supplies such as film, chemicals, bitewing tabs, biteblocks and film-positioning devices, and barrier envelopes. Also, you will begin to understand the maintenance problems associated with automatic processors, the infection control procedure problems associated with the daylight loader and the darkroom, and the time it takes to get a radiograph processed (especially with manual processing) in a tiny cubbyhole darkroom with no air circulation. So you are wondering about digital imaging. Should you trade one set of hassles for another? To help you decide, develop a comparison chart comparing the advantages and disadvantages of the two systems as you see it. What is your final decision?

## REVIEW QUESTIONS

1. Which of the following statements are true concerning cephalometric radiographs?
  - A. The Frankfort horizontal plane is the classic plane used in cephalometrics.
  - B. It is not necessary to record the soft tissue profile in the lateral cephalometric radiograph.
  - C. The posteroanterior cephalometric is the most common cephalometric radiograph produced.
  - D. The accepted distance from the x-ray source to patient in cephalometric radiography is 5 feet.
2. A cephalometric radiograph:
  - A. Is often used to measure changes and predict growth patterns.
  - B. Contains a soft tissue outline.
  - C. Is commonly used by orthodontists.
  - D. All of the above.
3. A radiographic image that looks like a picture of a skull taken back to front is called a:
  - A. Cephalometric lateral radiograph.
  - B. Posteroanterior view.
  - C. Lateral jaw.
  - D. Panoramic radiograph.
4. The anatomical structures of primary importance on TMJ projections are:
  - A. The condyle, joint space, and glenoid fossa.
  - B. The condyle and the maxillary tuberosity.



- C. The coronoid process and the articular eminence.  
D. The articular eminence, glenoid fossa, joint space, and condyle.
5. Which of the following does not use ionizing radiation?  
A. Tomography.  
B. CT.  
C. MRI.  
D. Digital radiography.
6. Computed tomography (CT):  
A. Has the ability to distinguish minor differences between body tissues.  
B. Allows manipulation of image contrast.  
C. Uses a computer to reconstruct images.  
D. All of the above.
7. A cassette:  
A. Emits light.  
B. Is a container for film and screens.  
C. Is an instrument to align the x-ray BID.  
D. Records the patient's exposure.
8. A grid is:  
A. Used to focus a beam of electrons on the focal spot.  
B. Used to limit the size of the beam and reduce radiation exposure.  
C. Never used because it has insignificant effects.  
D. Used to reduce scatter radiation to the film.  
E. Used to reduce the patient exposure to x-rays by removing deflected photons.
9. Intensifying screens are used with extraoral films to:  
A. Increase the exposure time.  
B. Improve image quality.  
C. Decrease radiation to the patient.  
D. Increase the kVp.
10. Screen films are used with intensifying screens because these films are:  
A. More sensitive to x-rays than to light.  
B. More sensitive to light than to x-rays.  
C. Coated with silver sulfide crystals.  
D. Coated with calcium tungstate crystals.
11. A cassette was opened in the darkroom to remove and process the exposed film. A piece of black paper was discovered on the surface of the intensifying screen. The paper most likely would produce:  
A. A white or light artifact.  
B. A black artifact.  
C. No artifact.  
D. Reticulation.
12. Which of the following is not a benefit of digital imaging?  
A. No chemical processing.  
B. Less radiation dose to the patient.  
C. Ability to perform image processing techniques.  
D. Sensor size.
13. An image with more pixels should have better \_\_\_\_\_ resolution than one with fewer pixels assuming the same pixel size.  
A. Spatial.  
B. Brightness.  
C. Contrast.  
D. Digital.  
E. Analog.
14. CCD sensors provide an image on the screen \_\_\_\_\_ than storage phosphor (PSP) sensors.  
A. That is smaller.  
B. That has lower resolution.  
C. Faster.  
D. Slower.
15. Photo stimuable phosphor (PSP) sensors:  
A. Provide an instant image on screen.  
B. Must be processed by a scanner to generate an image.  
C. Store the image as a latent image.  
D. Both A and C.  
E. Both B and C.
16. In general CCD sensors are \_\_\_\_\_ in active area, but \_\_\_\_\_ than regular dental film.  
A. Larger, thinner.  
B. Larger, thicker.  
C. Smaller, thinner.  
D. Smaller, thicker.
17. The PSP imaging cycle has \_\_\_\_\_ steps than the CCD imaging cycle.  
A. Fewer.                      C. More.  
B. Faster.                     D. Easier.
18. In lossy image compression formats such as JPEG:  
A. No image information is changed.  
B. Some image information is lost or changed.  
C. Compression ratios of greater than 12:1 can be used without problems.  
D. Only mild compression is achieved.  
E. The image is never degraded.

## 19. Digital panoramic systems:

- A. Are not yet available.
- B. Are lower resolution than film based systems.
- C. Can allow the image to be acquired and viewed in real time.
- D. Cannot be made by converting older equipment.

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# Radiation Health

CHAPTER 12: Radiation Biology

CHAPTER 13: Radiologic Health and Protection





# Radiation Biology

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *Relate a general knowledge of radiation biology.*
2. *Explain how tissues are affected by radiation.*
3. *Explain the various radiation factors involved in tissue damage.*
4. *Describe the host factors involving radiation injury.*
5. *State the factors affecting radiation sensitivity.*
6. *Define the various units used for radiation measurement.*
7. *Describe various concepts relating to radiation dose.*
8. *Relate a broad knowledge of specific risks to various body tissues.*
9. *Describe various DNA repair mechanisms.*
10. *List various radiation protection organizations.*
11. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                                                     |                                                            |                                                                   |                                                                                  |
|-----------------------------------------------------|------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------------------------|
| accumulative effects                                | Environmental Protection Agency (EPA)                      | linear energy transfer (LET)                                      | phagocytized                                                                     |
| apoptosis                                           | epilation (loss of hair)                                   | mass (total weight)                                               | quality of beam                                                                  |
| background radiation                                | erythema                                                   | mean active bone marrow                                           | radiation-induced cancer                                                         |
| Biological Effects of Ionizing Radiations Committee | excitation                                                 | millirad (mrad)                                                   | rad/rem                                                                          |
| biologically active molecules                       | exposure                                                   | millirem (mrem)                                                   | radiolysis of water                                                              |
| cataract                                            | exposure unit (X)                                          | molecule                                                          | radioresistant cells                                                             |
| Center for Devices and Radiological Health (CDRH)   | free radical                                               | mutations                                                         | radiosensitive tissue                                                            |
| chemicals of life                                   | genetic information                                        | National Council on Radiation Protection and Measurements (NCRPM) | risk estimate                                                                    |
| chromosome(s)                                       | gray (Gy)                                                  | nonlinear/linear                                                  | roentgen (R)                                                                     |
| critical biomolecular target                        | hormesis                                                   | nonthreshold dose                                                 | SI system                                                                        |
| deterministic (nonstochastic) effect                | hydrogen peroxide                                          | nonstochastic (deterministic) effect                              | sievert (Sv)                                                                     |
| direct effect                                       | hydroperoxyl radical                                       | Nuclear Regulatory Commission (NRC)                               | sterility                                                                        |
| DNA                                                 | hydroxyl-free radical                                      | Occupational Safety and Health Administration (OSHA)              | stochastic radiation effect                                                      |
| dose equivalent                                     | indirect effect                                            | organelles                                                        | threshold dose                                                                   |
| dose/absorbed dose                                  | International Commission of Radiological Protection (ICRP) | osteoradionecrosis                                                | tissue                                                                           |
| effective dose equivalent                           | ion pair                                                   |                                                                   | United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) |
|                                                     | ion/ionization                                             |                                                                   | xerostomia                                                                       |
|                                                     | latent period                                              |                                                                   |                                                                                  |
|                                                     | leukemia                                                   |                                                                   |                                                                                  |

## HOW TISSUES ARE AFFECTED BY RADIATION

Radiation biology is a portion of science that studies the effects of ionizing radiations on living organisms. It is virtually impossible to describe or discuss the effects of radiation without using some sort of descriptive phrase or word to describe the amount of radiation. Specific definitions will be given later, but for now the terms **exposure** and **dose** will be used to refer to the amount of radiation. Simply expressed, if you run through a water sprinkler you are **exposed** to a certain amount of water, but not all of it hits you and makes you wet (**dose**). The more times you run through the sprinkler, the more exposure you have and the wetter (the higher the dose) you get.

### EFFECTS IN ATOMS AND MOLECULES

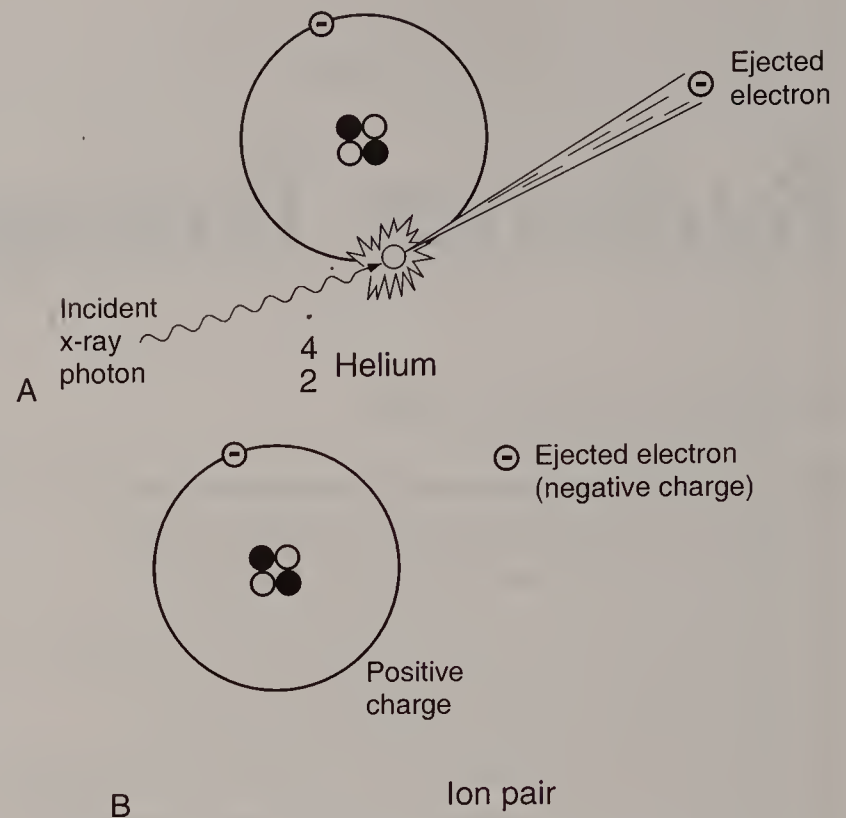
Atoms are the building blocks used to make the world. There are approximately 105 different kinds of atoms. Different atoms can be combined (added together in specific ways) to form molecules. Molecules can be small or big and can have a variety of different shapes and functions. Life as we now understand it takes place through a complex, integrated sequence of chemical reactions that occur within the cells of an organism (any living animal or plant). The very first effect of radiation occurs when the energy of the ionizing radiation (e.g., x-rays) is deposited within the chemicals that make up the living (biologic) tissue. When this energy is deposited within an atom or molecule, two effects may take place: **excitation** or **ionization**, which can result in molecular damage.

#### Excitation

Excitation occurs when an x-ray photon's energy field interacts with an atom's orbital electron, causing the electron to vibrate momentarily at a higher energy, much the way a guitar string vibrates when strummed. The energy produced by the orbital electron's temporary vibration (excitation) causes a change in the forces holding the atoms into molecules. The energy of vibration (excitation) may be released harmlessly through the emission of light and heat. If the energy of excitation is too large, it may produce a break in the molecular bond and disrupt the molecule.

#### Ionization

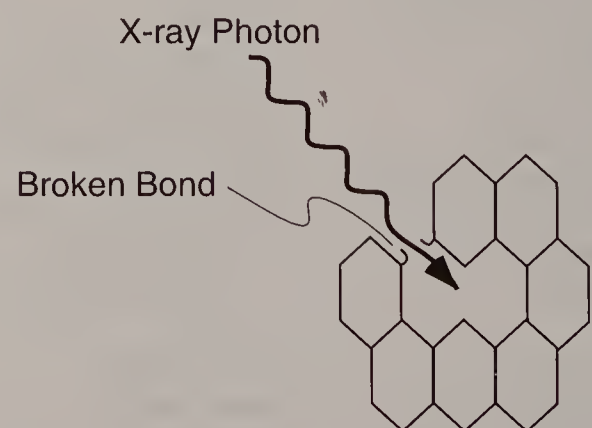
The main way photons of ionizing radiation dissipate their energy in matter is by colliding with and stripping away orbital electrons from an electrically neutral atom/molecule. The process is similar to a basketball player dribbling toward the basket and having the ball stripped out of his hands by an opponent. When an atom loses an electron, it is said to be ionized. An ionized atom (called an **ion**) is no longer electrically neutral and becomes more chemically reactive as it attempts to find an electron to replace the missing one (Fig. 12-1).



**Figure 12.1 Ionization of a Neutral Atom by X-Rays.** (A) Neutral atom with x-ray photon ejecting an orbital electron. (B) Ion pair formed by ejected electron (– charge) and the ionized atom with more protons (dark circles in the nucleus) than electrons (+ charge).

### Breaking of Molecular Bonds

When an atom is ionized, its chemical-binding properties change. If the atom is part of a larger molecule (macromolecule), the ionized atom may cause a breakage of the molecule into two or more pieces. (A molecule is a chemical combination of two or more atoms to form a specific chemical substance.) (Fig. 12-2). The broken molecule will no longer “work” chemically the way it is supposed to in the cell's chemical pathways. If enough molecules are damaged, there is a loss of cell function, disruption of



**Figure 12.2 Breaking of Molecular Bonds.** Breakage of a molecule's chemical bonds by direct action of radiation.



intracellular organelles (where cellular functions are performed), or even death of the cell.

## CHEMICAL EFFECTS OF RADIATION

### Radiolysis of Water (Interaction of Radiation With Water)

The human cell contains about 80% water and about 20% of other kinds of molecules, which for convenience we will refer to as the “chemicals of life,” or “biologically active molecules.” When an x-ray photon enters a cell, the energy of the photon has a much higher mathematical probability of interacting with a water molecule than one of the other types of molecules. The interaction of an ionizing radiation with a molecule of water is called **radiolysis**. X-ray photons strip the electrons from water molecules creating an ion pair, which consists of the ejected electron and a water molecule with an unpaired outer orbital electron referred to as a free radical. Free radicals, molecules containing an unpaired electron, are extremely reactive chemically. They may produce undesirable chemical combinations within the cell that may cause damage to the beneficial molecules of life, like DNA, RNA, and ATP. Water molecules are not the only ones that form free radicals upon ionization; the cell also contains molecules of  $O_2$ ,  $NO_2$ ,  $CO_2$ , etc., that may be ionized to produce free radicals.

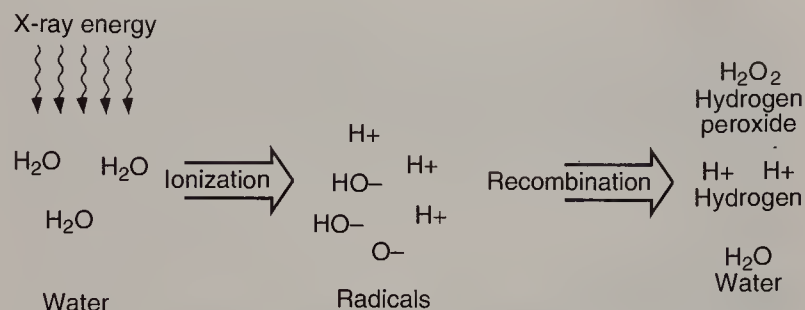
### Hydrogen and Hydroxyl Radicals

Hydrogen ( $H^*$ ) and hydroxyl ( $OH^*$ ) radicals are produced during the radiolysis of water. A hydroxyl radical ( $OH^*$ ) can bond with another hydroxyl radical ( $OH^*$ ) and form hydrogen peroxide ( $OH^* + OH^* = H_2O_2$ ), a substance poisonous to the cell. In addition, a **hydroperoxyl radical** ( $HO_2^*$ ) is formed when a **hydrogen-free radical** ( $H^*$ ) combines with molecular oxygen ( $O_2$ ). Hydroperoxyl radicals and hydrogen peroxide are believed to be harmful to the cell, producing important chemical changes that can lead to the formation of biologic damage (Fig. 12-3). It is also important to recognize that the  $H^*$  and  $OH^*$  radicals can also recombine to re-form a harmless molecule of water ( $H_2O$ ).

## BIOLOGIC EFFECTS OF RADIATION

X-rays are tiny bundles of energy (photons) that cannot be seen or felt. The injury they cause occurs to the atoms that make up the “chemicals of life” located within the cells of the human body.

Chemicals of life, for our purposes, are various kinds of molecules responsible for conducting and maintaining all the chemical reactions occurring within each cell. Energy deposited by x-ray photons and the free radicals formed by the irradiation of water ( $O_2$ ,  $CO_2$ , etc.) damages the chemicals of life within each cell. The more x-ray



**Figure 12.3 Radiolysis of Water.** Formation of radicals when water ( $H_2O$ ) is irradiated, and possible recombination to form hydrogen peroxide ( $H_2O_2$ ).

energy absorbed/deposited, the more chemicals of life are damaged. Examples of the chemicals of life are listed in the following box.

### EXAMPLES OF CHEMICALS OF LIFE

- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)
- Adenosine diphosphate (ADP)
- Adenosine triphosphate (ATP)
- Nicotinamide adenine dinucleotide (NAD)
- Cytochrome oxidase
- Glucokinase
- And many more

## TWO TYPES OF BIOLOGIC EFFECTS

Biologic effects of radiation are ultimately the result of damage to the chemicals of life and their subsequent impact on cellular metabolism and structure. The physical processes leading to damage of the chemicals of life may be divided into two major types: **direct effects** and **indirect effects**.

### Direct Effect

When the energy of ionization is deposited directly into the chemicals of life—such as DNA, RNA, proteins, or enzymes—damage is referred to as a direct effect. The ionization or excitation created by the photon results in breakage of the molecules’ chemical bonds, altering their precise three-dimensional chemical structure, and provides opportunities for other chemicals in their vicinity to form inappropriate chemical bonds. DNA is *the* critically important molecule located in the nucleus of the cell that carries the genetic (genes of heredity) information necessary for cell replication and regulation of all cellular activity. Years of research strongly support the concept that DNA is the irreplaceable “master” molecule that is the “critical biomolecular target” for radiation effects. If the master molecule is irreparably damaged by exposure to radiation, the cell will die. Non-DNA cell molecules destroyed by radiation exposure may be

replaced, as long as the DNA is functional. Direct effects of radiation are similar to a bullet through the heart or brain and result in immediate “death” of the molecule; the only difference is that the effect is occurring at the atomic/molecular level rather than at the organismal (organ) level.

### Indirect Effect

Destructive chemical changes to the chemicals of life can result from what is called the indirect effect of ionizing radiation. When a specific biologically active molecule such as DNA is acted on by free radicals previously produced by the interaction of radiation with water molecules ( $O_2$ ,  $NO_2$ ,  $CO_2$ , etc.), the destructive action of the ionizing radiation on the biologically active molecule is indirect in the sense that the deposition of radiation energy is not the immediate cause of the damage to the biologically active molecule (Fig. 12-4). The bonding of free radicals to any of the chemicals of life results in a change in the chemical properties of the chemicals of life; this change results in

the functional “death” of that molecule. Under ordinary circumstances, even when these poisonous or toxic substances are formed in cells by radiolysis of  $H_2O$ , other cells in the area are not affected and the overall functions of the tissue or organ may not be affected, providing time for the irradiated cell to potentially repair the damage. However, cellular destruction is not the only potential biologic effect; there is a very remote possibility that a cell may become malignant. The mathematical probability of dental x-rays causing a malignant transformation are estimated to be about one chance in a million billion (Hoffman and Katz, 1983).

### Cells

In living organisms (humans and animals), the smallest unit in which the chemical reactions of life can occur is within the cell. The cell is divided into two compartments: the nucleus and the cytoplasm. The nucleus is considered to be more radiosensitive than the cytoplasm to radiation because it contains the cell's critical operating molecules, including the DNA.

### Tissues

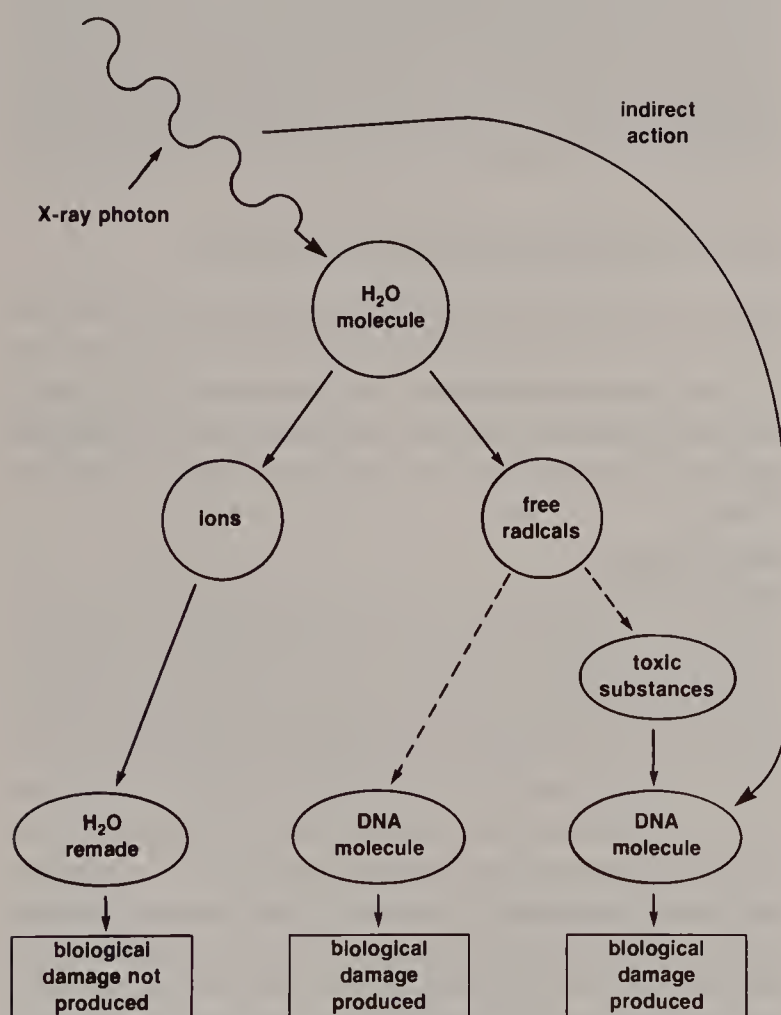
ent kinds of tissues may be combined to form organs and systems in the human body. Organs and organ systems serve specific purposes, such as food digestion, blood production and circulation, reproduction, and breathing. Cells and tissues can regenerate and recover from radiation injury. Most x-ray photons pass through the cell, causing little or no damage. Also, the body contains so many cells that the destruction of a single cell or a small

### Time-Scale of Radiation Damage

For radiation damage to become visible, hours, days, months, and even years may pass before a change is seen. The time interval between irradiation and development of the observed biologic effect is known as the **latent period**. It is important to remember that almost every cell has the ability to repair radiation damage. The lower the dose of radiation to the cell, the more capable the cell is of repairing the damage. Higher doses of radiation produce more severe damage to the cell, and it is less likely that the cell will be able to repair all the damage. Similarly, a scratch will heal quicker than a large, deep jagged cut.

### Accumulative Effects of Radiation

Whenever biologic tissue is exposed to radiation, there is some injury that is followed by repair. Radiobiologic studies indicate that repair processes exist in humans at all levels of cellular repair or replacement. However, it is assumed (correctly or incorrectly) that damage produced by high doses of radiation are never completely repaired and that some residual injury may remain within the DNA or the cytoplasm; just like a small scar may remain after a cut



**Figure 12.4 Indirect Effect.** When DNA is acted on by free radicals or toxic products of free radicals, it is called an indirect action. This is because the deposition of radiation energy (x-ray photon) was not the immediate cause of damage to the biologically active molecule. Also, if ions produced by radiation energy on the  $H_2O$  molecule are remade into  $H_2O$  again no biologic damage is produced.



**TABLE 12-1. Critical Organs in Dental Radiography**

| <i>Critical Organ</i> | <i>Resulting Disorder</i> |
|-----------------------|---------------------------|
| Lens of eye           | Cataracts                 |
| Gonads                | Genetic abnormalities     |
| Fetus                 | Congenital defects        |
| Bone marrow           | Leukemia                  |
| Thyroid gland         | Cancer                    |
| Skin                  | Cancer                    |

has healed. Each succeeding radiation exposure is assumed to add a small amount to this increment of radiation damage. This concept has become known as the **accumulative effect of radiation**. Thus, the effects of radiation are said to be cumulative from the standpoint that cellular repair processes are believed to never completely repair the damage, and unrepaired damage may lead to future health problems such as cancer, cataracts, birth defects, or premature aging. The tissues and organs that are considered “critical radiologically” in humans and are worthy of keeping exposure as low as possible are listed in Table 12-1. At the low levels of radiation given to a patient in diagnostic radiography, permanent residual injury will be virtually impossible to detect because it will be masked by the gradual accumulation of “normal aging injury” within the tissues.

### Determinants of Radiation Injury

Like most things in life, nothing is as simple as it may first appear; so it is with radiation effects. There are many factors that determine the severity of tissue damage after exposure to radiation. Some of these factors are listed in Table 12-2. The importance of only a few of these factors will be discussed in this chapter as they relate to dental radiation exposure.

## RADIATION FACTORS

There are many physical factors that ultimately influence the radiobiologic effect. The following are major contributors.

### Type of Radiation

Sparsely ionizing radiations, such as x-rays and gamma rays, deposit their energy in widely separated energy-depositing events when compared with densely ionizing radiation. Alpha particles (a densely ionizing particle) deposit all their energy in a very short distance. The potential biologic effect of x-rays is less than that associated with alpha particles. The type of radiation used to make dental radiographs is sparsely ionizing; therefore, it has less radiobiologic effect than other densely ionizing types.

**Linear Energy Transfer.** Linear energy transfer (LET) is an important concept relating to the amount of energy imparted to a tissue as the ionizing particle passes through. Large, slow-moving charged particles (such as alpha particles) have a high LET; that is, all their ionizing energy is deposited in a short distance and the distance between successive ionizing events is very small—sort of like shopping in a mall on Christmas eve with hordes of last-minute shoppers all packed in together. With low LET radiations, such as x-rays, the ionizing energy is randomly deposited at widely separated intervals and is rarely concentrated in a very small distance—similar to shopping at the mall on a week night about 30 minutes before closing: the people are scattered and widely separated. **High LET** radiations cause more damage than x-rays because they deposit more energy in a small space. A simple analogy might be how wet one gets in a cloud burst (high LET) versus a soft, fine drizzle (low LET).

### Total Dose

The larger the amount of energy deposited in a tissue (total dose of radiation), the more severe the radiobiologic effect. Most dental radiographic procedures require very small amounts of radiation to produce a radiographic image,

**TABLE 12-2. Factors Influencing Radiation Effects**

| <i>Host Factors</i>                | <i>Radiation Factors</i>                        |
|------------------------------------|-------------------------------------------------|
| Species of animal                  | Local area versus whole body exposure           |
| Intrinsic resistance               | Type of radiation (linear energy transfer)      |
| Type and sensitivity of tissue     | Penetrating ability of radiation                |
| Rate of cell division              | Total dose                                      |
| Sensitivity of tissue to radiation | Acute versus chronic exposure                   |
| Phase of cell cycle                | Dose and Dose Rate Effectiveness Factor (DDREF) |
| Ability to repair damage           |                                                 |
| Age, sex, ethnicity                |                                                 |

especially compared with some medical radiographic procedures (see “Effective Dose Equivalent” in this chapter).

**Penetrating Ability of Radiation  
(Quality of Beam)**

The more penetrating (higher energy) the ionizing radiation, the more severe the radiobiologic effect will be on tissues lying within deeper parts of the body. Low energy radiations tend to be absorbed by the superficial layers of the skin and, therefore, the potential harm to deeper tissues is reduced. The dental x-ray unit contains a filter to selectively remove long wavelength x-rays and reduce skin dose.

**Acute Versus Chronic Exposure**

An acute exposure to an ionizing radiation occurs when all the energy is given in a very short period. Dose for dose, an acute exposure produces more severe radiobiologic effects than chronic exposures. Chronic exposure occurs when a small amount of radiation is given over a prolonged period. For chronic radiation exposures, the radiobiologic effect is less because the body/tissue has an opportunity to repair the damage between successive exposures. Dental radiographic exposures more closely resemble chronic exposure situations, because the patient is radiographed at widely separated intervals (months to years).

**Local Area Versus Whole Body**

Exposure of the entire organism to radiation produces more severe systemic effects than exposure of a small (local) area. Dental radiographic units expose a small, well-defined area of the head and neck (depending on the procedure). Thus, dental radiographic procedures are not considered to result in significant exposure to the whole body. In dentistry, the circular beam of radiation is limited to only the area of diagnostic interest, and this circular area (2.75 inches in diameter) may be further reduced by the use of rectangular collimation.

**HOST FACTORS**

**Species of Animal**

Different species of animals have differing sensitivities to lethal effects of radiation. Most mammals have approximately the same sensitivity and are relatively sensitive to radiation effects when compared to reptiles, insects, and bacteria which are more resistant.

**Intrinsic Resistance of the Organism**

Just as humans have differing “natural” sensitivities to contracting the flu during flu season, there are similar differences in “intrinsic resistance” to radiation effects. Individuals who might potentially be more or less sensitive to radiation effects cannot be identified by any physical characteristic or feature.

**Type and Sensitivity of Tissue**

Different tissues of the body have differing sensitivities to developing radiation effects. Some tissues are very sensi-

TABLE 12-3. Tissue and Organ Sensitivity

| <i>Relative Sensitivity</i> | <i>Tissue/Organ</i>        |
|-----------------------------|----------------------------|
| High                        | Small lymphocyte           |
|                             | Bone marrow                |
|                             | Reproductive cells         |
|                             | Intestinal mucosa          |
| Intermediate                | Connective tissue          |
|                             | Breast (women)             |
|                             | Small blood vessels        |
|                             | Growing bone and cartilage |
| Fairly low                  | Salivary gland             |
|                             | Thyroid gland              |
|                             | Skin                       |
| Low                         | Muscle                     |
|                             | Nerve                      |

tive to radiation (blood-forming tissues such as bone marrow), and others are quite resistant to the lethal effects of radiation (muscle and nerve such as the masseter muscle and inferior alveolar nerve) (Table 12-3).

**Rate of Cell Division**

Cells that divide rapidly during their normal “life” tend to be more sensitive to radiation damage than cells that do not divide at all. For example, malignant tumor cells divide rapidly and can be destroyed by radiation, whereas nerve cells that do not divide on a regular basis appear to be relatively insensitive to radiation.

**Sensitivity of Tissue to Radiation**

Experiments have clearly demonstrated that some of the cells and tissues of the human body are more sensitive to x-radiation than others and may die following relatively low amounts of x-radiation; these are called **radiosensitive tissues and organs**. Cells that appear to be less harmed by large amounts of x-radiation are called **radioresistant cells**. Cells and tissues that are not particularly sensitive or resistant to radiation are intermediate in their sensitivity to radiation. A list of some types of tissues and their sensitivity to radiation are listed in Table 12-3.

In the early 1900s two researchers, Bergoine and Tribondeau (Travis, 1989), found that cells that divided more frequently and were less well-differentiated were more sensitive to radiation-induced cell death than were cells that did not divide rapidly. Historically, their observations became known as the “Law of Bergoine and Tribondeau.” In the intervening years, their “law” has become less well accepted because numerous exceptions have been identified. Two other researchers, Ancel and Vitemberger (Travis, 1989) observed that from a radiation exposure standpoint, all cells exposed to a given dose



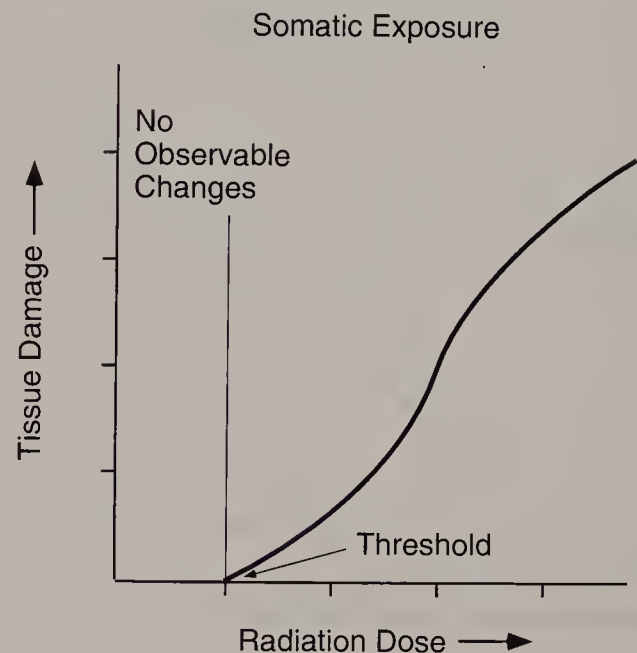
of radiation would be equally affected/damaged, regardless of cell type. They argued that the difference between radiation sensitive cells and radioresistant cells was simply a matter of timing. Cells that divide more rapidly express the damage more rapidly than those cells that are not dividing. Their argument makes sense, in that if you were taking an exam and someone tied each person's shoe laces together, all would be equally affected; however, those students who finished early and got up to leave would manifest the shoe lace "damage" more quickly than those who took longer on the exam. Thus, those students who remained at the end of the exam would appear to be more "resistant" to the effect than those who had finished early. So it is with cells and tissues.

### Damage at the Organismal Level

Radiation biologists divide the human body into two basic types of tissues: somatic and genetic/reproductive. **Somatic** tissues are tissues of the body that are not inherited from parent to child. Examples of somatic tissues are salivary glands, muscles, bones, nerves, kidneys, connective tissues, and skin. **Genetic/reproductive** tissues are those tissues responsible for producing the next generation of offspring and specifically include the oocytes (eggs) in the female ovary and spermatogonia (male sperm-forming cells). The main reason for classifying tissues as somatic or genetic is that radiation damage to somatic tissues only influences the individual who has been exposed to the radiation. Radiation damage to genetic/reproductive tissues is inherited from one generation to the next, just like eye and hair color. The only difference is that all radiation changes passed from one generation to the next are considered to be harmful. Genetic effects are, therefore, considered to be more serious and to have a long-term negative influence on the health and welfare of a population.

### Threshold Dose

When animals are exposed to radiation, small amounts of radiation exposure to somatic tissues do not appear to produce any visible changes in the tissue until a certain **threshold dose** is reached (Fig. 12-5). This threshold dose depends on the kind of tissue exposed to radiation. For example, when toasting marshmallows over a fire, one can see the "threshold effect." If the marshmallow is placed too high over the fire, there is not enough heat to toast the outside; if it is too close to the fire, instant cremation, flames, and charcoal on the outside result. Somewhere between these two extremes there is a distance and a length of time over the fire that will produce the first golden brown change in the surface of the marshmallow. This is a sign that it is time to begin turning the marshmallow to produce the golden brown perfection with a warm, soft center. Once the surface of the marshmallow begins to turn golden brown, then the longer it stays in that position, the darker it gets until it begins to blister, burn, and turn black. If this sounds much like sunburn, it

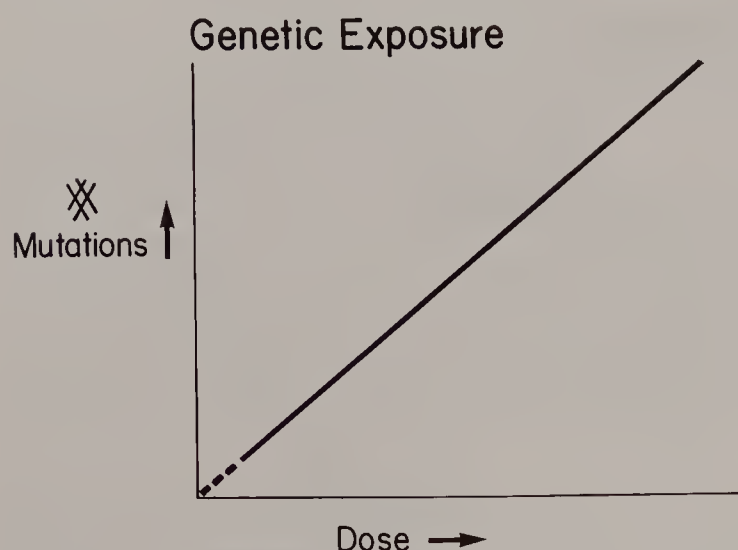


**Figure 12.5 Threshold Dose.** Typical dose-response curve illustrating a threshold nonlinear (curved-line) type of biologic response.

is—the longer the exposure to sunshine, the more severe will be the burn. Once the threshold at which the skin first begins to turn pink is passed, the skin begins to burn. So it is with all human somatic tissues. Small exposures produce no observable change. With increasing levels of exposure, a threshold will be reached, at which time a specific radiation effect becomes visible. Higher exposures produce progressively more severe changes. Changes such as **epilation** (hair loss), **erythema** (skin reddening), **cataract formation** (opacity on lens of eye), and **sterility** (inability to reproduce) follow a **threshold, nonlinear** (curved-line) type of dose-response curve. In modern terminology, these effects are referred to as **deterministic** (nonstochastic) radiation effects.

### Nonthreshold Dose

Exposure of genetic tissues to radiation causes mutations. **Mutations** are changes in the information contained by the chromosomes (linear thread of DNA) within the sperm and egg cells. Genetic changes are always considered bad, and once incorporated into the eggs or sperm of the parent, can subsequently be passed from the affected parent(s) to their children, grandchildren, and great grandchildren. Mutations have the potential to produce children who may have a higher mathematical probability of having birth defects including leukemia, increased susceptibility to developing cancers, and physical deformities of various types. The formation of mutations follows a "nonthreshold" or linear (straight-line) type of dose response (Fig. 12-6). What this means is that small amounts of radiation have the potential to produce a small number of mutations in chromosomes; with progressively increasing doses, more and more mutations are



**Figure 12.6 Genetic Exposure.** Typical dose-response curve illustrating a nonthreshold linear (straight-line) type of biologic response.

formed. When one drives a car, the car's speed follows a nonthreshold or linear pattern. When the gas pedal is depressed a little, the car goes slowly; when the pedal is pressed down more and more, the car goes faster and faster. Similarly, the number of mutations increases with increasing exposure to radiation. In modern terminology, these effects are referred to as stochastic radiation effects and include such changes as genetic mutations, cancer, and tumor induction.

#### Other Factors Influencing Radiation Bioeffects

Space does not permit discussing everything that might influence radiobiologic outcomes. Suffice it to say that more than 100 years of research into the effects of ionizing radiation have demonstrated that age at the time of exposure, sex, ethnicity, temperature, and nutrition may all have a role in modifying radiation outcomes. We have learned that the nucleus has a "DNA damage-control biosystem" (Polycove, 1998) that is capable of monitoring, correcting or slowing the cell cycle until DNA damage can be corrected. This damage-control biosystem contains more than a dozen physiologic processes designed to monitor and correct damage to the DNA from "normal" chemical reactivity within the nucleus and incidental exposures to ionizing radiation. Even if the damaged DNA is not corrected, the damaged cell may undergo "apoptosis"—a cell-controlled disintegration of the nucleus and cytoplasm, allowing the cell to be phagocytized by macrophages located in the tissues. This process is referred to as "cell-mediated cell death or altruistic cell suicide," and may provide a cellular alternative to undergoing malignant transformation. In addition, there are hundreds of articles supporting the concept that low doses of radiation may have a beneficial effect on tissues by stimulating intranuclear and cytoplasmic repair processes and immune system surveillance. The technical term for this potential beneficial effect of low doses of ra-

diation is "hormesis." We also have learned that low doses of low LET radiations have significantly less (more than 2.5 times less) cancer-producing potential than high doses and high dose rates, a concept called the Dose and Dose Rate Effectiveness Factor (DDREF). Dental diagnostic radiographic procedures are typically very low dose and low LET.

## RADIATION UNITS AND MEASUREMENTS

### UNITS OF MEASURING RADIATION

The following paragraphs mention several different units of measurement for radiation and for radiation risk. The dental health-care worker must know that there is an "old system" and a "new system" for measuring radiation units. The problem arose in 1985, when a new International System (SI) of measurement was adopted worldwide. Before 1985, an old terminology was used in textbooks and journals. Both systems are presented here. We realize it is frustrating to have to deal with two different sets of units, and it would be better if only one could be used. (An example of two sets of measuring units used today is the Celsius and Fahrenheit scales for temperature.) However, we have to deal with two different units of measuring radiation.

### RADIATION MEASUREMENT

To understand the potential harmful effects of radiation, it is important to know the amount of radiation associated with the harmful effects. It may seem difficult to measure something that cannot be seen, touched, felt, or smelled. Scientists measure radiation in the same way that others have determined a measure for a gallon of gasoline, a liter of soda, an ounce of gold, a pound of sugar, a ton of steel, or a kilowatt of electricity. The units, gallon, liter, ounce, pound, ton, and kilowatt represent certain quantities or amounts that are accepted by custom and tradition of usage for hundreds of years.

Historically, the units roentgen (R), rad, and rem were the units by which radiation was measured and referred to relatively large quantities of x-ray energy. For dental radiographic procedures, the term milliroentgen (mR), millirad (mrad), and millirem (mrem) are used to refer to a unit of measurement 1000 times smaller; thus, 1 rad is equivalent to 1000 millirads, and 1 mrad = 1/1000 rad. In the new SI system of measurement, the units gray and sievert are used, along with milligray (mGy) and millisievert (mSv), to represent units 1000 times smaller. At first glance, the switch from old units to new units seems pretty straight forward, since both have a large parent unit (the rad or gray) and a corresponding unit 1000 times smaller (the millirad or milligray). The problem is that the



**TABLE 12-4. Radiation Units—Conversion Table**

|               | <i>SI System</i>            |                                   |                                   |                                   | <i>Old Units</i>   |                                    |
|---------------|-----------------------------|-----------------------------------|-----------------------------------|-----------------------------------|--------------------|------------------------------------|
|               | <i>SI<br/>gray<br/>(Gy)</i> | <i>SI<br/>centigray<br/>(cGy)</i> | <i>SI<br/>milligray<br/>(mGy)</i> | <i>SI<br/>microgray<br/>(μGy)</i> | <i>Old<br/>rad</i> | <i>Old<br/>millirad<br/>(mrad)</i> |
| Base unit     | 1                           | 100                               | 1,000                             | 1,000,000                         | 100                | 100,000                            |
| 1/10th        | 0.1                         | 10                                | 100                               | 100,000                           | 10                 | 10,000                             |
| 1/100th       | 0.01                        | 1                                 | 10                                | 10,000                            | 1                  | 1,000                              |
| 1/1,000th     | 0.001                       | 0.1                               | 1                                 | 1,000                             | 0.1                | 100                                |
| 1/10,000th    | 0.0001                      | 0.01                              | 0.1                               | 100                               | 0.01               | 10                                 |
| 1/100,000th   | 0.00001                     | 0.001                             | 0.01                              | 10                                | 0.001              | 1                                  |
| 1/1,000,000th | 0.000001                    | 0.0001                            | 0.001                             | 1                                 | 0.0001             | 0.1                                |

Each horizontal line represents equivalent expressions in different units of the same size. In dentistry, the SI units gray (Gy) and sievert (Sv) are equivalent, since the quality factor (QF) for x-rays is 1 (gray × QF = sievert).  
In the “old system” of radiation units, the roentgen (R), rad, and rem are equivalent.

radiation units called grays (Gy) and sieverts (Sv) are 100 times bigger! Thus, 1 gray is equal to 100 rads, and 1 sievert is equal to 100 rems.

Converting rads, rems, grays, and sieverts can be a bit confusing. Table 12-4 illustrates common conversions.

## EXPOSURE

### How Much Radiation Comes Out of the X-Ray Machine?

Exposure is a property of the x-ray beam, just like the amount of light emitted by a light bulb. Exposure is a measure of the number of x-rays making up the beam of radiation and the energy transferred from the x-rays to molecules of air under very standardized conditions. The old unit of exposure was the roentgen (R). A roentgen is defined as the quantity of photons that will produce a defined number of ion pairs (about 2 billion) in a cubic centimeter of air at standard temperature and pressure. Physicists convert the number of ion pairs released into an electrical charge that they measure in a unit called coulombs (C). One dental bitewing or periapical radiograph exposes the patient to approximately 0.3 R (300 mR). The new unit of exposure is simply called the “exposure unit” (X). The X unit is the number of photons that will produce 1 coulomb of charge per kilogram of air (1 X unit = 1 C/kg air). An exposure measurement does not describe the size of the x-ray beam or the amount of radiation actually absorbed by the patient’s tissues.

### Dose

Dose is the amount of x-ray energy absorbed by a unit mass (total weight) of tissue. Tissue absorbs x-ray energy differently than air, depending on the density (compact-

ness). For example, fat, muscle, and bone have different densities. When a person is irradiated, some x-rays pass through the body and no energy is deposited, while other x-ray photons may be partially or completely absorbed by the patient. Exposure therefore does not equal dose. The SI unit for dose is the gray (Gy) and is defined as the amount of energy (called a Joule) absorbed per kilogram tissue (1 Gy = 1 J/kg). The old unit for absorbed dose is the rad, defined as the energy (called the erg) absorbed per gram of tissue (1 rad = 100 erg/gm). These units can be simply converted by using the following formula: 1 Gy = 100 rad or 1 rad = 0.01 Gy. Note: 0.01 Gy may also be written as 1 centigray (cGy) and is the SI unit equivalent in size to the rad (1 rad = 1 cGy). Dose is of more interest to biologists and health-care workers than exposure, because dose describes how much energy is deposited into the tissues, which in turn provides an indication of how much biologic damage may occur from the radiation.

## SUMMARY OF EXPOSURE AND DOSE

Exposure and dose are two different concepts. They should not be confused. Radiation exposure refers to the amount of radiation that comes out of the x-ray unit and reaches the person. Because radiation has the capability of passing completely through the body, not all the energy that a person is exposed to is actually absorbed by the body. The amount of x-ray energy actually deposited within the tissues of the body is called the dose or absorbed dose. The absorbed dose is typically used as an indication of potential harm. In most cases, the harmful effects of radiation increase with increasing absorbed dose.

### Dose Equivalent

Dose equivalent is a concept that allows the comparison of the biologic effect of different types of ionizing radiation. Alpha particles, beta particles, gamma rays, protons, and neutrons are other types of ionizing radiation. Equal doses of different types of radiation produce different amounts of biologic damage. For example, 50 cGy (rad) of neutrons would cause much more biologic damage than 50 cGy (rad) of x-rays.

The dose equivalent takes differences in biologic damage into consideration by using a radiation quality factor (QF) to adjust the dose. The QF is 1 for x-rays, beta particles, and gamma rays; 5 for low-energy neutrons and protons; and 20 for alpha particles and higher-energy neutrons.

The symbol used to designate “dose equivalent” is H. Therefore, to calculate dose equivalent, the following formula is used:

$$H (\text{dose equivalent}) = D (\text{dose}) \times QF (\text{quality factor})$$

X-rays are the standard against which all other radiations are measured, so the QF for x-rays is 1. Therefore, for x-rays, if a patient received 10 Gy, the dose would be 10 Gy and the dose equivalent would be:

$$10 \text{ Gy} \times 1 = 10 \text{ Sv}$$

In contrast, if the patient received 10 Gy of low-energy neutrons (QF = 5), the dose equivalent would be:

$$10 \text{ Gy} \times 5 = 50 \text{ Sv}$$

This simply reminds us that low-energy neutrons are approximately 5 times more efficient in damaging the cell than an equal dose of x-rays. The concept of dose equivalent is of little concern in dentistry, since we only use x-rays that have a QF of 1. Therefore, dose of 1 mGy is equivalent to a dose of 1 mSv in dentistry, and these units may be used interchangeably. Why does anyone bother to distinguish between dose and dose equivalent? Radiation therapists and nuclear reactor operators have to be concerned about dose equivalent, because they use several different types of radiation with different QFs.

### Effective Dose Equivalent

Both exposure and dose are independent of the size of the x-ray beam or the volume of tissue irradiated. However, common sense would (correctly) suggest that 1 Sv of x-rays to the right hand would be less dangerous than 1 Sv of x-rays to the whole body. The right hand has relatively few cancer-susceptible tissues (bone marrow and skin) and is a relatively small body part. In contrast, the whole body has many cancer-susceptible tissue types and has a

much greater volume. The absorbed doses in each situation are the same, yet the risk is obviously much greater in the whole-body situation. Another example: 1 Sv of x-rays to the right hand would be much less hazardous than 1 Sv of x-rays to the right breast. Although both tissue volumes involved are about the same, breast tissue is much more susceptible to radiation-induced cancer than are any of the tissues of the hand. It is important to understand that when a complete-mouth set of dental radiographs are taken, the beam indicating device (BID) does not stay in the same place for each radiograph. The BID is moved around the patient's face so that the total amount of x-ray energy is not concentrated over one area; in this way, the tissues of the face receive relatively small amounts of radiation.

The concept of effective dose equivalent was introduced to help understand the assessment of the biologic consequences (risk) of radiation to a localized part of the body and the degree to which this local irradiation would increase a person's “whole body” risk of developing cancer, or producing offspring with genetic anomalies.

Effective dose equivalent is abbreviated H(E), with units of Sv (usually stated in micro ( $\mu$ ) Sv or millionths of a sievert). The risks taken into account with H(E) are cancer induction and the induction of genetic mutations. Therefore, if one wants to compare the risk from two different x-ray exposures (e.g., comparing the risk of four bitewings versus one panoramic radiograph), effective dose equivalent rather than dose equivalent should be used. Because both dose equivalent and effective dose equivalent are stated in units of Sv, one must carefully look at each table's caption to determine which concept is under consideration. See Table 12-5 for effective dose equivalents from diagnostic x-ray examinations in microsieverts ( $\mu$ Sv).

### ASSESSING RISKS FROM DENTAL RADIOGRAPHY

There is no doubt that x-rays are potentially dangerous. Therefore, the dental health-care worker is ill-advised to take a casual attitude or approach to the use of x-rays.

Many of the biologic effects described previously are not potential risks in dental radiography. Some of these effects (cataracts, osteoradionecrosis, xerostomia [dry mouth], epistaxis [nose bleed], erythema [skin reddening], and epilation [hair loss]) have threshold doses significantly higher than could ever occur in dentistry. Some effects, such as bone marrow destruction, gastrointestinal necrosis, and cerebrovascular syndrome, require not only high doses but also whole-body exposure. Other effects may be associated with lower doses and still not be a risk in dental radiography, because that particular area of the body is not significantly irradiated (fetal abnormalities, genetic mutations, thyroid, and breast cancer).



**TABLE 12-5. Effective Dose Equivalents From Diagnostic X-Ray Examinations (microsieverts [ $\mu$ Sv])**

| <i>Examination</i>                                                                                      | <i>Effective Dose Equivalent (<math>\mu</math>Sv)</i> |
|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Panoramic radiograph                                                                                    | 7                                                     |
| Full-mouth intraoral radiographs (20 films)                                                             |                                                       |
| D speed film, round collimation                                                                         | 84                                                    |
| E+ speed film, rectangular collimation                                                                  | 33                                                    |
| F speed film rectangular collimation                                                                    | 26                                                    |
| Bitewing radiographs (4 films)                                                                          |                                                       |
| D speed film, round collimation                                                                         | 17                                                    |
| E+ speed film, rectangular collimation                                                                  | 7                                                     |
| F speed film rectangular collimation                                                                    | 6                                                     |
| Chest                                                                                                   | 80                                                    |
| Upper gastrointestinal tract                                                                            | 2400                                                  |
| Barium enema                                                                                            | 4060                                                  |
| Abdomen                                                                                                 | 560                                                   |
| Effective dose equivalent to average U.S. resident from background radiation per year (including radon) | 3000                                                  |
| 1000 $\mu$ Sv = 1 mSv = 100 mrad                                                                        |                                                       |

### Risk Estimates to the Eye

The threshold for induction of cataracts is about 2000 mSv. Dental exposures to the lens and cornea of the eye are primarily from scattered radiation and are reported to be less than 0.5 mSv when an open, round BID is used and 0.16 mSv when rectangular collimation is used. Panoramic radiographic exposures to the lens and cornea of the eye are extremely small (approximately 0.09 mSv per radiograph). The risk of dental radiographic procedures contributing significantly to the occurrence of eye problems appears to be extremely remote (Gibbs et al., 1987; Weissman and Sobkowski, 1970).

### Gonadal Dose

Heritable (genetic) effects are those seen in the progeny of irradiated persons. There is little information about genetic effects of radiation exposure in humans; to date, no such effects have been clearly demonstrated from exposure to diagnostic radiographic procedures. There have been no statistically significant increases in genetically related disease in the children of atomic bomb survivors. The gonadal dose is so small from dental radiography that the risk of heritable defects is negligible.

### Risk Estimates for Pregnancy

Exposure of a fetus from dental radiographic procedures during pregnancy would be similar in magnitude to that

of the reproductive organs. Previous studies suggest that the production of congenital defects from doses below 100 mSv is very small when compared with the normal risk for congenital defects (4.6%) and is negligible at 50 mSv or less (NCRP Report 54, 1977). Embryonic exposure to dental radiography is in the range of 0.002 mSv with rectangular collimation. If the patient wears a leaded apron, the exposure drops to virtually zero, in the 0.001 to 0.003 mSv range. However, it is prudent to routinely use leaded torso aprons on all female patients during the first trimester of pregnancy, and radiation exposure should be held to a minimum. A leaded torso apron should be used on all patients as tangible evidence of the dental office's attempt to minimize all unnecessary exposure and risk to a patient from dental radiographic procedures.

### Cancer Is the Principal Biologic Risk in Dental Radiography

The principal biologic risk from dental radiography is radiation-induced cancer. As mentioned previously, cancer induction probably has no threshold dose. Even a small radiation dose may increase the patient's statistical probability of cancer development, similar to the statistical probability that as a vehicle's speed increases, the probability of getting a ticket or being involved in a fatal accident increases. There are no cancers that are uniquely caused by x-rays. X-rays simply increase the probability that a patient may die of cancer (statistically the "spontaneous/natural" cancer death rate in the U.S. is about 20%), and dental radiography increases this probability by a very tiny amount.

### Which Tissues Have the Highest Risk for Cancer From Dental Radiation?

The risk of cancers resulting from a dental radiographic exposure is the sum of the risks of individual radiosensitive organs. The highest estimate of risks in dental radiography are for **leukemia** (cancer of the bone marrow) and cancer of the **thyroid**.

**Leukemia Risk.** The region of the mandible and maxilla involved in dental radiography contains a very small percentage of active bone (blood-producing) marrow. The skull contains approximately 10% of the available bone marrow in the body, with the mandible accounting for less than 1% of the total marrow. An increased incidence of leukemia is directly related to the total amount, or percentage, of bone marrow irradiated. The **mean active bone marrow dose** is the dose of radiation averaged over the entire bone marrow (Bushong, 1993). The mean active marrow dose resulting from an intraoral FMX ranges from 0.06 mSv for rectangular collimated BIDs to 0.142 mSv for round BIDs and 0.01 mSv for panoramic radiography (White, 1992). Studies have found no relationship between the level of **background radiation** (3.0 mSv or 3000  $\mu$ Sv/year effective dose) and the incidence of

leukemia (Court-Brown et al., 1960; Craig and Seidman, 1961), congenital malformations (Schuman, 1970), and neonatal deaths (Grahn and Kratchman, 1963).

**Thyroid Cancer Risk.** Under most circumstances, the thyroid gland is not irradiated by the primary beam of radiation during intraoral radiography; however, the thyroid gland is exposed to scatter radiation during an FMX; the dose is in the area of 0.3 mSv. This low dose may be reduced by about 50% through use of the thyroid collar. The thyroid dose from panoramic radiography is also small, in the range of 0.04 mSv. There is no reliable evidence that thyroid cancer increases at doses less than 100 mSv. There appears little chance that dental radiation will ever be associated with an increase in thyroid cancer.

Sources of Risk

Comparing risks of x-rays to other life-style activities with equal or higher risk may or may not be helpful in demonstrating the relative safety of x-rays. Table 12-6 depicts some "One In One Million Risk of Fatal Outcome."

Background Radiation

Every day, humans are exposed to radiation from within the environment. This environmental radiation is called background radiation. It is important because we cannot do anything about it. The average annual background effective dose to the U.S. population is about 3000  $\mu$ Sv (3.0 mSv) including radon gas exposure. Higher elevations, such as Denver, Colorado, will receive about 240  $\mu$ Sv more background radiation than the rest of the United States as an average, primarily because of an increase in cosmic radiation at higher elevations. Therefore, if a person living in the United States in an average location had an FMX (26  $\mu$ Sv effective dose equivalent) and a panoramic radiograph (6  $\mu$ Sv effective dose equivalent) taken by the very best techniques (rectangular collimation, F+ speed film, and rare earth screens), each year it would be only one-seventh of the risk (32  $\mu$ Sv) of a per-

TABLE 12-6. One in One Million Risk of Fatal Outcome

| Risk       |                      | Nature                |
|------------|----------------------|-----------------------|
| 20 minutes | A 60-year-old man    | Death (CVD, cancer)   |
| 2 months   | In Denver, CO        | Cancer                |
| 10 miles   | By bicycle           | Accident              |
| 300 miles  | By automobile        | Accident              |
| 10 days    | Typical factory work | Accident              |
| One        | Cigarette            | CVD, cancer           |
| 500 ml     | Wine                 | Alcohol-related death |
| 125 ml     | Whiskey              | Alcohol-related death |
| 1500 ml    | Beer                 | Alcohol-related death |
| 30 cans    | Diet soda            | Cancer                |

son living in Denver (240  $\mu$ Sv per year of cosmic radiation higher than average) who was not exposed to dental radiation. This type of data may be used by the health professional to help place the potential radiation risk to a patient in terms that they may more easily understand (Table 12-7).

Natural or background radiation is by far the largest contributor (82%) to the radiation exposure of persons living in the United States today (NCRP Reports 93, 94, 95, 1987). Diagnostic radiation (medical and dental) accounts for approximately 11% of all exposure from major sources of radiation to U.S. populations (Table 12-7). Only about 1% of the total diagnostic radiation, or about 0.1% of the total average annual effective dose of ionizing radiation to a person in the United States, results from dental radiography (United Nations, 1988). This can be compared with radon, which is estimated to contribute to more than half (55%) of human background exposure.

TABLE 12-7. Average Annual Effective Dose of Ionizing Radiations ( $\mu$ Sv) to a Person in the United States (1000  $\mu$ Sv = 1 mSv)

| Source                                                                                                                                    | $\mu$ Sv       | Percentage of Annual Average Effective Dose |
|-------------------------------------------------------------------------------------------------------------------------------------------|----------------|---------------------------------------------|
| Natural (environmental)                                                                                                                   |                |                                             |
| External                                                                                                                                  |                |                                             |
| Cosmic                                                                                                                                    | 270            | 8.00%                                       |
| Terrestrial                                                                                                                               | 280            | 8.00%                                       |
| Radon                                                                                                                                     | 2000           | 55.00%                                      |
| Other                                                                                                                                     | 400            | 11.00%                                      |
| Rounded total (natural)                                                                                                                   | 3000 (3.0 mSv) | 82.00%                                      |
| Artificial                                                                                                                                |                |                                             |
| Medical                                                                                                                                   |                |                                             |
| X-ray diagnosis                                                                                                                           | 386            | 10.90%                                      |
| Nuclear medicine                                                                                                                          | 140            | 4.00%                                       |
| Dental                                                                                                                                    |                |                                             |
| X-ray diagnosis                                                                                                                           | 4              | 0.10%                                       |
| Consumer products                                                                                                                         | 100            | 3.00%                                       |
| Other                                                                                                                                     |                |                                             |
| Occupational                                                                                                                              | <10            | 0.03%                                       |
| Nuclear fuel cycle                                                                                                                        | <10            | 0.03%                                       |
| Fallout                                                                                                                                   | <10            | 0.03%                                       |
| Miscellaneous                                                                                                                             | <10            | 0.03%                                       |
| Rounded total (artificial)                                                                                                                | 600 (0.6 mSv)  | 18.00%                                      |
| Natural plus artificial                                                                                                                   | 3600 (3.6 mSv) | 100.00%                                     |
| From National Council on Radiation Protection and Measurements. NCRP Reports 93, 94, 95, 100. Bethesda, MD: NCRP, 1987, 1987, 1987, 1989. |                |                                             |



Of interest in this regard are reports of high natural background in other parts of the world where significant populations receive from 15 mSv to 40 mSv annually, without apparent increases in leukemia, cancer, or birth defects; these levels are from 5 to 13 times higher than in the United States (Kesavan, 1997; Sohraby, 1997).

### Summary of Radiation Risks

Available evidence indicates that all radiation, no matter how small the dose, has the potential for producing undesirable effects with very low statistical probability on both somatic and genetic tissues. Although repair processes occur within the cell, it is unknown if complete recovery from the effects of radiation occurs. It is assumed that there are small amounts of residual damage that persists within cells and is cumulative. As a patient's dose increases, the risk of developing adverse sequelae such as cancer, leukemia, cataracts, or mutated reproductive tissues increases. The severity of the consequences can be minimized by using every possible means to reduce patient exposure. The current estimate of the average effective dose from natural or background sources producing fatal cancer, nonfatal cancer, and hereditary effects is approximately 4400  $\mu$ Sv per year (12  $\mu$ Sv/day). We can estimate that an FMX taken with F+ speed film and rectangular collimation (26  $\mu$ Sv) is equivalent to 2 days of background exposure.

The risks from dental radiography are numerically very small, like one chance in a million billion (Hoffman and Katz, 1983). However, it is reasonable to accept the notion that the information gained from a properly justifiable radiographic examination by far outweighs the potential risk of harm. Science is increasingly discovering that there are mechanisms within the cell nucleus that continually monitor and repair damage to the DNA linear strand in the cell nucleus. Such damage occurs as a result of "spontaneous" or "endogenous" damage, which is produced by the continuous interaction of various atoms and molecules together through the dynamics of cellular metabolism. Every hour, human and other mammalian cells undergo at least 50 to 100 times more spontaneous or "natural" DNA damaging events than would result from the absorption of 1 cGy (rad) of ionizing radiation. The miracle is that this spontaneous or natural damage appears to be successfully repaired minute by minute, hour by hour, year after year. If the process did not work effectively, there would be no humans left alive. Billen (1990) estimates that there are approximately 8000 to 10,000 DNA-damaging events of various kinds occurring in each cell every hour. The absorption of 1 cGy of radiation would produce an additional 80 DNA damage sites. The question to the reader is, "If the nucleus can effectively handle the repair of 8000 to 10,000 natural DNA damaging events per hour, shouldn't it be able to handle an additional 80 DNA damage sites without overloading or short circuiting?"

As a way of maintaining perspective on this issue, think of dinner guests who would presumably leave a few more dirty dishes for the dishwasher to "deal with." In the majority of instances, the dishwasher would simply wash the extra dishes without complaining or breaking down. Although there were more dishes to wash, there was the benefit of the pleasurable social interaction with friends that makes the added work and inconvenience of doing the extra dishes well worth the effort. It is the author's opinion that this is the way the nuclear repair process treats the extra damage produced by low levels of diagnostic radiation—no big deal, simply a "few more dishes to wash." Similarly, significant health benefits can be derived because of the diagnostic information obtained through the judicious, prudent use of ionizing radiation.

### RADIATION PROTECTION ORGANIZATIONS

There are a host of local, state, national, and international organizations established to make recommendations and establish policies governing the use of ionizing radiation. Each has a role to play in assuring adequate protection of both occupationally and nonoccupationally exposed persons. These organizations are listed below.

**United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (International)**—Reviews and assesses current research in radiation biology and protection, and suggesting risk estimates for radiation-induced cancer and genetic effects.

**Biological Effects of Ionizing Radiations (BEIR) Committee (appointed by the National Academy of Sciences (NAS) (United States)**—Reviews and assesses current research in radiation biology and protection, and suggesting risk estimates for radiation-induced cancer and genetic effects.

**International Commission of Radiological Protection (ICRP)**—Often takes the lead in formulating concepts in radiation protection and recommends dose limits.

**National Council on Radiological Protection and Measurement (NCRPM) (United States)**—Formulates concepts in radiation protection and recommends dose limits.

**Note:** The ICRP and NCRP suggest dose limits and safe practices, but neither body has any jurisdiction to enforce their recommendations. Each state also has its own Bureau of Radiation Safety, which governs practices within that state.

**The International Commission on Radiation Units and Measurements (ICRU) (International)**—Makes recommendations on radiologic units of measurement.

**Nuclear Regulatory Commission (NRC)**—Establishes radiation protection regulations and supervises nuclear power/weapons facilities. Formally known as the Atomic Energy Commission.

**Environmental Protection Agency (EPA)**—Has the responsibility in the United States for providing guidance to federal agencies.

**Occupational Safety and Health Administration (OSHA)**—Is responsible for all occupational radiation protection regulations that are not regulated by the NRC.

**National Center for Devices and Radiological Health (NCDRH)**—Regulates the manufacture of radiation-producing equipment such as x-ray machines, microwave ovens, video display terminals, and medical ultrasound equipment. The NCDRH (formerly known as the Bureau of Radiological Health [BRH]) is an organization within the U.S. Food and Drug Administration. The **U.S. Food and Drug Administration (FDA)** is a part of the **Department of Health, Education and Welfare (DHEW)** of the U.S. government.

## LABORATORY EXERCISE

Have each student prepare an answer to a patient who refuses any x-ray examination in your dental office, because the patient is fearful of dental x-radiation and its harmful effects.

## REVIEW QUESTIONS

1. Cell sensitivity to radiation is more pronounced:

1. During mitosis.
2. During periods of increased metabolism.
3. During embryonic development.
4. In muscle cells.
5. In nerve cells.
- A. 1, 2, and 3.
- B. 1, 2, and 5.
- C. 1, 3, and 5.
- D. 2, 3, and 4.
- E. 2, 3, and 5.

2. Which of the following tissues is most susceptible to radiation?

- A. Nerve tissue.
- B. Muscle tissue.
- C. Brain tissue.
- D. Blood-forming tissue.

3. Theoretically, the biologic response to a given dose of radiation would be greater (more severe) with:

- A. An anoxia of the tissue being irradiated.
- B. A higher dose rate.
- C. A smaller area of tissue exposure.
- D. Lower linear energy transfer (LET).

4. Which of the following latent effects can be associated with low-dose, whole-body radiation?

- A. Shock.
- B. Epistaxis (nose bleed).
- C. Epilation (loss of hair).
- D. Leukemia.

5. To a person in the United States, the average effective dose of ionizing radiation from natural background radiation is about:

- A. 10 mSv/year.
- B. 3 mSv/year.
- C. 6 mSv/year.
- D. 50 mSv/year.

6. A certain amount of radiation is needed before the clinical signs of damage to somatic cells appear. The amount of radiation after which visible damage can be produced is called the:

- A. Latent dose.
- B. Threshold dose.
- C. Hazard dose.
- D. Scattered radiation dose.
- E. Background radiation dose.

7. Which of the following is an SI unit of radiation absorbed dose expressed in joules per kilogram of irradiated tissue?

- A. Roentgen (R).
- B. Curie.
- C. rem.
- D. Gray (Gy).

8. The SI unit of exposure of air is called:

- A. One coulomb per kilogram.
- B. Gray.
- C. Rad.
- D. Relative biologic effectiveness (RBE).

9. A radiation-damaged cell can pass along damage to offspring cells. This is an example of:

- A. Somatic effect.
- B. Genetic effect.
- C. Latent effect.
- D. Indirect effect.



10. X-radiation affects the incidence of cancer, leukemia, and other abnormalities by:
  - A. Increasing their incidence among the general population.
  - B. Increasing the patient's incidence of each disease.
  - C. Producing specific types of cancer or other abnormalities more often in an exposed population.
  - D. Storing the radiation within the tissue, creating continual damage after exposure has ceased.
11. Which of the following is not considered a critical organ?
  - A. The brain and spinal cord.
  - B. The bone marrow.
  - C. The gonads.
  - D. The thyroid gland.
12. Damage to nuclear DNA can:
  - A. Never be repaired.
  - B. Only be partially repaired.
  - C. Be repaired by the cell's cytoplasm.
  - D. Be repaired by the DNA damage-control biosystem.
13. Hormesis, as it is related to radiation exposure, may best be described as:
  - A. Mutagenic effect of ionizing radiation on DNA.
  - B. The disruption of cytoplasmic functions following irradiation.
  - C. Beneficial effect of low doses of radiation.
  - D. Toxic effect of radiation at any dose.
14. The biologic effects of ionizing radiation at a cellular/nuclear level may be significantly reduced by:
  - A. DNA damage-control biosystem.
  - B. Apoptosis.
  - C. Hormesis.
  - D. All of the above.
15. Which *one* of the following would be considered a deterministic effect of radiation:
  - A. Thyroid cancer.
  - B. Cataract.
  - C. Leukemia.
  - D. Skin cancer.
  - E. All of the above.
16. Inherited birth defects resulting from a parent's exposure to ionizing radiation before conception of
 
  - A. Stochastic effect.
  - B. Deterministic effect.

- C. Hormetic effect (hormesis).
- D. Nonstochastic effect.

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# Radiologic Health and Protection

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *State the basic factors affecting radiologic health.*
2. *Explain how to minimize patient radiation doses.*
3. *Describe all concepts associated with operator protection.*
4. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                                                 |                      |                                  |                                 |
|-------------------------------------------------|----------------------|----------------------------------|---------------------------------|
| As Low As Reasonably Achievable Concept (ALARA) | dosimetry monitoring | leaded torso aprons (thyroid)    | plastic pointed cone position   |
| beam indicating device (BID)                    | E+ speed film        | long BID (round and rectangular) | rare earth intensifying screens |
| collimation                                     | F speed film         | maximum permissible dose (MPD)   | selection of radiographs        |
| constant potential                              | electronic timers    | nonoccupational exposure         | thyroid collar or shield        |
| distance                                        | film-holders         | occupational exposure            | wall shielding                  |
|                                                 | filtration           |                                  |                                 |
|                                                 | kilovoltage (kVp)    |                                  |                                 |

## RADIOLOGIC HEALTH

### INTRODUCTION

Because the effects of x-rays at low-level radiation doses cannot currently be measured, the basic assumption is made that every dose of radiation produces some potential biologic damage. The dental health-care worker's goal is to keep radiation exposures to the minimum that are necessary to meet diagnostic requirements. Therefore, efforts have been made to determine the most appropriate balance between the potential risk to the patient and the obvious benefits of radiation in terms of improved diagnosis and treatment. Efforts to identify this acceptable balance point have resulted in the establishment of radiation protection standards by various national committees on radiation protection.

### NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

The National Council on Radiation Protection and Measurements (NCRP) is a private organization of scientists who are experts in various aspects of radiation and operate under a congressional charter, but do not have legal status. They make **maximum permissible dose (MPD)** recommendations that are published periodically in handbooks. The NCRP is purely advisory, but most state and federal laws are based on NCRP recommendations.

#### MPD

By definition, the **MPD** is the amount of radiation that an individual is allowed to receive from artificial sources of radiation, such as x-ray machines, except when the individual is a medical or dental patient. This is a level of radiation dose that represents an acceptably low risk of

harmful effects. Since the first recommendation of by the NCRP in 1931 of 50 Roentgens per year (0.2 R per work-day), the MPD has been lowered on three occasions. The MPD is now only one tenth of its initial level. Recommended exposures have been lowered because of growing concern over the increasing use of diagnostic radiation and apprehension about the mounting evidence that small doses can cause leukemia and carcinoma.

tionally exposed, i.e., those persons who are normally expected to use or work around radiation as a normal part of their job (dentists, assistants, hygienists), and nonoccupationally exposed, i.e., those persons who do not work with radiation (front office staff, general public, family in waiting rooms). Also, in the event of pregnancy, an occupationally exposed woman would be permitted to receive the same dose as a nonoccupationally exposed person. In addition, there are dose limits recommended for different organs or parts of the body because of their different sensitivities to radiation. The permissible levels for each of

With a properly designed office, properly functioning

x-ray machines, and proper dental radiography procedures, x-ray machines should not cause any occupational or nonoccupational person to receive anywhere near the MPD. In fact, if a dental office's dosimetry service indicates that the office is receiving even one tenth of the MPD, office procedures should be carefully evaluated because routine dental radiography should result in almost no increase above background levels to any member of the dental staff or public. When calculating the MPD or dose limits for occupationally or nonoccupationally exposed persons, radiation received from environmental background and diagnostic medical and dental exposures (for the individual's personal health care) are specifically excluded from calculations, primarily because medical and dental exposures and environmental background radiation cannot be effectively controlled or limited. Therefore, the concept of MPD does not apply to doses that someone receives as a dental or medical patient. The government does not limit the radiation dose that patients receive because it recognizes that to set such a limit might prevent physicians and dentists from prescribing radiographs that would greatly benefit the patient. However, radiation operators are required to use the minimum amount of radiation possible to obtain the information

TABLE 13-1. Maximum Permissible Doses

| <i>Class of Exposed Individual</i>                                               | <i>Maximum Permissible Dose (mSv)</i> |
|----------------------------------------------------------------------------------|---------------------------------------|
| Radiation workers (dentists, assistants, hygienists) (annual)                    |                                       |
| Effective dose equivalent limit (whole body)                                     | 50                                    |
| Partial body dose equivalent limits                                              |                                       |
| Skin                                                                             | 150                                   |
| Forearms                                                                         | 300                                   |
| Hands                                                                            | 750                                   |
| Other organs and organ systems (e.g., red bone marrow, breast, lung, and gonads) | 500                                   |
| Lifetime cumulative exposure                                                     | 10 (times age in years)               |
| Public exposures (annual)                                                        |                                       |
| Effective dose equivalent limit, continuous or frequent exposure                 | 1                                     |
| Effective dose equivalent limit, infrequent exposure                             | 5                                     |
| Dose equivalent limits for lens of eye, skin, and extremities                    | 50                                    |
| Trainees younger than 18 years of age (annual)                                   |                                       |
| Effective dose equivalent limit                                                  | 1                                     |
| Dose equivalent limit for lens of eye, skin, and extremities                     | 50                                    |
| Pregnant women (with respect to fetus)                                           |                                       |
| Total dose equivalent limit                                                      | 5 (during gestation period)           |
| Dose equivalent limit in 1 month                                                 | 0.5                                   |

Summary of National Council on Radiation Protection and Measurements. Exposure of the U.S. population from diagnostic and medical radiation. NCRP Report 116. Washington, DC: NCRP, 1993. Recommendations external exposures.



required to diagnose and treat each patient. Therefore, one of the many responsibilities of a licensed or certified dental health-care worker is to use x-rays carefully and only for each patient's benefit, as described in the following paragraphs.

### ALARA Concept

An important radiation protection concept is the **As Low As Reasonably Achievable (ALARA)** concept. In principle, this concept does not specify a specific level of radiation dose for exposed persons as the MPD concept does. Simply stated, ALARA means that every reasonable measure will be taken to assure that occupationally and nonoccupationally exposed persons will receive the smallest amount of radiation possible. The implications of this concept will be discussed more fully in the section on operator and patient protection. Currently, ALARA is considered the most appropriate, relevant radiation concept and should be considered the radiation protection concept of choice.

## PATIENT RADIATION PROTECTION

Patients may want to know how careful a dental health-care worker is with x-rays and may ask a question such as, "I have heard that x-rays are dangerous. What do you do to protect me against them?"

### RADIATION PROTECTION

The following recommendations are designed to minimize the somatic and genetic exposures to patients from dental diagnostic radiographic procedures. Many of the factors have been discussed elsewhere in this book and are included in this section as a means of integrating information on radiation protection. It should be noted that all suggestions will secondarily minimize the exposure to the radiation operator and consequently the results may be considered of potential double benefit to the patient and the dental health-care worker.

#### Decisions for Selection of Radiographs

First, the operator should expose no one to x-rays without a good reason. This means that "routine radiographs," which are radiographs taken without considering the patient's clinical findings and history, should **not** be taken. An example of routine radiographs would be to make a full-mouth series or a panoramic radiograph on every new patient without a prior examination. Another example would be bitewing radiographs on every patient every 6 months. A further example would be to take a full-mouth survey when a panoramic radiograph would serve equally well. Instead of this approach, the dental health-care worker should examine and question the pa-

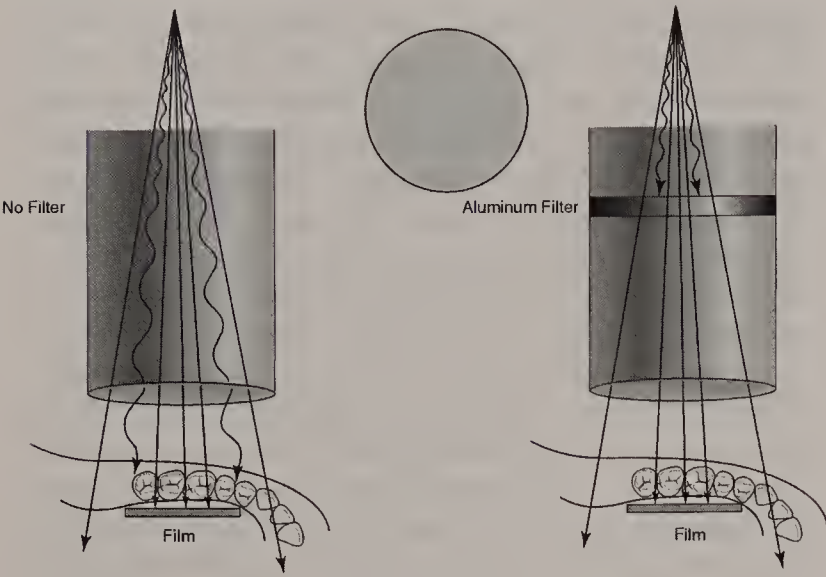
tient before deciding whether to make radiographs and, if radiographs are needed, which radiographs should be made. A Food and Drug Administration (FDA) panel has published a set of radiographic selection criteria—which include patient signs, symptoms, developmental stage, and historical features—that help in the decision about which radiographs to take and when to take them (U.S. Department of Health and Human Services, 1989). If a radiograph would not change the diagnosis or treatment or if a radiograph is highly unlikely to provide any additional helpful information, it should probably not be taken. Postoperative radiographs should be taken only when there is a clinical indication and not as verification for third-party payment plans. It is always prudent to use only the minimum number of films (i.e., a panoramic radiograph rather than the full-mouth survey) required to treat a patient adequately. This applies to all patients, whether pregnant, young, old, new, or recall. Pregnancy is not a contraindication for dental radiography.

#### Decisions Made at the X-Ray Machine

**Kilovoltage (kVp).** The x-ray machine should be operated at the highest kilovoltage (kVp) consistent with a good image, usually 70 to 90 kVp. An x-ray machine that is incapable of being operated at least at 60 kVp should **not** be used. High-kilovoltage operation produces more "useful" x-rays and fewer low-energy rays that are absorbed by the patient without contributing to the quality of the image. Dental x-ray techniques using higher kilovoltages reduce the effective dose delivered per intraoral examination. It has been reported by Gibbs et al. (1988) that the effective dose to the patient was reduced up to 23% in one study by increasing kilovoltages from 70 to 90 kVp.

**Constant Potential X-Ray Machines.** This generator design converts the alternating current (AC) to direct current (DC) to produce a homogeneous beam of consistent wavelengths during the whole exposure. This type of dental x-ray machine can reduce the patient exposure by 20% over conventional machines. Because this is an integral design feature, older machines cannot be converted to **constant potential**. Because lower exposures are necessary, it is important to follow the manufacturer's instructions.

**Filtration.** The x-ray beam should be filtered properly. Filtration preferentially removes soft, low-energy, long-wavelength x-rays from the beam (Fig. 13-1). These rays are undesirable because they are absorbed by the patient (increasing the patient's dose) without contributing to the formation of the radiographic image (no increased benefit). Filtration is stated in millimeters of aluminum (mm Al), which is the material most commonly used. A dental x-ray machine operating at 50 to 69 kVp should have at least 1.5 mm Al equivalent filtration, whereas a machine operating at 70 kVp or more should have at least 2.5 mm Al equivalent filtration.

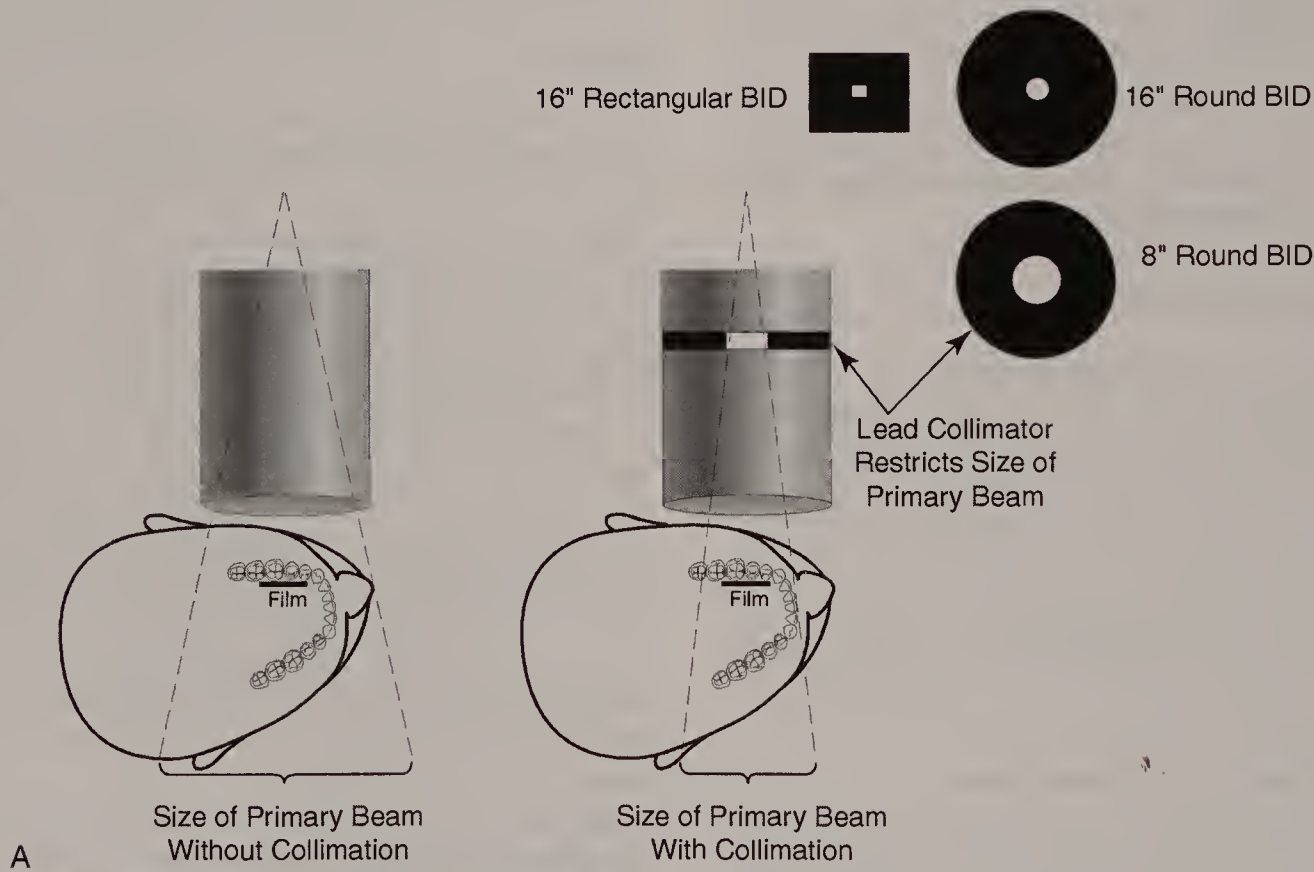


| Minimum Total Filtration<br>Operating Voltage (kVp) | Aluminum Filtration<br>(mm) |
|-----------------------------------------------------|-----------------------------|
| 50 to 69                                            | 1.5                         |
| 70 and above                                        | 2.5                         |

From National Council on Radiation Protection and Measurements. Dental x-ray protection. NCRP Report 35. Washington, DC: NCRP, 1970.

In panoramic and cephalometric x-ray machines, selective filtration of both low- and high-energy photons with rare earth materials, in combination with aluminum filtration, has reduced patient exposure by 20 to 80% compared with conventional aluminum filtration alone. Adequate filtration should be confirmed by expert (such as a factory representative or state inspector) periodic inspection of the x-ray machine.

**Collimation of the Beam.** It is required by federal law to collimate (limit) the field of radiation at the patient's skin

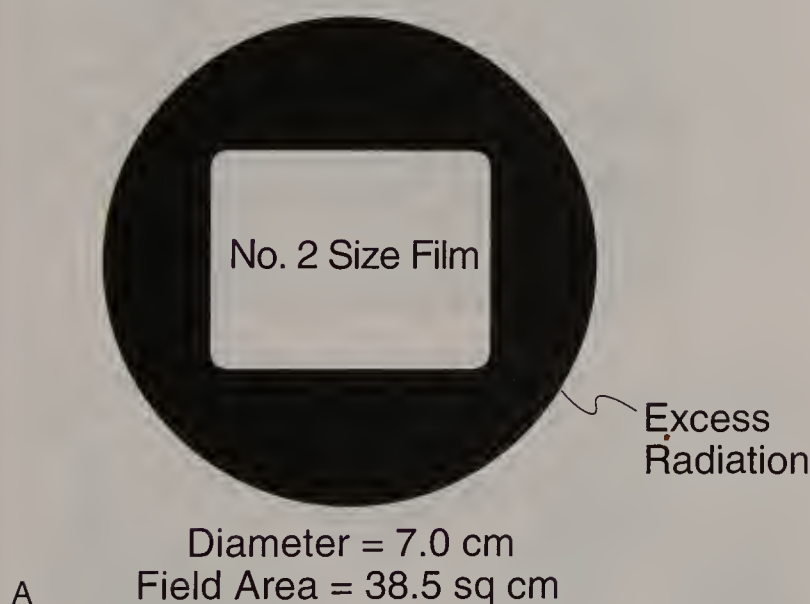


**Figure 13.2 Collimation.** (A) Collimation is the restriction of the cross-sectional area of the beam and is usually done with a collimator (diaphragm). A collimator can be a flat piece of lead with a round hole in it to restrict the useful beam to an area no larger than 2.5 inches in diameter when measured at the end of the BID. The size and shape of the hole in the center depends on whether the BID is short/long or rectangular/round. The collimators on the top right are for long, round BIDs (upper) and short, round BIDs (lower). (B) Collimator aperture sizes: (left) long, round BID—dime size; (middle) short, round BID—quarter size; (right) rectangular, long BID—smallest.

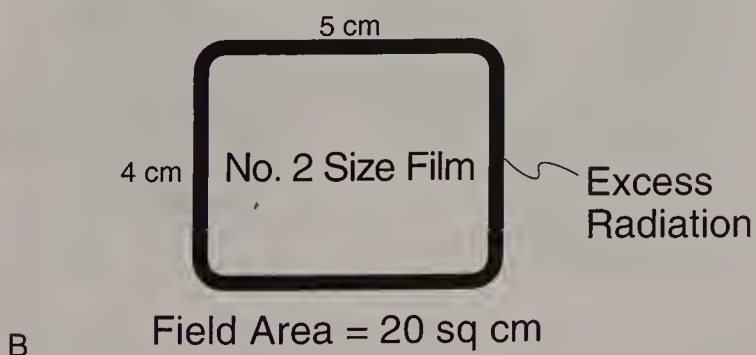


surface to a circle having a diameter of no more than 7 cm (2.75 inches). **Collimation** means restriction of the cross-sectional area of the beam, and this is usually done with a lead diaphragm (collimator) within the tubehead or at the end of a lead-lined cylinder (incorrectly referred to as a cone) (Fig. 13-2). Because the dimensions of a No. 2 intraoral regular film are  $3.2 \times 4.1$  cm, the patient exposure using the circular collimation as required by law (7-cm diameter) is actually almost 3 times the area necessary to expose the film. Therefore, patient exposure can be significantly reduced by limiting the beam even more. It is highly recommended that instead of using round collimation, rectangular collimation (which restricts the beam to approximately the size of the film) be used. Use of rectangular collimation reduces the exposed area to approximately 48% compared with round collimation (Fig. 13-3). Rectangular collimation also improves image quality by reducing fog from scatter, resulting in a radiograph with

## Round Collimator



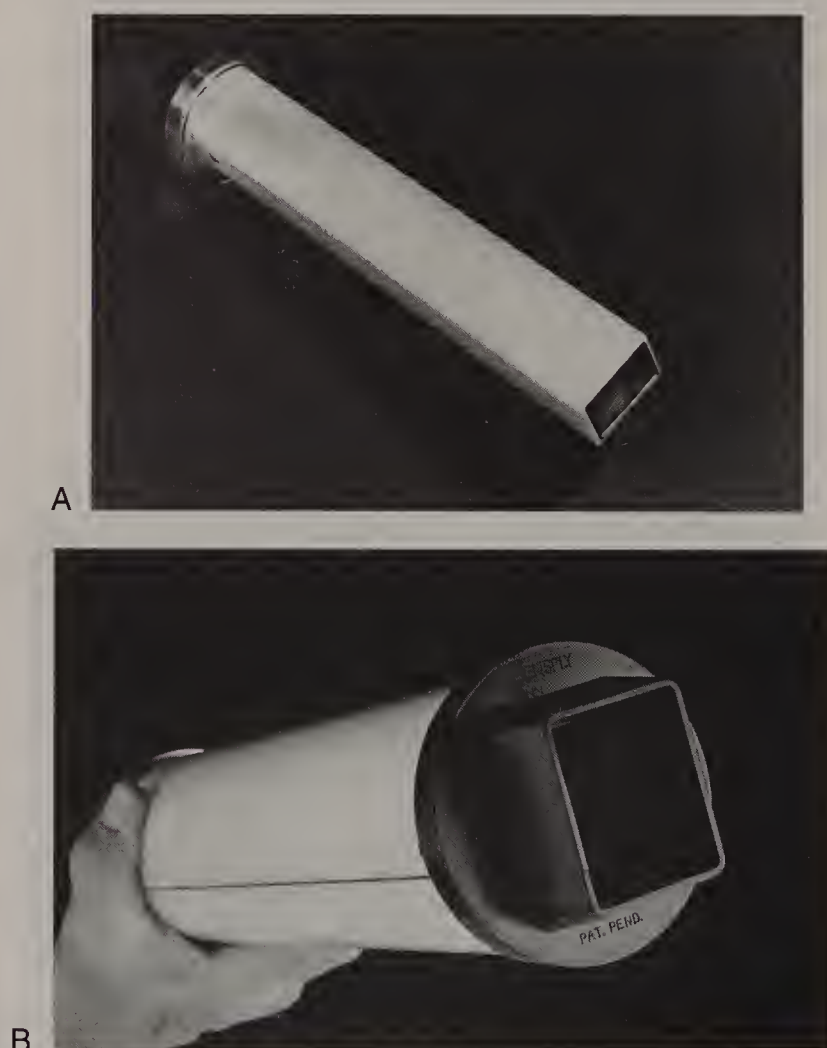
## Rectangular Collimator



**Figure 13.3 Rectangular Collimation.** By using a rectangular collimator (B) rather than a round cylinder beam restrictor (A), the area irradiated has been decreased by 48%.

better resolution and better contrast. Rectangular collimation of the x-ray beam can be accomplished by one or a combination of methods. Dentsply/Rinn XCP film-holders (Elgin, IL) used in conjunction with a Margraph rectangular BID (Margraph Corp., Jenkintown, PA) or with a round BID with a Dentsply/Rinn Universal rectangular collimator attached to it can be used to reduce patient exposure (Fig. 13-4). Also, the Precision Instrument (Masel, Philadelphia, PA) can be expected to produce similar results (Fig. 13-5).

**Use of Long BID (Cone).** The lead-lined cylinder or rectangular collimator protruding from the x-ray machine functions as a **beam indicating device (BID)**. The BID serves to show the radiographer where the beam will strike the patient. There are three lengths of BIDs: 8 inches, 12 inches, and 16 inches (Fig. 13-6). A lead-lined long BID is preferred because it results in less beam divergence. Therefore, there is less volume of patient's tissue irradiated per exposure (Fig. 13-7). **Pointed plastic cones** are not recommended because they increase scattered radiation to all areas of the patient's head, neck, and reproductive organs



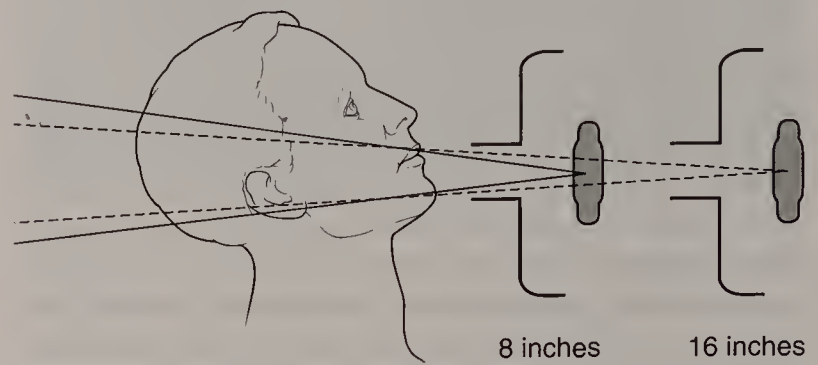
**Figure 13.4 Rectangular BID Collimation.** (A) Margraph long, rectangular BID. (Margraph Corp.) (B) Dentsply/Rinn Universal Rectangular Collimator attached to long, round BID.



**Figure 13.5 Masel Precision Instruments.** The Masel Precision Instruments collimate the circular x-ray beam to a rectangular-shaped beam at the patient's face, reducing unnecessary radiation exposure to the patient.

(Fig. 13-8). In addition, a much greater volume of tissue is irradiated due to scattered radiation from the plastic pointed cone (Fig. 13-9). Also, by use of the lead-lined, long open-ended BID rather than the shorter BID, the diagnostic quality of the radiographic image is improved because less scatter radiation is produced.

**Use of Electronic Timers.** The timer on the x-ray machine should be electronic. Mechanical timers are imprecise when used for the short exposures needed in modern dental radiography. Mechanical timers are also not accu-



**Figure 13.7 Long BID Reduces Radiation to Patient.** As source-film distance is increased, the volume of tissue irradiated is decreased. White areas represent the extra volume of tissue exposed when an 8-inch distance is used rather than the 16-inch distance.

rate for exposures less than 1 second and are not recommended (Fig. 13-10). The timer on the x-ray machine should have a "dead man" control, which shuts the machine off immediately, regardless of timer setting, unless finger or foot pressure is held continuously on the timer switch throughout the desired exposure. The electronic timer is calibrated in sixtieths of a second, corresponding to the 60 cycles per second of alternating current that powers the machine. Each 1/60 of a second exposure results in one pulse of x-rays produced.



**Figure 13.6 Long and Short BIDs.** (A) (Above) Short and (below) long round, open-ended, lead-lined cylinders or BIDs. (B) Types of (1) rectangular collimators and (2) long Dentsply/Rinn rectangular BIDs for different x-ray machines. Rectangular BIDs are not available from Dentsply/Rinn. At present, contact Margraph Corp., 611 Harper Ave., Jenkintown, PA 19046. (3) Masel Precision Instruments (anterior and posterior instruments). (4) Rectangular BID for recessed anode tubehead.





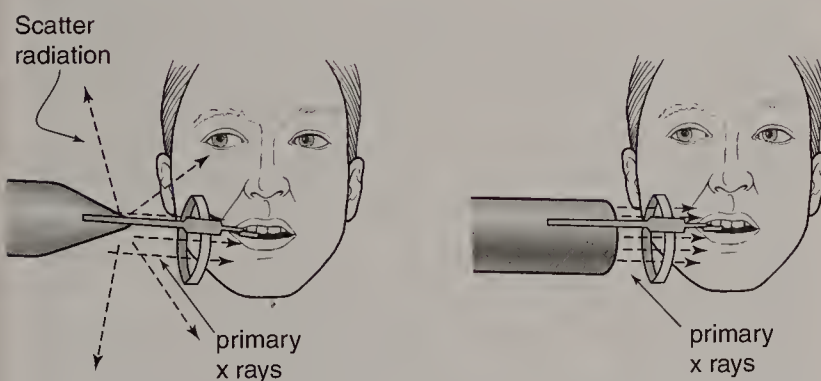
**Figure 13.8 Short, Plastic Pointed BID.** Short, plastic pointed BID (arrow) on vintage x-ray machine.



**Figure 13.10 Mechanical Timers.** A mechanical timer (arrow) on an older dental x-ray machine. When the button is pushed, it closes the circuit and allows the current to flow without interruption. These timers are inaccurate for exposure times shorter than 1 second.

POINTED BID

OPEN ENDED BID



**Figure 13.9 Scattered Radiation From Short, Plastic Pointed BID.** (Left) Pointed BID: short, plastic pointed BID produces a major source of scatter radiation when irradiated by the primary x-ray beam. (Right) Open-ended BID: the source of scatter radiation is eliminated when the open-ended cylinder is used.

### Decisions Made at the Chair

**High-Speed Film.** The fastest and most appropriate film should be used. Currently, the film speeds available are D, E+, and F. The Kodak Company markets three speeds of film: Kodak Ultra-speed film (D speed film), EKTASPEED Plus film (E+ speed film), and Kodak INSIGHT film (F speed film). Kodak INSIGHT (F speed

dosage to the lowest possible exposure with any intraoral film on the market today. By switching to Kodak INSIGHT (F speed film) from Kodak Ultra-speed film (D speed film), dentists can lower their radiation exposure settings by as much as 60%. Dentists using an E+ speed film, such as Kodak EKTASPEED Plus Intraoral Dental Film, can lower their radiation exposures as much as 20% by switching to Kodak INSIGHT (F speed) film.

**Rare Earth Intensifying Screens.** Patient x-ray exposure during panoramic and other extraoral projections can be further reduced by using rare earth intensifying screens and high-speed film. The higher speed of the rare earth/T-Mat grain film (flattened silver halide grains)

combinations are twice as fast as conventional calcium tungstate screen/film combinations (Miles et al., 1989; Ponce et al., 1986).

**Film-Holding Devices.** A film-holding device should be used. The purposes of this device are to avoid using the patient's fingers to hold the film in place, thus avoiding an unnecessary radiation dose to the fingers; to more accurately align the film with the teeth, and the BID with the film; and to avoid retaking radiographs caused by improper alignment. Film-holding devices are essential if rectangular collimation is used, because the smaller, narrow beam leaves almost no room for error in aiming the BID at the film.

**Leaded Protective Aprons and Thyroid Collars or Shields.** The patient should be provided with a leaded torso apron and a leaded thyroid shield (Fig. 13-11). Although exposure to the gonads is negligible, a leaded apron provides shielding and thus further reduces genetic and carcinogenic risk to pelvic, abdominal, and thoracic tissues. Breast and bone marrow are the somatic tissues of greatest concern here. Leaded torso (body) aprons will reduce genetic exposure by 98% for panoramic radiography, and the leaded apron should cover both the front of the pa-



**Figure 13.11** **Leaded Torso Apron and Thyroid Collar.** Example of a protective leaded torso apron and thyroid collar.



**Figure 13.12** **Panoramic Leaded Apron.** The panoramic leaded apron should cover both the front and the back of the patient because both sides of the patient are exposed in panoramic x-ray projections. The leaded thyroid shield cannot be used because it interferes with the panoramic image.

tient's chest as well as the shoulders and back because the tubehead exposes the film from this position (Fig. 13-12). Additionally, for intraoral radiography, a leaded thyroid collar or shield will reduce the dose to the thyroid gland by approximately 50%. An added benefit of both leaded apron and thyroid shield is that patients appreciate this precaution.

### Decisions Made in the Darkroom

Correct film processing procedures necessarily include a wide variety of subcategories, because each factor will significantly improve the quality of the radiograph. If neglected, these same factors will severely degrade the quality of the radiograph.

**Darkroom Lighting Decisions.** The darkroom must be kept free from light leaks. White light should not be allowed to leak in around doors, plumbing, air conditioning ducts, windows, and so on because it will produce film fog. An appropriate safelight filter should be used in the darkroom to permit the operator to work in the dark without producing film fog during various stages in film processing. The Kodak GBX-2 (red) safelight filter is a universal safelight filter that can be used in darkrooms where both intraoral and extraoral, such as panoramic and cephalometric films, are handled. This includes films that are used with the rare earth screens. A standard 15-W bulb should be used with most films, and the safelight lamps should be placed at a minimum of 4 feet from the working area. The ML-2 (light orange) filter should not be used with panoramic or other extraoral films. The ML-2 is designed to be used with the intraoral D speed dental film only. It will fog panoramic and E+ and F intraoral films.



**Full Development Processing Decisions.** When radiographs are to be processed by the manual (hand-dip) method, time/temperature processing is absolutely essential because it is the only way to ensure maximum development of the radiographic image. In all instances, full development should be used (e.g., 5 minutes at 70°F). The exposure time can be reduced when the film is given full development. For example, the radiation exposure may be decreased by 25% without interfering with the quality of the film image. It has been estimated that to shorten developing time by 1 minute, it would be necessary to increase the patient's exposure by at least 30%—an extremely unwise thing to do. Sight or visual development techniques are prohibited because they encourage overexposure to the patient and underdevelopment of the radiographic image.

**Decisions About Processing Solutions.** Processing solutions should be changed regularly, stirred thoroughly twice each day, kept covered to prevent oxidation when not in use, and not subjected to excessively high temperatures. Weekly quality control checks should be performed to ensure optimal processing and quality radiographs. (It should be done daily with automatic processors.) Chemicals should also be replenished according to the manufacturer's instructions. Depleted or contaminated chemicals can result in a nondiagnostic radiograph that necessitates a retake, thus doubling the patient's dose for that image. Manual processing tanks or automatic processor tanks and rollers should be cleaned and checked regularly and frequently. The darkroom should be immaculate, and the counter tops devoid of wet or dried chemicals, which could adversely affect the quality of the films before or after processing.

**Decisions About a Quality Assurance Program.** Every dental office should have a written quality control program. There should be one staff member who is responsible for implementing the plan daily and for monitoring all exposure, processing, and equipment maintenance steps. In this way, the cause of any substandard radiographs can be quickly detected and corrected, thus preventing future retakes (see Chapter 8).

### Decisions About the Viewbox

Radiographs should be properly mounted in opaque mounts and viewed in a dimly lit room with a properly functioning illuminator (viewbox). An illuminator with variable intensity is helpful when viewing radiographs that have been overexposed (too dark) or underexposed (too pale). Many retakes can be avoided by adjusting the light source on the viewbox. If all other steps have been followed but the radiographs are not viewed under ideal conditions, the radiographic image could be misinterpreted.

## OPERATOR RADIATION PROTECTION

### General Concepts

The operator should be ready to answer clearly and completely when asked about the precautions taken on behalf

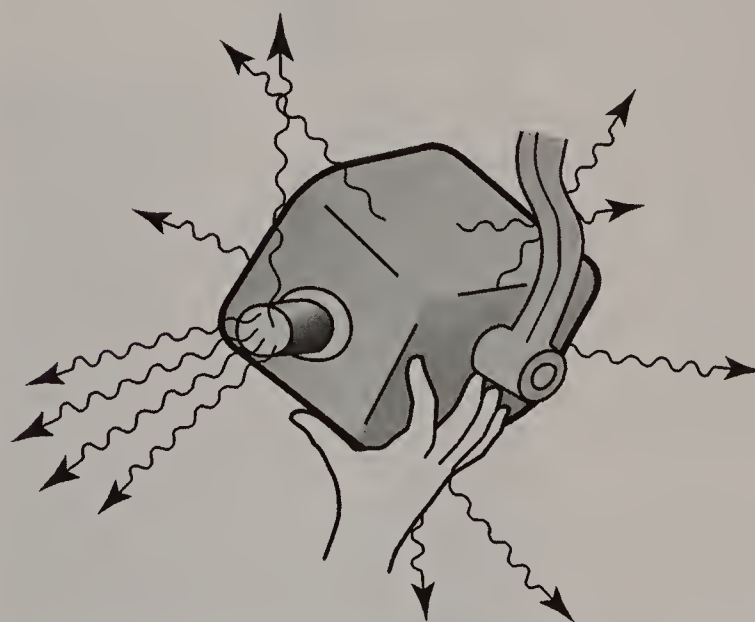
of the patient when radiographs are made. In addition, new members of the office staff will surely have their own welfare in mind. They have already learned that humans may develop cancer from an overexposure to radiation. What should they be told when they ask, "What is done in this office to protect me from occupational radiation exposure?" There are several procedures operators can use to minimize their occupational exposure in the dental office. Most of them are based on certain fundamental concepts concerning x-rays, which are that (1) x-rays travel in a straight line from their source, (2) x-radiation intensity of the beam decreases as the distance from the source increases (inverse square law), and (3) x-rays can be scattered in their path of travel.

The operator of dental x-ray equipment may be potentially exposed to primary radiation from the useful beam, leakage radiation from the tube housing, and scattered radiation usually from the patient's skull. Leakage radiation is radiation other than the useful beam that escapes through the protective shielding of an x-ray tube housing. Because x-rays radiate in straight lines from the source, there is need for a metal housing for the tube. Despite the metal tube housing, there is a small amount of radiation that will leak. The operator should never hold the BID or tube housing to steady it during exposure (Fig. 13-13).

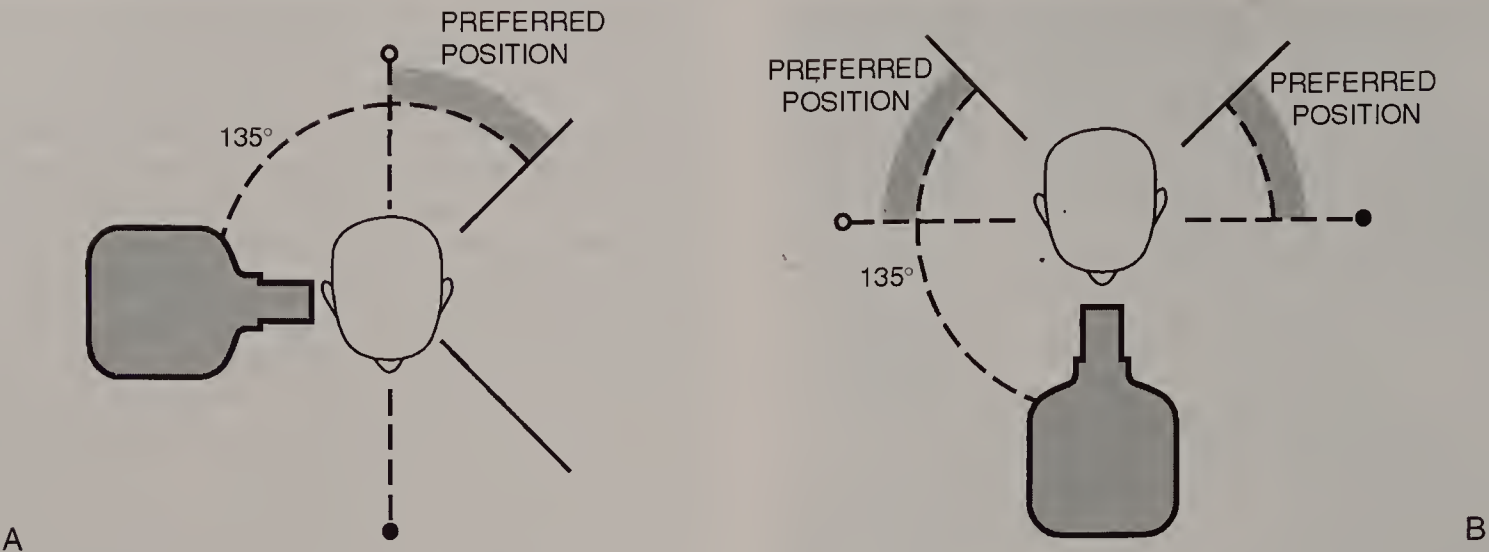
### Three Basic Methods to Reduce Occupational Exposure

There are three basic methods to reduce the occupational dose from x-rays: position, distance, and shielding. These methods can be used to the operator's advantage, as summarized in the following paragraphs.

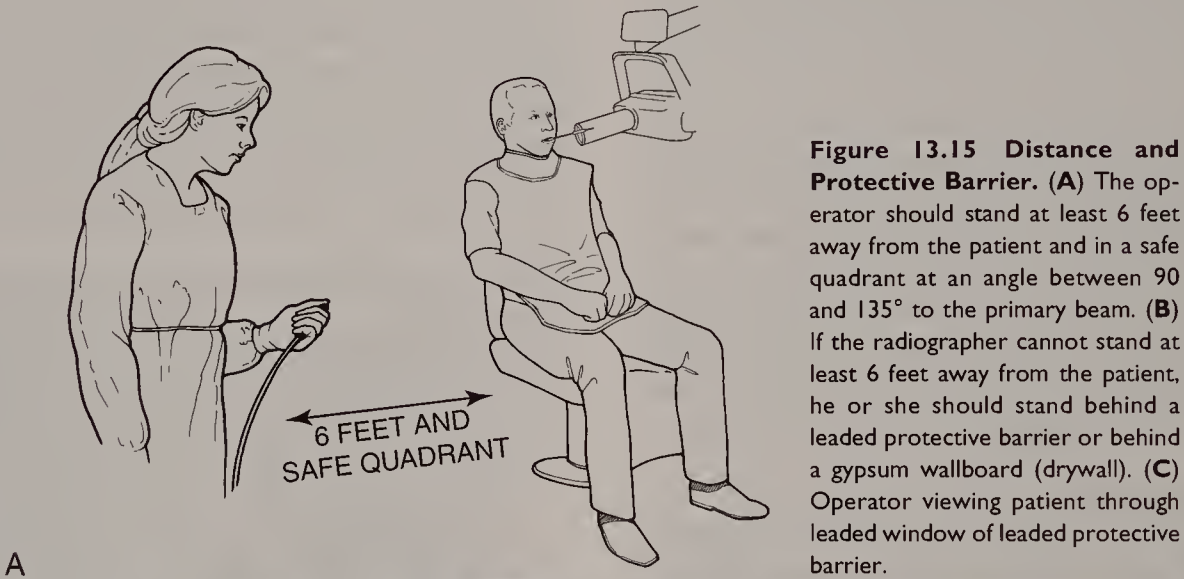
**Position and Distance.** The most effective way of reducing operator exposure to primary radiation is to enforce strict application of the position and distance rule (i.e., the



**Figure 13.13 Tubehead Leakage Radiation.** Never hold the BID or tubehead during exposure because of leakage radiation from the tubehead.



**Figure 13.14 Preferred Positions.** (A) Preferred position for posterior radiographs. (B) Positions of greatest safety for operator during x-ray exposure to patient for anterior radiographs. The circles represent 90° positions; the operator should stand in the area designated "preferred position," at least 6 feet away from the BID tip.



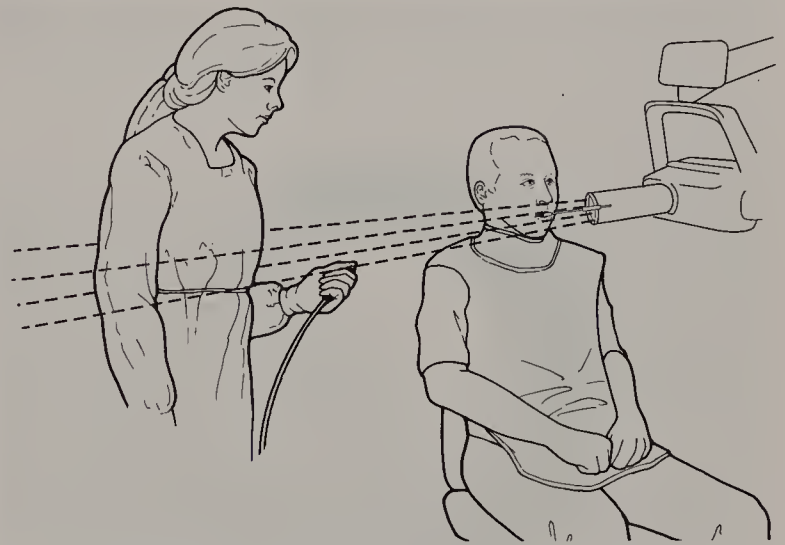
**Figure 13.15 Distance and Protective Barrier.** (A) The operator should stand at least 6 feet away from the patient and in a safe quadrant at an angle between 90 and 135° to the primary beam. (B) If the radiographer cannot stand at least 6 feet away from the patient, he or she should stand behind a leaded protective barrier or behind a gypsum wallboard (drywall). (C) Operator viewing patient through leaded window of leaded protective barrier.





operator should stand at least 6 feet away from the patient and in a safe quadrant at an angle between 90 and 135° to the primary beam) (Fig. 13-14).

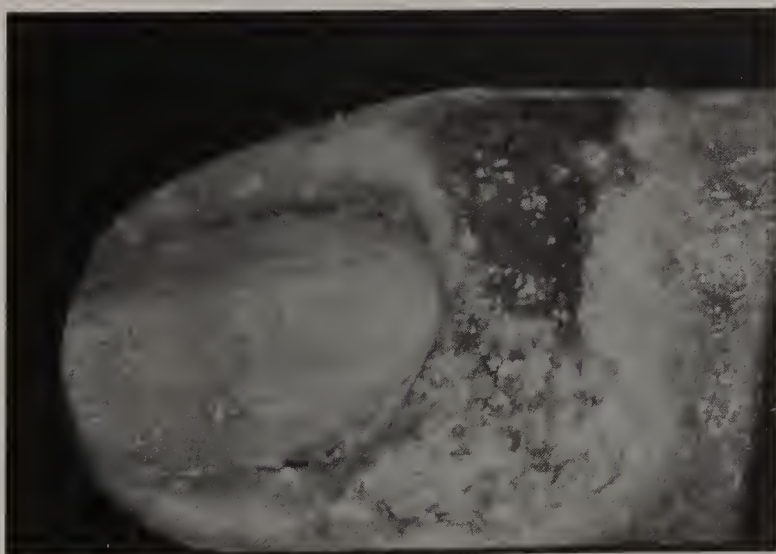
If the operator cannot stand at least 6 feet from the patient during the exposure, he or she should stand behind an appropriate protective barrier or outside the operatory behind a wall (Fig. 13-15). Dental personnel should not hold films in the patient's mouth. Squamous cell carcinoma of the fingers can be caused by this practice (Fig. 13-16). The tubehead or BID should never be held or stabilized during exposure, and the operator should never stand directly in line with the primary beam of radiation (Fig. 13-17). Dentists, dental hygienists, dental assistants, and dental radiology technicians should never stand in the primary beam to restrain a patient during x-ray exposure.



**Figure 13.17 Primary X-Ray Beam.** The operator should never stand unprotected in the direct path of the primary x-ray beam.



A



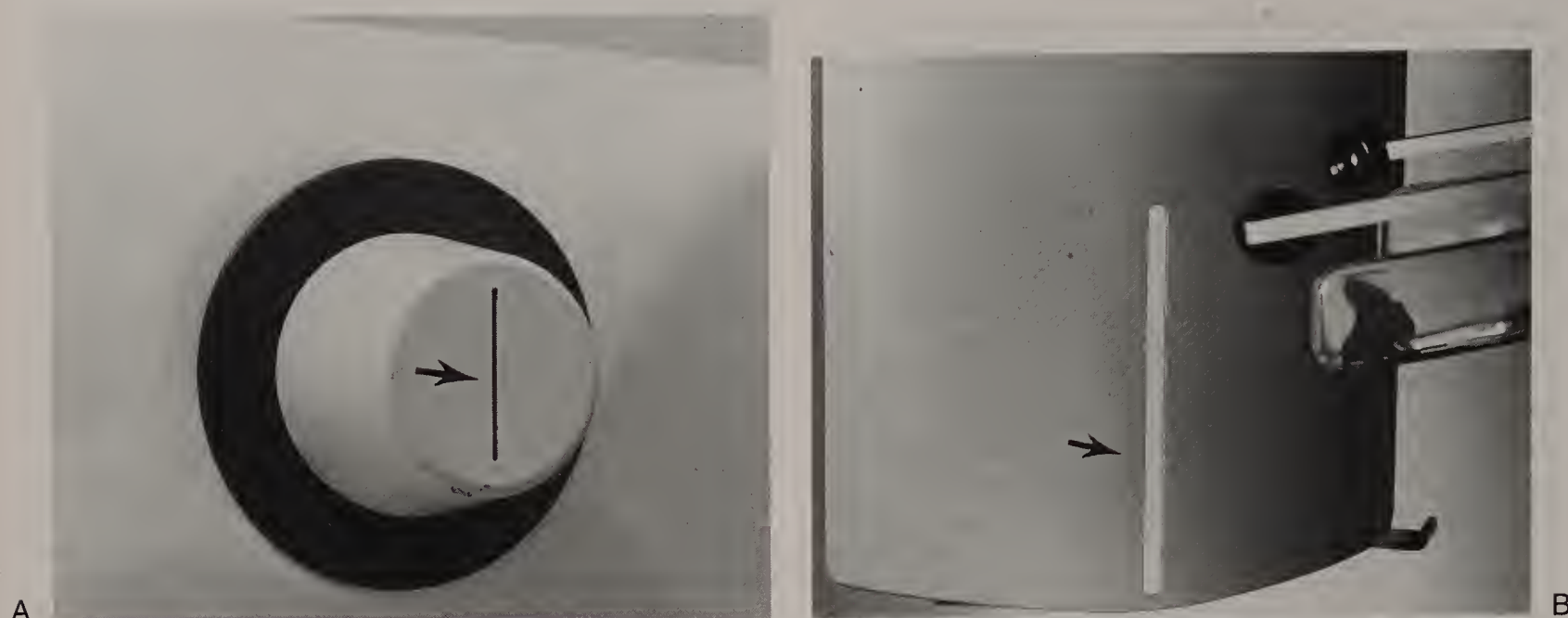
B

**Figure 13.16 Radiation Damage to Operator.** (A) Dystrophic nail changes from radiation. (B) Squamous cell carcinoma of dentist's finger caused by holding films in patient's mouth.

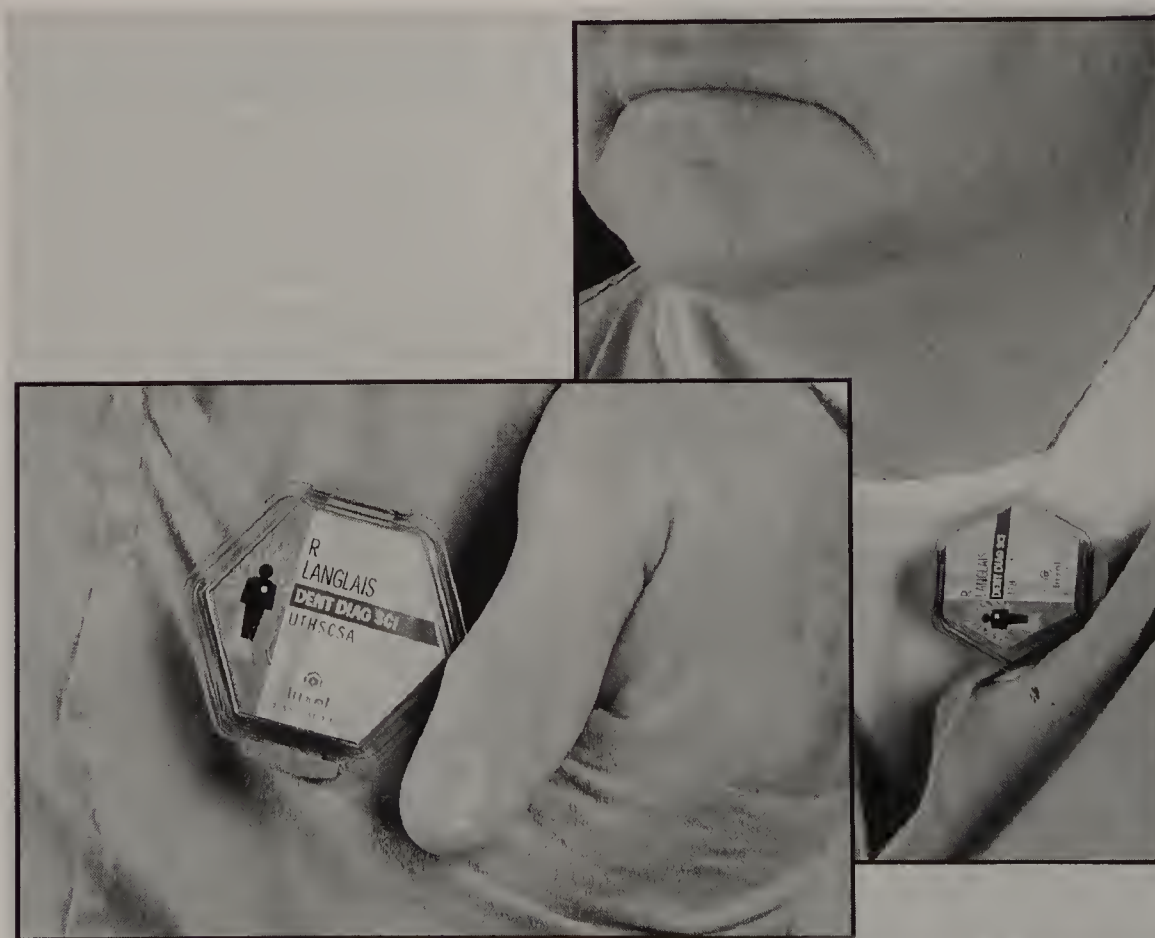
When a patient has to be restrained during exposure, a relative or friend of the patient should do so. The relative or friend should be provided with a leaded apron and gloves so they have maximum protection during exposure. Scattered radiation from panoramic x-ray units is relatively small, owing to the narrow beam of radiation and the narrow shielding collimation at the cassette carrier (Fig. 13-18). Using the MPD guidelines for occupationally exposed persons of 1 mSv per week, an operator could conceivably expose 4000 panoramic radiographs per week with safety if he or she stood 2 meters from the unit (2 meters equals approximately 6 feet). However, to be prudent, the operator should stand behind a barrier if he or she cannot stand 6 feet from the panoramic x-ray machine.

**Shielding.** If the operator must stand closer than 6 feet from the patient and machine, he or she should leave the room or take a position behind suitable wall shielding during exposure of the film. Minimal shielding requirements for dental operatories are provided by the NCRP (NCRP Report 35, 1970). A physicist or radiography inspector can determine how much shielding is needed for a given situation. The walls of the dental x-ray operatory must be of sufficient density or thickness to limit the exposure of nonoccupationally exposed persons (for instance, persons working in an adjacent office) to legally acceptable levels. Usually, it is not necessary to line the walls with lead to meet this requirement. A wall constructed of gypsum wallboard (drywall) has been determined to be sufficient for the average dental office (MacDonald et al., 1983).

**Radiation Dosimetry Monitoring Service.** Subscribing to one of the many film badge services provides an excellent tangible way to express concern for reducing and monitoring radiation exposure to office staff (Fig. 13-19). Quarterly reports (monthly or semiannually are also available) from a film badge service provide appropriate



**Figure 13.18 Panoramic X-Ray Collimation.** The scattered radiation from panoramic x-ray machine is relatively small due to (A) the narrow beam of radiation from the tubehead, and (B) the narrow shielding collimation at the cassette carrier.



**Figure 13.19 Radiation Dosimetry Monitoring Service.** Personal monitoring badge. The film badge contains a lithium fluoride crystal. When returned to the company, the badge is processed and compared optically with known amounts of radiation. The resulting exposure is reported to the dental office. The dosimetry badge is usually worn on the clothing over the front of the hip, chest, or neck as shown here.



legal documentation that staff members have or have not received excessive radiation exposure during their employment in the office. These reports also serve as a direct way of monitoring the staff's willingness to abide by office safety rules regarding radiation exposure procedures. An additional advantage to monitoring office personnel is that a series of radiation reports indicating little or no exposure serves to allay any apprehension the office staff may have about receiving potentially damaging exposure to x-radiation. If the doses are high, it alerts the staff to look for improper procedures followed in the office or for problems in barrier design. It also provides a written record of staff exposures in the unlikely but possible event that one of the staff members develops cancer and blames it on the office x-ray procedures.

### CASE-BASED PROBLEM-SOLVING

1. You have a pregnant patient who is concerned about getting dental x-rays. Outline the available protective measures for this patient. What is your final recommendation?
2. You have an employee who takes dental radiographs and is fearful that small daily doses of exposure could lead to cancer or a deformed fetus. Outline the protective measures available to allay this employee's fears.

### REVIEW QUESTIONS

1. Greater beam limitation is achieved when the BID is \_\_\_\_\_ and the diameter of the opening is \_\_\_\_\_:
  - A. Shorter, smaller.
  - B. Longer, bigger.
  - C. Shorter, bigger.
  - D. Longer, smaller.
2. Which type of radiation is produced when the primary beam of x-ray photons interact with the pointed plastic cone?
  - A. Primary radiation.
  - B. Scattered radiation.
  - C. Characteristic radiation.
  - D. Remnant radiation.
3. Which of the following procedures will reduce your x-ray exposure as an x-ray operator?
  - A. Standing at least 6 feet away from the tubehead when making an exposure.
  - B. Standing behind an appropriate barrier or outside the x-ray room.
  - C. Never holding or stabilizing the tubehead during exposures.
  - D. All of the above.
4. Collimation of a beam refers to:
  - A. The selective removal of soft radiation from the beam.
  - B. The selective removal of hard radiation from the beam.
  - C. The reduction of the beam diameter.
  - D. The process of reducing the beam intensity by 50%.
5. Filtration is used in dental x-ray machines to remove:
  - A. Scatter radiation.
  - B. High-energy photons.
  - C. Long-wavelength photons.
  - D. Low-energy electrons.
6. All of the following are good ways to reduce exposure except:
  - A. Using fast film; E speed is the fastest.
  - B. Using an 8-inch BID.
  - C. Using the paralleling technique.
  - D. Using higher kilovoltage settings.
7. Depending on the circumstances, when films are to be held in the mouth of a child, the dental radiographer should:
  1. Hold them himself/herself.
  2. Ask the assistant to hold the film.
  3. Ask a parent or guardian to hold the film.
  4. Use film-holders.
  - A. 1 and 4.
  - B. 2 and 3.
  - C. 2 and 4.
  - D. 3 and 4.
8. A dental health-care worker is using a film badge service to measure his or her radiation exposure. The service reports that the badge was exposed to 5 mSv in the previous month. The worker should:
  - A. Stop taking x-ray films immediately.
  - B. Report to a physician for a blood count.
  - C. Ignore the report because the reading is insignificant.
  - D. Evaluate x-ray procedures and take steps to reduce unnecessary radiation.

9. During pregnancy, a patient:
  - A. Should be advised of her legal rights before being irradiated.
  - B. Should be warned about possible miscarriage.
  - C. Should never be irradiated for dental radiographs.
  - D. May be irradiated for dental radiographs by taking the necessary precautions.
10. As a radiation worker, you should not be exposed to more than an effective dose of 50 mSv a year. But in x-raying yourself for dental treatment, you are exposed to about 50 mSv. Which of the following reconciles these contradictory statements?
  - A. Because you need dental radiographs, you can be given an unlimited amount of radiation.
  - B. As a patient you can be given any amount of radiation, regardless of damage.
  - C. Exceptions can be made.
  - D. Whole-body radiation is different from specific-region radiation.
11. The dental health-care worker should not hold the:
  - A. Film during exposure.
  - B. Tube during exposure.
  - C. Patient during exposure.
  - D. All of the above.
12. Some of the most effective means of controlling secondary radiation are:
  1. Lead lined BID.
  2. Increasing kVp.
  3. Using filters.
  4. Decreasing film speed.
  - A. 1 and 3.
  - B. 2 and 3.
  - C. 1, 2, and 3.
  - D. 2, 3, and 4.
13. X-ray filters are usually made of:
  - A. Copper.
  - B. Lead.
  - C. Aluminum.
  - D. Stainless steel.
14. Collimators are usually made of:
  - A. Copper.
  - B. Lead.
  - C. Aluminum.
  - D. Stainless steel.
15. A film badge:
  1. Is affected by ionizing radiation.

2. Is affected by other forms of radiant energy such as heat.
  3. Should be worn by all occupationally exposed persons.
  4. Is used to identify x-ray films.
- A. 2 and 4.
  - B. 1 and 3.
  - C. 1, 2, and 3.
  - D. 1, 3, and 4.

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# Radiologic Imaging Interpretation

- CHAPTER 14: Normal Intraoral Radiographic Anatomy
- CHAPTER 15: Radiologic Diagnosis of Periodontal Disease
- CHAPTER 16: Abnormalities of Teeth
- CHAPTER 17: Radiologic Diagnosis of Caries
- CHAPTER 18: Radiologic Diagnosis of Periapical Disease





# Normal Intraoral Radiographic Anatomy

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Recognize the anatomical features of the teeth and periodontium.
2. Recognize the anatomical features of the maxilla in radiographs.
3. Recognize the anatomical features of the mandible in radiographs.
4. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

|                              |                         |                         |                                   |
|------------------------------|-------------------------|-------------------------|-----------------------------------|
| alveolar bone                | external oblique ridge  | malar bone              | nasopalatine (incisive)           |
| antrum                       | genial tubercles        | mandibular canal        | foramen                           |
| canals of Scarpa             | hamular process         | mandibular foramen      | periodontal ligament space (PDLs) |
| canals of Stensen            | incisive canal          | maxillary sinus         | pulp                              |
| computed tomography (CT)     | incisive foramen        | maxillary tuberosity    | radiolucent                       |
| coronoid process             | incisive fossae         | median maxillary suture | radiopaque                        |
| dentin                       | inferior alveolar canal | mental foramen          | zygomatic arch                    |
| dentinoenamel junction (DEJ) | inverted-Y              | mental ridge            | zygomatic bone                    |
| enamel                       | lamina dura             | mylohyoid line or ridge | zygomaticomaxillary suture        |
|                              | lateral fossa           | nasal fossa             |                                   |
|                              | lingual foramen         |                         |                                   |

## TEETH AND SUPPORTING STRUCTURES

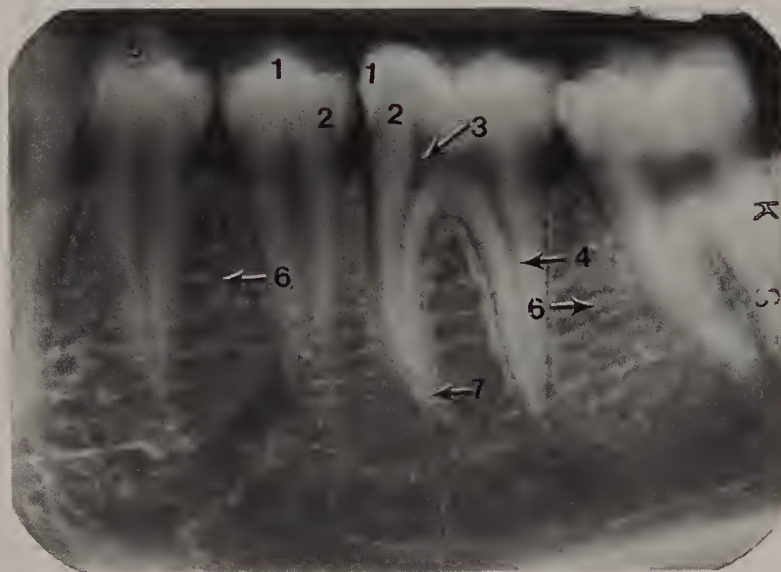
### INTRODUCTION

Radiologically, the thicker, more mineralized, or denser a tissue, the more radiopaque it will appear in the image; less dense, thinner, or demineralized tissue appears less dense or radiolucent in the image. Strictly speaking, the terms **radiolucent** (dark/black) and **radiopaque** (light/white) are used in plain or ordinary radiographic images, such as intraoral, panoramic, and extraoral radiographs. In plain film radiography, the images are usually referred to as radiographs. When x-ray images are ob-

tained by **computed tomography (CT)**, they are referred to as images or scans. Structures and diseases, as viewed in CT images, are referred to as areas of increased density (radiopaque) or decreased density (radiolucent). The exact density can be measured by the computer in Hounsfield units, and this measurement is referred to as the CT number. Today, CT and advanced imaging terminology has trickled down into everyday usage in dental imaging.

### ENAMEL (RADIOPAQUE)

Enamel is the most radiopaque (white) of any tissue seen radiologically and covers the coronal portion of the tooth.



**Figure 14.1 Normal Anatomy of Tooth and Supporting Structures.** The enamel and dentin line of demarcation is very sharp. The enamel is whiter than dentin, because enamel is much denser. (1) Enamel, (2) dentin, (3) pulp chamber, (4) pulp canal, (5) buccal cusp, (6) alveolar bone, and (7) root apex.

When a radiograph has been correctly exposed and processed, there is a difference in density between the enamel and the underlying dentin (Fig. 14-1). The line of demarcation between enamel and dentin is referred to as the **dentinoenamel junction (DEJ)**. The most common disease affecting enamel is caries.

### DENTIN (RADIOPAQUE)

**Dentin** may be seen immediately beneath the enamel in the coronal portion of the tooth and also makes up most of the root structure. In a correctly exposed and processed radiograph, dentin appears less dense or lighter than the underlying pulp but darker than the overlying enamel (Fig. 14-1). The most common disease affecting dentin is caries, which has extended through the enamel of the crown or cementum of the root to the dentin.

### PULP SPACE (RADIOLUCENT)

The **pulp** is contained within the pulp chamber and root canal portions of the tooth. The pulp tissue is not visible radiographically. The spaces that contain the pulp are visible and are the most radiolucent (dark) portions of the tooth (Fig. 14-1). In younger individuals, the pulp spaces tend to be large; they decrease in size with advancing age. The root canal space is also radiolucent and is centered within the root. In normal instances, the root canal space tapers gently toward the apex. The apical foramen is the terminal portion of the root canal space at the apex of the tooth through which the vital elements of the tooth pass (Fig. 14-1). The most common disease affecting the pulp

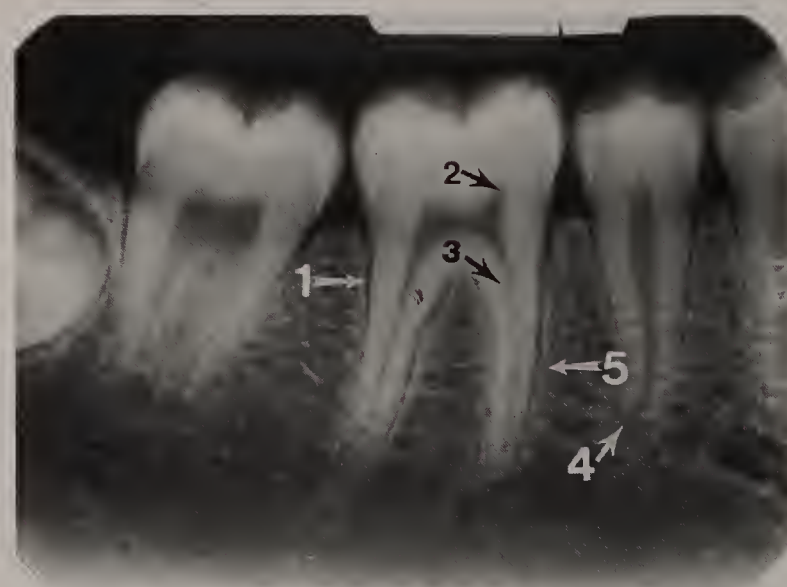
is inflammation due to bacterial infection as a sequela of deep caries, trauma, or advanced periodontal disease.

### LAMINA DURA (RADIOPAQUE)

The **lamina dura** is the thin layer of compact alveolar bone that lines the tooth socket. The lamina dura forms a continuous white (radiopaque) line around the tooth root (Fig. 14-2). In reality, it is perforated by many small openings (cribriform plate) that carry branches of the intra-alveolar nerves and vessels to the periodontal ligament and the cementum of the tooth. A thickened lamina dura at the apical region of a developing tooth is a sign of tooth eruption. Thinning or absence of the lamina dura is seen in pulpal and periodontal disease and in diseases such as fibrous dysplasia, hyperparathyroidism, and Paget's disease.

### PERIODONTAL LIGAMENT SPACE (PDLS) (RADIOLUCENT)

The periodontal ligament is not visible radiographically but is contained within the **periodontal ligament space (PDLS)**. In the radiograph, it is seen as a distinct radiolucent line just outside the root portion of the tooth and inside the lamina dura (Fig. 14-2). The PDLS is wider in younger individuals and narrows with advancing age. The PDLS may become widened due to tooth mobility (Fig. 14-3) or the presence of disease, such as scleroderma, metastatic disease, osteosarcoma, and chondrosarcoma (Fig. 14-4). The PDLS disappears in ankylosis.



**Figure 14.2 Periodontal Ligament Space and Lamina Dura.** The periodontal ligament space is a distinct radiolucent line just outside the root portion of the tooth and inside the lamina dura. (1) Periodontal ligament space, (2) pulp horn, (3) two root canals in mesial root, (4) apex of root, and (5) lamina dura.





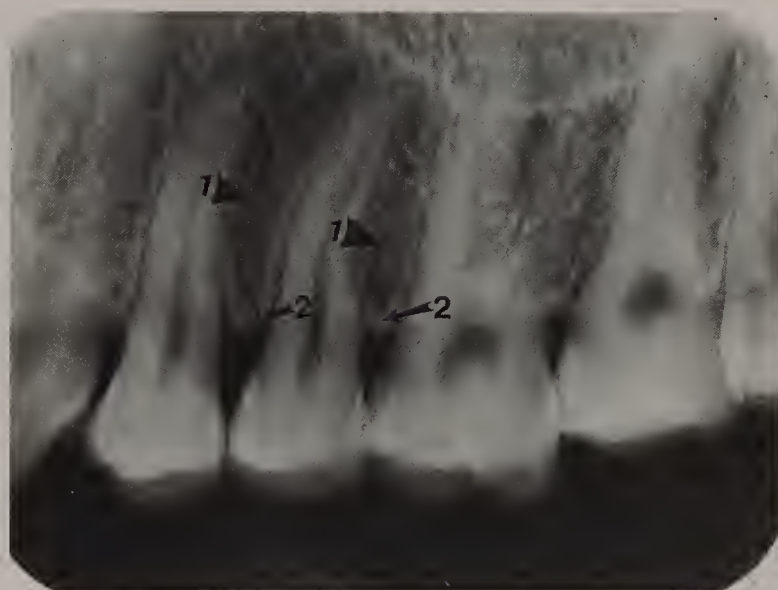
**Figure 14.3 Tooth Mobility from Periodontal Ligament Thickening.** Note thickening of periodontal ligament and lamina dura (arrows) of maxillary incisor being moved posteriorly by orthodontic appliances.

### ALVEOLAR BONE (RADIOPAQUE)

The alveolar bone is made up of the inner and outer cortical plates, the cancellous or spongy alveolar bone proper, and the lamina dura (Fig. 14-5). The cortical bone at the alveolar crest should be intact and may be seen as a thin, white (radiopaque) line. A loss of alveolar bone is commonly seen in periodontal disease (Fig. 14-6). Cortical bone thinning is seen in osteoporosis.



**Figure 14.4 Periodontal Ligament Space Thickening in Chondrosarcoma.** Panoramic radiograph of a patient with chondrosarcoma of mandibular left mandible. Widening of the periodontal ligament space of the mandibular second premolar and the first molar (arrows) are signs of possible osteosarcoma or chondrosarcoma of the jaws, in addition to periodontal disease.



**Figure 14.5 Alveolar Bone.** Radiograph of (1) maxillary premolar region alveolar bone, trabeculae, and narrow spaces as well as (2) alveolar bone crest with thin, white (radiopaque) cortical bone.

## ANATOMICAL STRUCTURES OF THE MAXILLA

### MEDIAN MAXILLARY SUTURE (MEDIAN PALATAL SUTURE) (RADIOLUCENT)

The median maxillary suture lies between the two palatal (palatine) processes of the maxilla. It appears as a dark (radiolucent) line extending in the midline between the maxillary central incisors back to the posterior aspect of the palate (Fig. 14-7). There is sometimes a funnel-shaped widening at the anterior aspect, known as the anterior median maxillary cleft. This is sometimes associated with a di-



**Figure 14.6 Loss of Alveolar Bone in Periodontal Disease.** Panoramic radiograph of a young adult with rapidly progressive periodontitis. (1) Severe alveolar bone loss. (2) Periodontal ligament thickening indicating possibility of tooth mobility. (Patient has generalized advanced horizontal bone loss.)

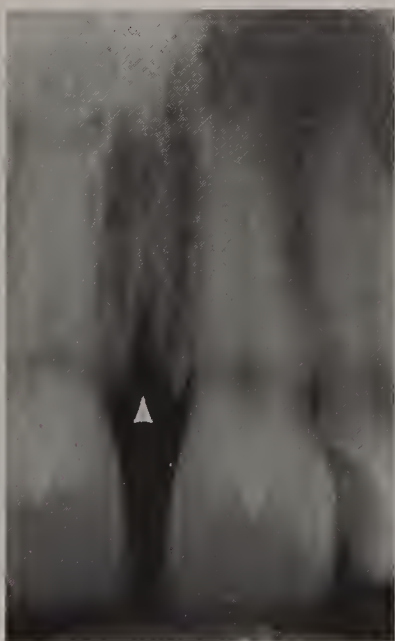


**Figure 14.7 Median Palatal Suture.** Median maxillary suture appears as a dark (radiolucent) line in the midline between the central incisors extending back to posterior aspect of the palate (arrowheads).

astema (space) between the central incisors and represents a variation of normal anatomical structure (Fig. 14-8).

### NASOPALATINE (INCISIVE) FORAMEN (RADIOLUCENT)

The nasopalatine (incisive) foramen is located just posterior to the maxillary central incisors and is formed by the



**Figure 14.8 Anterior Median Maxillary Cleft.** Note funnel-shaped widening of anterior median maxillary cleft (arrowhead). This is sometimes associated with diastema between maxillary central incisors, as shown here.



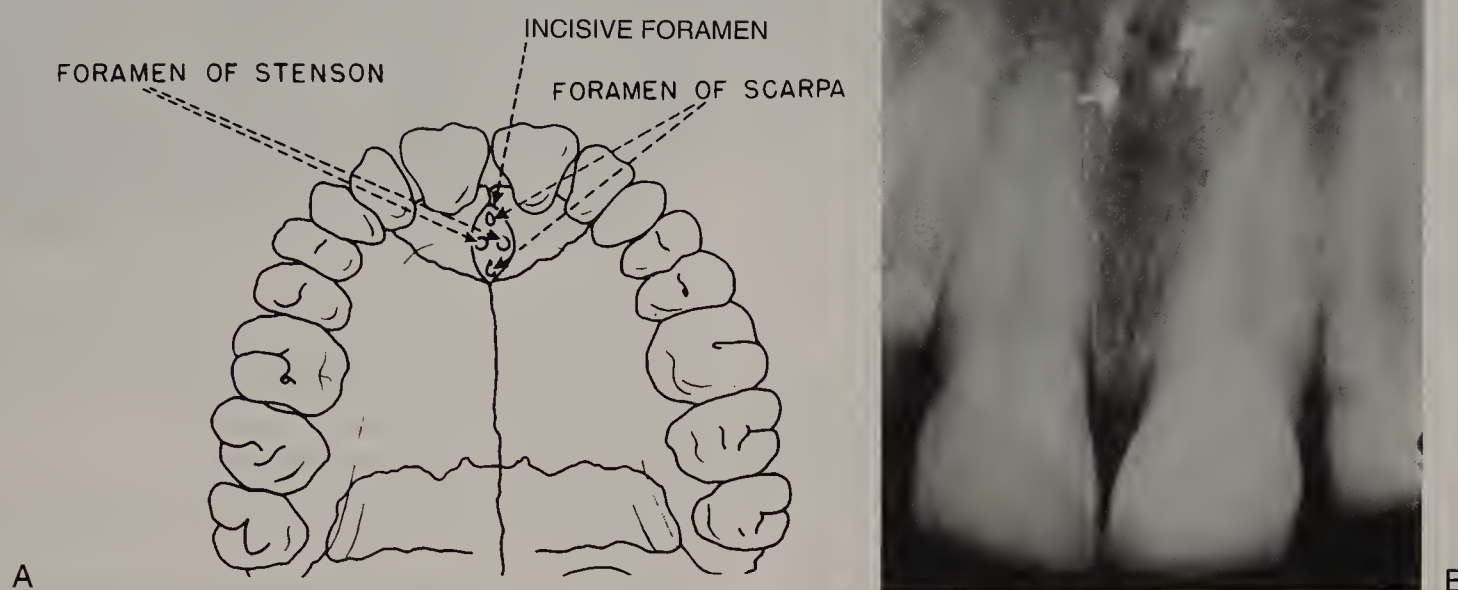
**Figure 14.9 Radiograph of Nasopalatine (Incisive) Foramen.** Nasopalatine (incisive) foramen is the oval radiolucency between the maxillary centrals (arrowheads).

union of the two palatal processes of the maxilla. It may be a symmetrically oval, round, or heart-shaped radiolucency and may be small or large (Fig. 14-9). It rarely has a cortical (white) outline (border). Yet, if a cortical border is present, it usually indicates transformation into a nasopalatine (incisive) cyst. The nasopalatine (incisive) foramen transmits the nasopalatine nerves and vessels. The nasopalatine nerve is a branch of the sphenopalatine ganglion, supplies the nasal roof and septum, and extends downward and forward in a groove in the vomer bone and the cartilaginous septum. On reaching the anterior portion of the floor of the nose, the nasopalatine nerve enters and traverses the canal of Stensen and finally emerges on the hard palate through the nasopalatine (incisive) foramen. There is one canal of Stensen on each side of the nasal septum, and both lateral canals of Stensen terminate at the nasopalatine (incisive) foramen. Sometimes, the two canals of Stensen further subdivide into the four canals of Stensen and Scarpa. When the additional two smaller canals of Scarpa are found, they are seen in the midline—one in front of the other—and serve as passageways for the nasopalatine nerves (Fig. 14-10).

### NASAL FOSSAE (RADIOLUCENT)

In some cases, particularly when excessive vertical angulation is used, the nasal fossae may be seen in the intraoral radiograph. They are divided by the nasal septum (white) in the midline (Fig. 14-11). The nasal fossae, being cavities in bone, appear in radiographs as dark images. They are radiolucent or dark because they contain air, at least in some part. Hazy gray images may be seen arising from the lateral walls of both fossae and may extend almost to the septum; these represent the anterior





**Figure 14.10 Foramina of Scarpa and Stensen.** (A) The incisive foramen, just behind the upper central incisors, is formed by the union of halves of the maxilla. Lateral canals within this fossa, on each side of the midline (foramina of Stensen), transmit the nasopalatine nerves and the terminal branch of the descending palatine artery. In some individuals, additional canals within the fossa (canals of Scarpa) are found in the midline. When present, these also serve as passages for the nasopalatine nerves. (B) Radiograph revealing four small radiolucent holes (arrows) representing the foramina of Stensen and Scarpa.

portions of the **inferior turbinate**, the soft tissue of which covers the thin leaf-like **nasal conchae** bones.

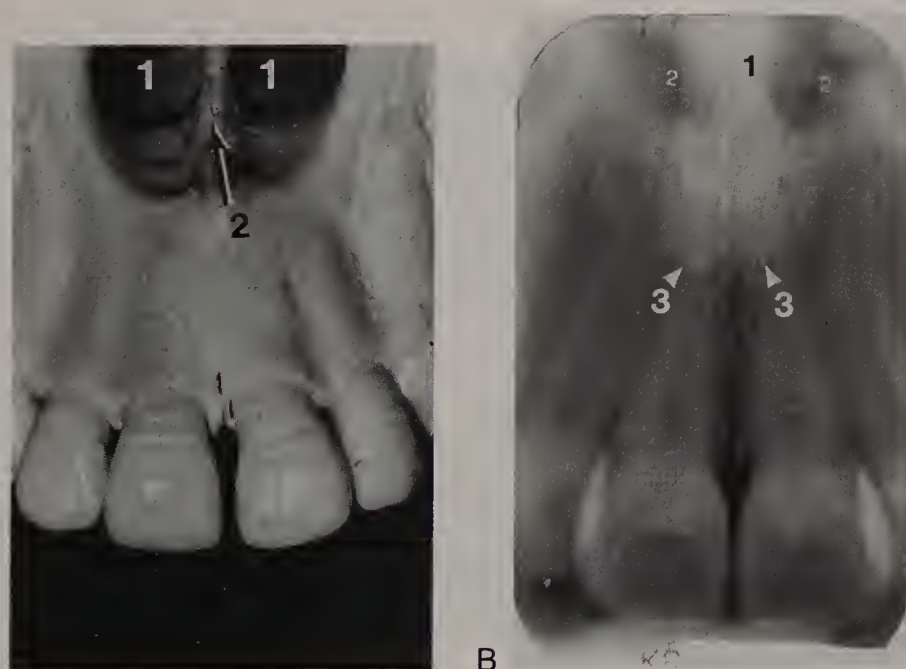
#### MAXILLARY AND MANDIBULAR (INCISIVE) LATERAL FOSSAE (RADIOLUCENT)

Incisive fossae represent depressions in the outer surface of the alveolar bone between the maxillary lateral incisor and canine teeth and between the mandibular canines.

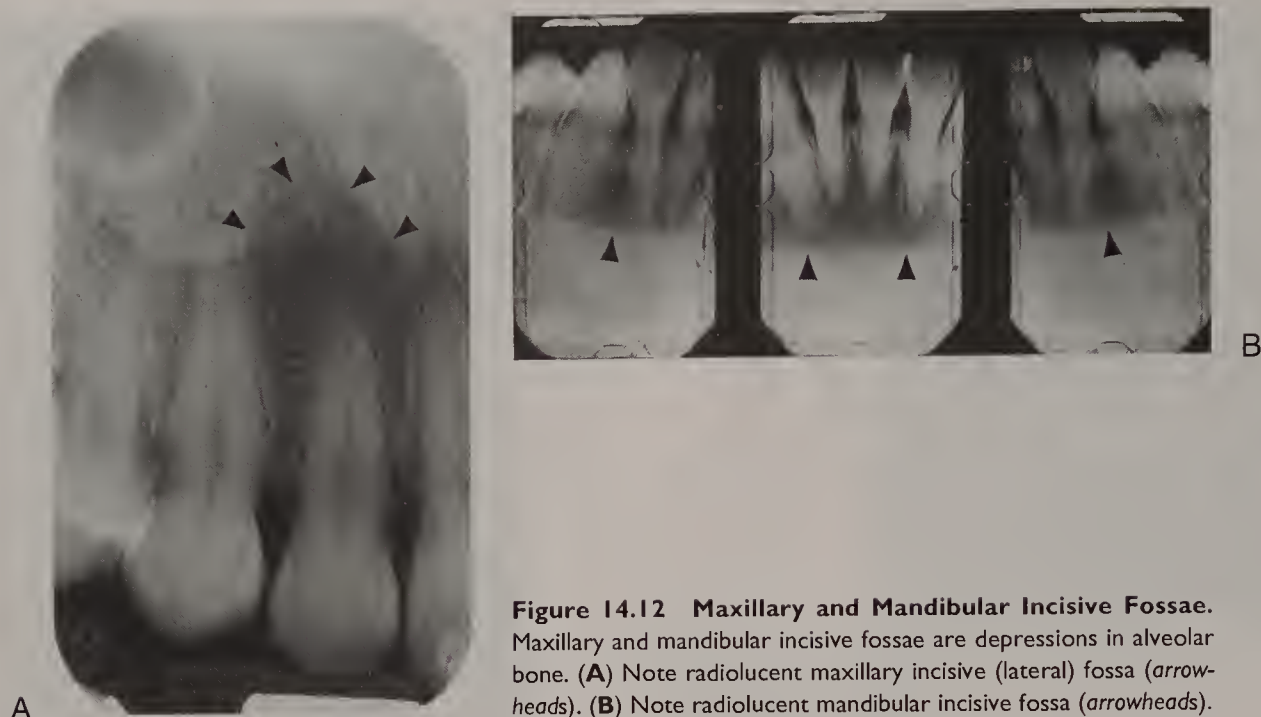
The **lateral fossa (incisive)** produces a relatively more radiolucent (dark) area in the alveolar bone (Fig. 14-12). This radiolucency or darkness in the bone may sometimes give the impression that there is disease in the bone.

#### LATERAL-CANINE AREA (RADIOPAQUE)

The **inverted-Y** is an important anatomical landmark. It is especially useful in locating the maxillary canine area in



**Figure 14.11 Nasal Fossae.** (A) Skull: (1) nasal fossae and (2) nasal septum. (B) Radiograph of nasal fossae: (1) nasal septum, (2) nasal fossa, and (3) tip of nose.



**Figure 14.12 Maxillary and Mandibular Incisive Fossae.** Maxillary and mandibular incisive fossae are depressions in alveolar bone. (A) Note radiolucent maxillary incisive (lateral) fossa (arrowheads). (B) Note radiolucent mandibular incisive fossa (arrowheads).

edentulous surveys. It is formed by the cortical lining of the anterior wall of the maxillary sinus and the floor of the nasal fossa (Fig. 14-13). The Y-shaped landmark is valuable in identifying and differentiating cysts in this region, because this anatomical landmark tends to be altered or obliterated by adjacent pathology. The most common cyst found in this region is the globulomaxillary cyst.



**Figure 14.13 Maxillary Lateral Canine Region.** Radiograph of the maxillary lateral canine region that illustrates the inverted-Y formed by the (2) floor of the nasal fossa and (1) the anterior wall of the maxillary sinus.

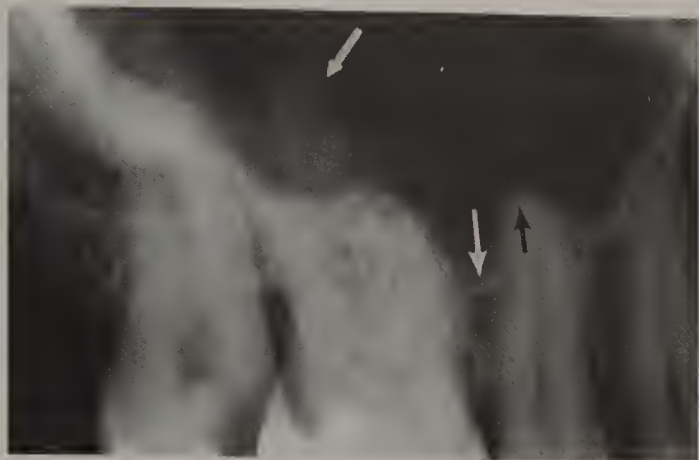
### MAXILLARY SINUS (MAXILLARY ANTRUM) (RADIOLUCENT)

The **maxillary sinus** is one of the paranasal sinuses, and only the maxillary sinus is referred to as the antrum. The **antrum** is an air-filled cavity that communicates with the nasal fossa via the maxillary sinus ostium, an opening (orifice) that is not visible in the periapical radiograph. The lower half of the maxillary sinus is revealed on the radiograph as a dark shadow. The margin of the cavity is a thin layer of dense bone (the cortex) that appears as a white line (Fig. 14-14). This line tends to be irregular, much like a pencil-line on an artist's sketch that has a rough surface texture. Although it may not always look like it on the radiograph, there is usually a lamina dura surrounding root



**Figure 14.14 Maxillary Sinus (Antrum).** The floor of the maxillary sinus is revealed as a thin, white line (arrows).





**Figure 14.15 Radiographic Appearance of Maxillary Sinus Molar Roots.** The maxillary sinus sometimes extends down between the roots of the posterior teeth and may give the appearance that one or more roots are protruding into the sinus (antrum) (black and white arrows).

apices immediately adjacent to the antral (sinus) floor except in disease. The antrum proper (cavity or sinus) sometimes extends down between the roots of the maxillary posterior teeth, especially the lingual (palatal) and buccal roots of the maxillary first molars, which may give the appearance that one or more roots protrude into the antrum (sinus) (Fig. 14-15). This downward extension of the max-

illary sinus is known as **pneumatization**. Pneumatization occurs with advancing age, especially when a maxillary molar is extracted prematurely (Fig. 14-16). Pneumatization can be accelerated by chronic sinus disorders such as infection and allergy.

### MAXILLARY TUBEROSITY (RADIOPAQUE)

The alveolar process of the maxilla is arranged in the form of a curve (dental arch curve) that extends to the **maxillary tuberosity**, a rounded elevation on the posterior region of both sides. Tuberosities are important in the retention of dentures (Fig. 14-17).

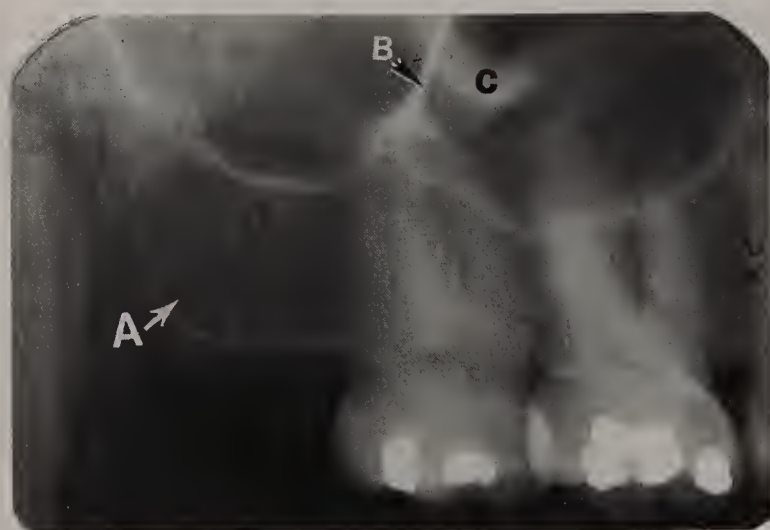
The tuberosities may be completely occupied by the maxillary sinus. When extracting a third molar, such an affected area of the whole body of the tuberosity may be removed with the tooth. The tuberosity may contain pathology, such as odontogenic tumors and cysts.

### ZYGOMATIC (MALAR) BONE AND ZYGOMATIC ARCH (RADIOPAQUE)

The **zygomatic bone** is the small quadrangular (cheek) bone sometimes called the **malar bone** or **zygoma** (Fig. 14-18). The general shape of the inferior border of the malar bone



**Figure 14.16 Pneumatization of Maxillary Sinus.** (A) After the premature removal of maxillary molars, it is not uncommon for the antrum to pneumatize down to the alveolar crest in the premolar/molar areas. (B) Radiograph showing pneumatization of the maxillary first molar area by the antrum into the alveolar bone after removal of the maxillary first molar. The arrow identifies the floor of the maxillary sinus.



**Figure 14.17 Maxillary Tuberosity.** (A) The maxillary tuberosity is a rounded elevation on the posterior region or both sides. (B) Maxillary sinus septum. (C) Zygomatic or malar bone.

on the radiograph roughly resembles the letter “U.” The limbs of the “U” represent the lateral walls of the maxillary sinus where the anterolateral and posterolateral walls meet. The dark area between them represents a recess or extension of the maxillary sinus into the malar (cheek) bone. When this recess or air space is deep into the malar bone, the image is dark; when there is no recess, the area is gray or white. The zygomatic arch is formed by the temporal process of zygomatic bone and the zygomatic process of the temporal bone, with the zygomaticomaxillary suture in between.

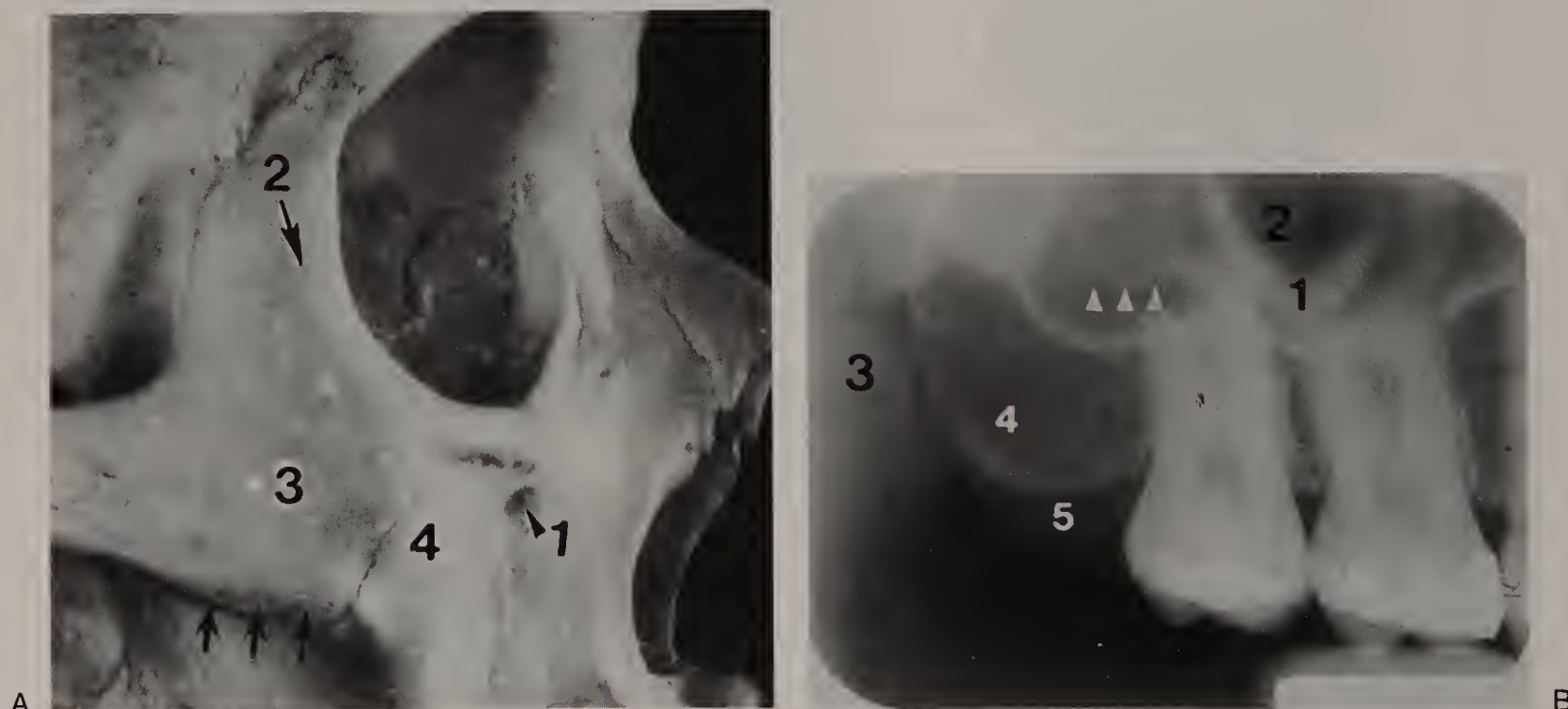
## HAMULAR PROCESS (RADIOPAQUE)

The hamular process is a landmark that consists of a hook-like process arising from the inferior tip of medial pterygoid plate of the sphenoid bone. It is the posterior boundary of the pterygomaxillary notch or fissure, which is an important prosthodontic landmark in the construction of maxillary complete dentures. This hamular process is seen just posterior to the maxillary tuberosity (Fig. 14-19).

## ANATOMICAL STRUCTURES OF THE MANDIBLE

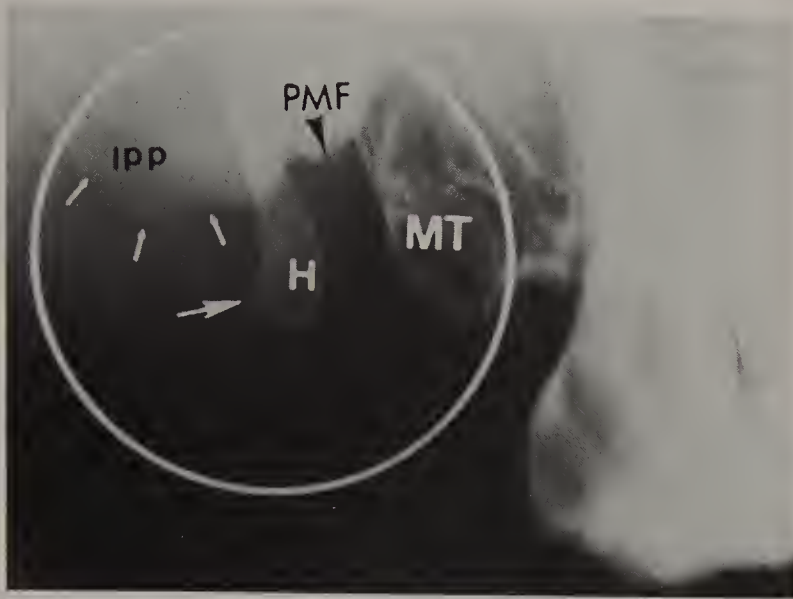
### CORONOID PROCESS OF MANDIBLE (RADIOPAQUE)

This structure is a thin, triangular eminence of the mandible that is flattened lateromedially. It lies medial to the zygomatic arch, and on its medial surface is the insertion of the temporalis muscle. It is the anterior slope of the sigmoid notch of the mandible. The coronoid process is sometimes seen on the maxillary posterior molar periapical radiograph (Fig. 14-20). The coronoid process may become enlarged due to hypertrophy (bilateral) or tumor such as osteochondroma (unilateral); in either case, this causes limited jaw opening.

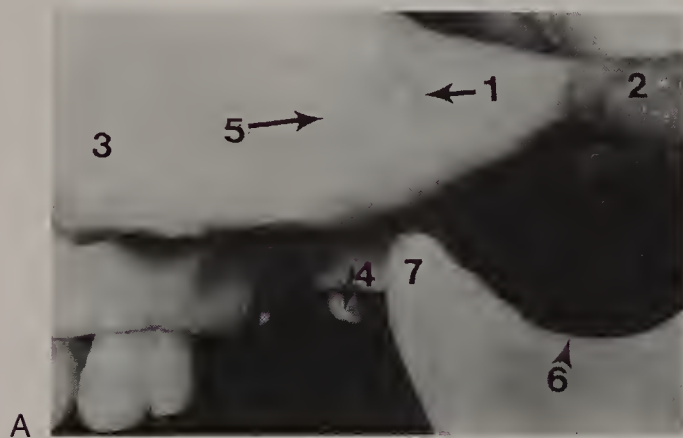


**Figure 14.18 Zygomatic (Malar) Bone.** (A) Anatomical structure of lateral facial side of skull. (1) Infraorbital foramen, (2) frontal process of zygomatic bone, (3) zygomatic or malar bone (arrows indicate lower border of zygomatic bone), and (4) zygomatic process of maxilla. (B) Radiograph of (1) U-shaped zygomatic or malar (lower cortical border) bone with (2) dark radiolucent maxillary sinus above. (3) Coronoid process of mandible, (4) maxillary tuberosity, (5) soft tissue over tuberosity, and (arrows) lower border of zygomatic arch.





**Figure 14.19 Hamular Process of Medial Pterygoid Plate.** Tuberosity of maxilla, and the pterygomaxillary notch or fissure (prosthodontic landmark). Radiograph of hamular process (H), pterygomaxillary fissure (PMF), maxillary tuberosity (MT), and lateral pterygoid plate (lpp).



A

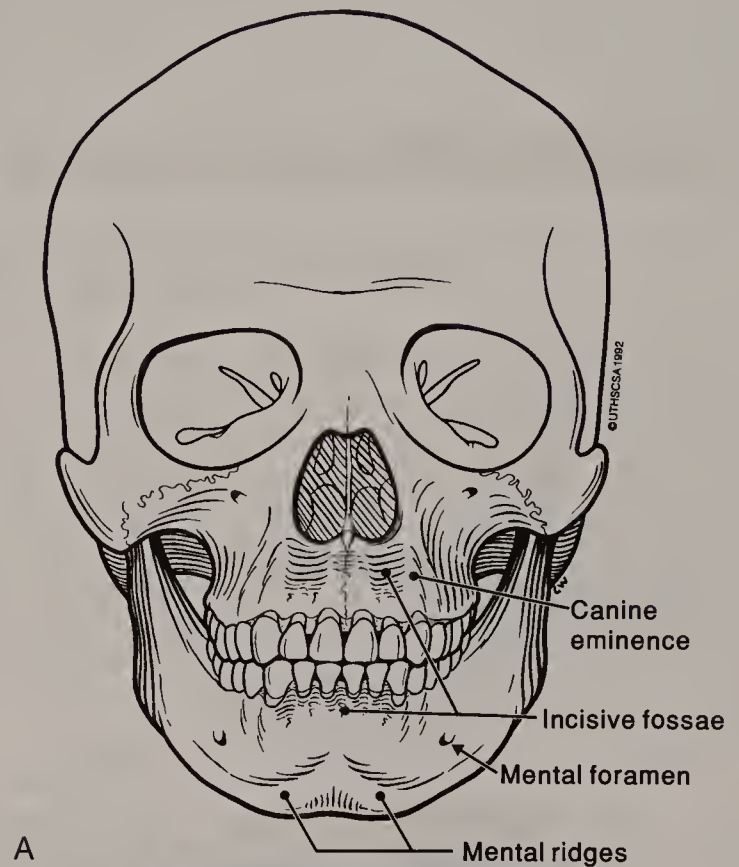


B

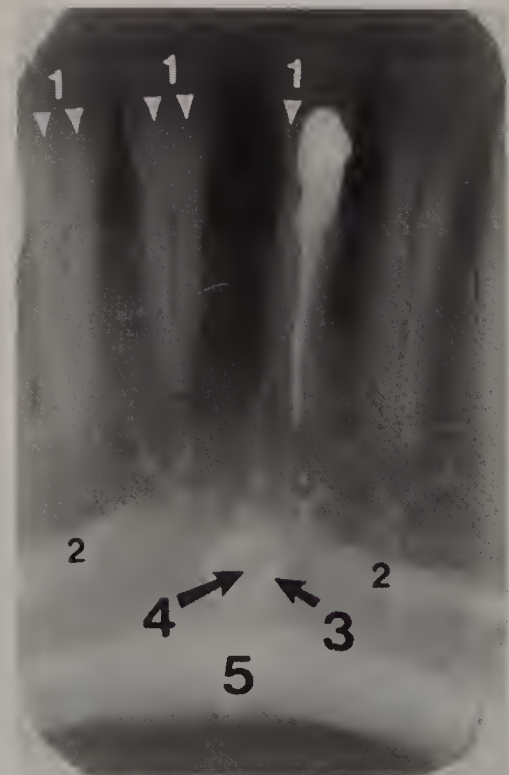
**Figure 14.20 Coronoid Process of Mandible.** (A) Anatomical structures of the skull in the posterior maxillary region. (1) Zygomaticotemporal suture, (2) zygomatic process of temporal bone, (3) zygomatic bone (malar) bone, (4) hamular process of medial pterygoid plate of sphenoid, (5) temporal process of zygomatic bone, (6) sigmoid or mandibular notch of mandible, and (7) coronoid process of mandible. Note: 5 and 2 form zygomatic arch. (B) Radiograph of (7) coronoid process of mandible. (1) Zygomaticotemporal suture, (2) zygomatic arch, (3) zygomatic or malar bone, (4) hamular process of medial pterygoid plate of sphenoid bone, (5) temporal process of zygomatic bone, (6) sigmoid notch of mandible, (8) lateral pterygoid plate, (9) maxillary tuberosity, and (10) pterygomaxillary fissure.

## MENTAL RIDGES OR TUBERCLES (RADIOPAQUE)

The mental protuberance is a triangular eminence of denser bone on the inferior, anterior aspect of the mandible. The raised portions of the mental protuberance on either side of the midline form the mental ridges or tubercles (Fig. 14-21).



A



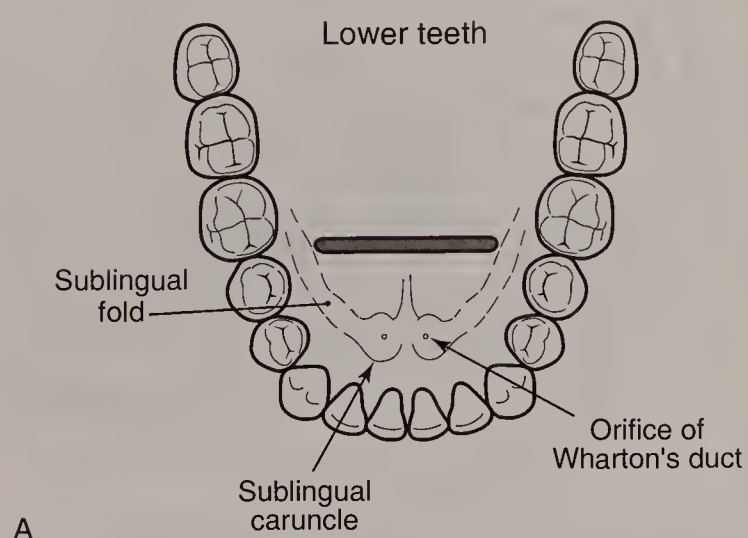
B

**Figure 14.21 Mental Ridges (Tubercles).** (A) Outer surface of mandible showing mental ridges (tubercles), mental foramen, incisive fossae, and canine eminence. (B) Radiograph showing (2) mental ridges (1) and lip line. Note (3) genial tubercles, (4) lingual foramen, and (5) lower cortex of mandible.

## SUBLINGUAL SOFT TISSUES (RADIOPAQUE)

Sublingual soft tissues are occasionally visualized as radiopacities superimposed on or below the roots of mandibular anterior and premolar teeth (Weidman and Warman, 1999). Examples of these images are seen in Figure 14-22. These soft tissue radiopacities are caused by

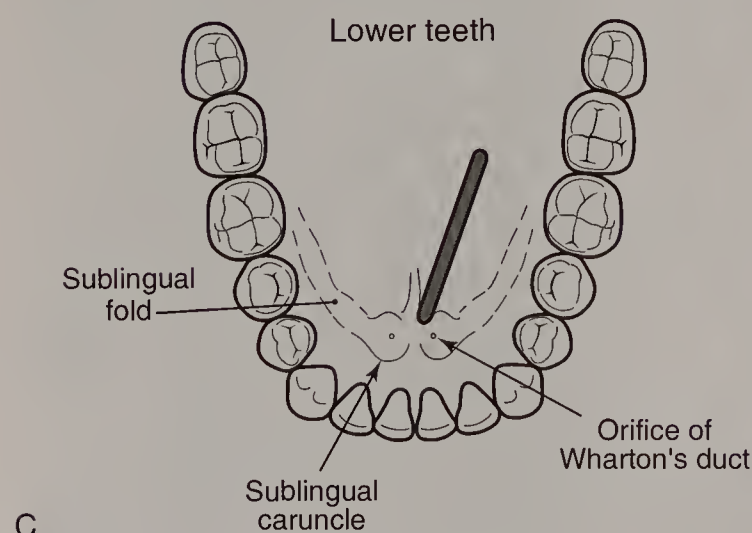
the superimposition of sublingual folds of tissue and its underlying structures in the floor of the mouth. The sublingual folds of tissue are bilateral elevations of mucosa in the floor of the mouth, located between the tongue and the mucosa of the mandible. These sublingual tissue radiopacities must be differentiated from other anatomic structures, such as the mylohyoid ridges, mental ridges, mandibular tori, and the tongue.



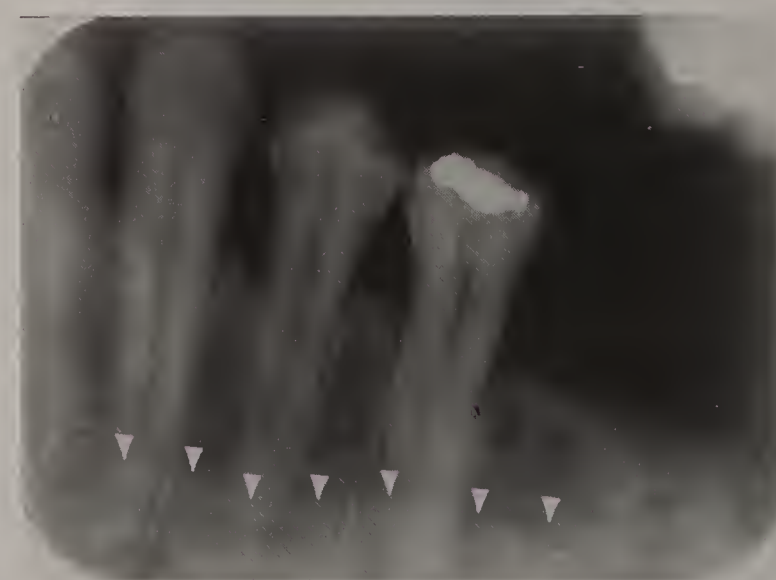
A



B



C



D

**Figure 14.22 Sublingual Soft Tissue Radiopacities.** (A) Film packet placed behind salivary caruncles into the sublingual soft tissue folds. The downward pressure of the film packet on the tissue of the floor of the mouth causes the sublingual soft tissue folds to bulge up in front of the film packet and increases the radiopacity of superimposed sublingual soft tissue. (B) Sublingual soft tissue radiopacity below apices of anterior teeth (*arrowheads*). (C) Film packet placed medially to sublingual fold and salivary caruncle. The bulk mass of the sublingual gland affects the radiopacity of the radiographic image in the premolar area. (D) Radiopacity of superimposed sublingual soft tissue superimposed across the mandibular premolars. The film packet could not be not pressed down far enough, causing the apex of the second premolar to be "cut off." (Courtesy of Drs. Burton Weidman and Earl Warman, University of Medicine and Dentistry of New Jersey, New Jersey Dental School.)





**Figure 14.23 Mental Foramen.** Radiograph of mental foramen (arrows).

### MENTAL FORAMEN (RADIOLUCENT)

The mental foramen conducts the mental vessels and nerves; a circular radiolucent area is seen below the premolar teeth on either side, midway between the upper and lower border of the body of the mandible (Figs. 14-21A and 14-23). The location varies from the distal of the canine to the second premolar area. It may be located at the apex of either premolar and may resemble periapical pathology of pulpal origin or cementoma.

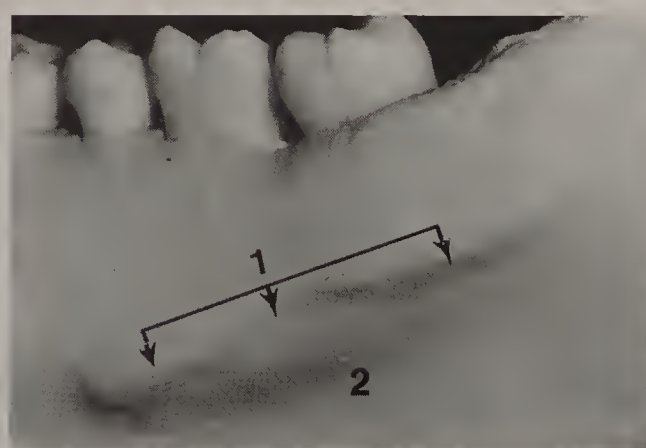
### EXTERNAL OBLIQUE RIDGE (RADIOPAQUE)

The external oblique line ridge is located on the buccal side of the mandible and may be followed in an obliquely upward direction from the mental tubercle to the anterior border of the ramus. It is seen as a radiopaque (white) line of varied width and density that passes across the molar region. The triangularis and inferior labial quadratus muscles are attached to anterior portion of the line ridge. The external oblique ridge serves as a mark of division between the reticular (net-like) alveolar bone above and the denser mandibular bone below (Fig. 14-24A, C).

### MYLOHYOID LINE OR RIDGE (RADIOPAQUE)

The mylohyoid line or ridge is located on the lingual aspect of the mandible and is sometimes referred to as the

ment for the mylohyoid muscle of the floor of the mouth and extends from the molar region to the premolar area. Radiographically, the mylohyoid ridge is a radiopaque (white) line, often seen below the apices of the molar teeth and the external oblique ridge (Fig. 14-24B, C).



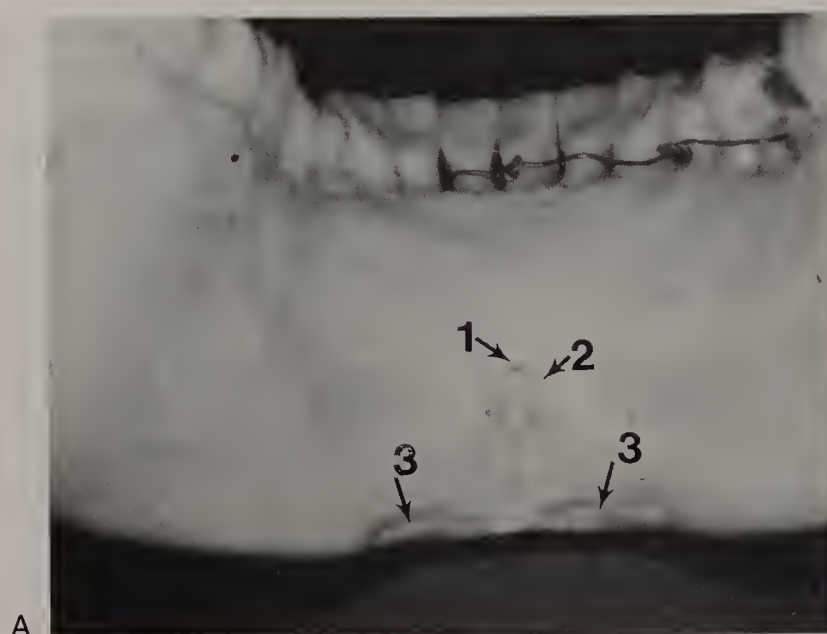
B



C

**Figure 14.24 External Oblique Ridge and Mylohyoid Ridge.** (A) External surface of mandible showing (2) mental foramen, (3) ex-

showing (1) mylohyoid ridge and (2) submandibular gland fossa. (C) Radiograph of posterior mandible. (1) Buccinator crest, (2) external oblique ridge, (3) mylohyoid ridge, and (4) submandibular gland fossa (mandibular canal superimposed).



**Figure 14.25 Genial Tubercles (Mental Spines) and Lingual Foramen.** (A) (1) Inner surface of anterior mandible lingual foramen, (2) genial tubercles, and (3) digastric fossae. (B) The doughnut-shaped radiopacity (arrow) is the genial tubercles, and the radiolucent center is the lingual foramen that transmits a small lingual nutrient vessel.

### GENIAL TUBERCLES OR MENTAL SPINES AND LINGUAL FORAMEN (RADIOPAQUE/RADIOLUCENT)

The **genial tubercles** are located on the inner surface of the body of the mandible in the midline. These tubercles are the points of insertion of the genioglossus and geniohyoid muscles bilaterally to the upper and lower genial tubercles, respectively. On the periapical radiograph, the genial tubercles appear as roundish, localized areas of increased density (radiopaque) with a small, dark (radiolucent) round spot in the middle representing the small radiolucent **lingual foramen** for the passage of a small lingual nutrient vessel (Fig. 14-25).

### MANDIBULAR CANAL OR INFERIOR ALVEOLAR CANAL (RADIOLUCENT)

The **mandibular canal** or **inferior alveolar canal** starts at the **mandibular foramen** on the inner aspect of the ramus and passes in a downward and forward direction through the mandible. As it passes forward, it also moves from the lingual side of the body of the mandible in the third molar area to the buccal side in the premolar region. It appears as a narrow, dark (radiolucent) ribbon between two white (radiopaque) lines representing the canal walls (Fig. 14-26). In the region of the mental foramen, the mandibular nerve bifurcates into its terminal branches known as the incisive and mental nerves. The smaller **incisive canal** can sometimes be

seen on some radiographs and runs anteriorly from the mental foramen area. The exact location of the mandibular canal is important in the placement of implants, the removal of third molars, and the implementation of planned surgical procedures. Interruptions in the wall(s) of the canal or displacement of the canal indicate a close relationship to pathology. The canal may also be widened due to the presence of vascular or neural pathology within.

### FOREIGN MATERIALS OVERVIEW

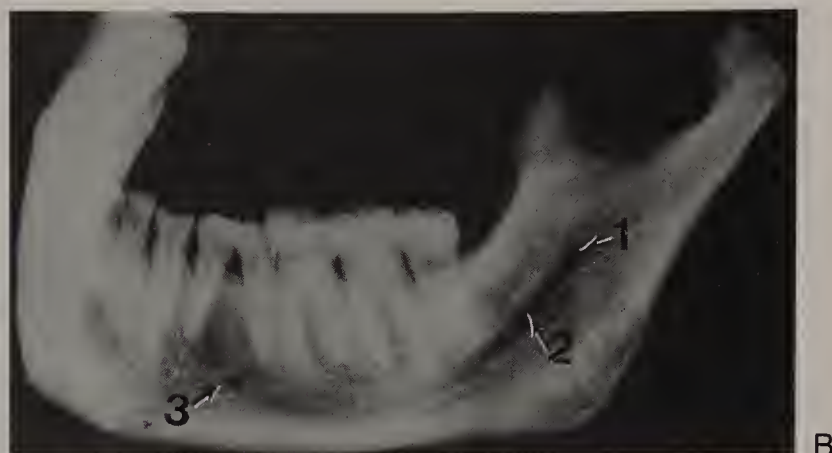
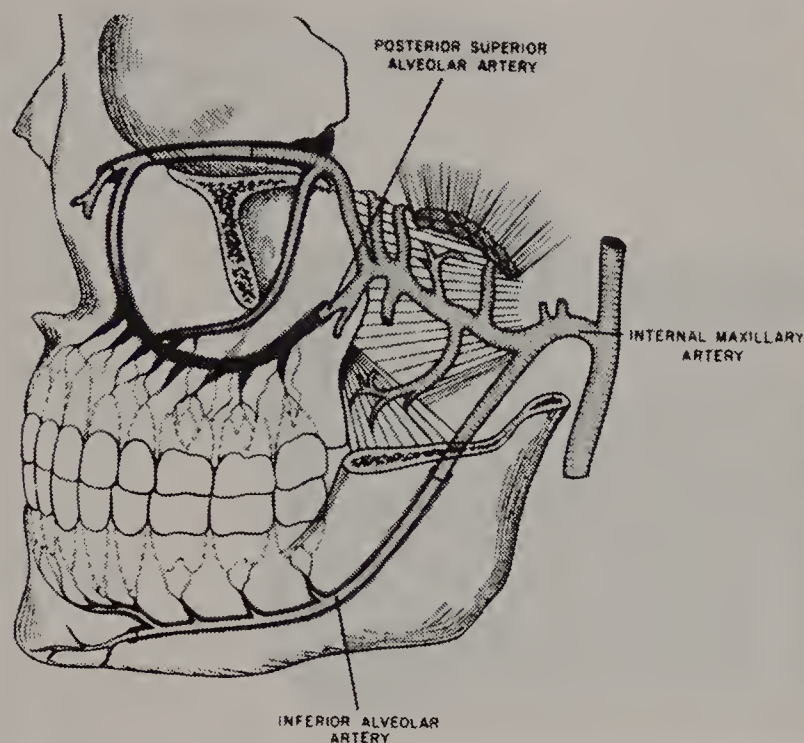
The recognition of foreign materials in dental radiographs is usually self-evident. The foreign material may be within an air space, soft tissue, bone, or tooth. Foreign materials usually represent a permanent record of something that has been done to the patient therapeutically, iatrogenically (introduced by treatment), or as a result of accident or voluntary procedure.

Probably the most important reason for the recognition of a foreign material is to observe signs of the patient's reaction or nonreaction to the foreign substance. Occasionally, older radiolucent dental materials no longer in use may be seen in older patients, and their appearances must also be recognized.

### Endodontic Materials (Fig. 14-27)

During the endodontic procedure, the temporary presence of broaches, files, rubber dam clamp, and frame as well as film-holding devices are noted. Endodontic restorative

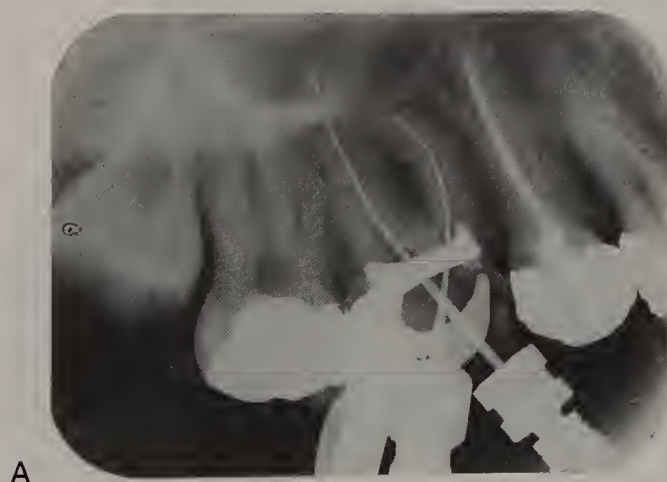




**Figure 14.26 Mandibular (Inferior Alveolar) Canal.** (A) The artery, descends with the mandibular (inferior alveolar) to the mandibular foramen on the medial side of the ramus of the mandible. It runs along the mandibular canal and is accompanied by nerve and veins. It gives off a few branches to the cancellous bone and roots of the teeth. Opposite the second premolar teeth, the nerve and vessels divide into the incisive and mental branches. (B) Radiograph of a dry mandible revealing the (1) mandibular foramen, (2) mandibular canal, and (3) mental foramen. (C) Intraoral radiograph of mandibular molar region revealing mandibular canal (arrowheads).

materials include gutta percha, silver points, and root canal sealer material. Each of these is progressively more radiopaque than the other. Several types of post materials may be seen to fill the cervical portion of the root canal. These posts may be preformed scored metal types, screw types, and cast gold types. The posts are cemented in place

with a radiopaque crown and bridge type cement. Retrograde amalgam may be seen at the apex of an endodontically treated tooth that had previously undergone an apicoectomy. Broken endodontic instruments, such as files, may sometimes remain within the root canal space as part of the permanent filling material of that space.



**Figure 14.27 Endodontic Materials.** (A) Rubber dam clamp, endodontic files, and gutta percha root canal filling. (B) Retrograde amalgam, gutta percha, post and core, and crown restorations (from apex toward crown).



**Figure 14.28 Restorative Materials.** (A) Radiolucent silicate and radiopaque composite. (B) Amalgam restorations, pin in pulp, resulting periapical lesion. (C) Radiopaque cement and temporary acrylic crown, and cast gold anterior restoration. (D) Porcelain crown, radiopaque cement, and gutta percha root canal filling. (E) Temporary aluminum crown. (F) Cast gold crowns.



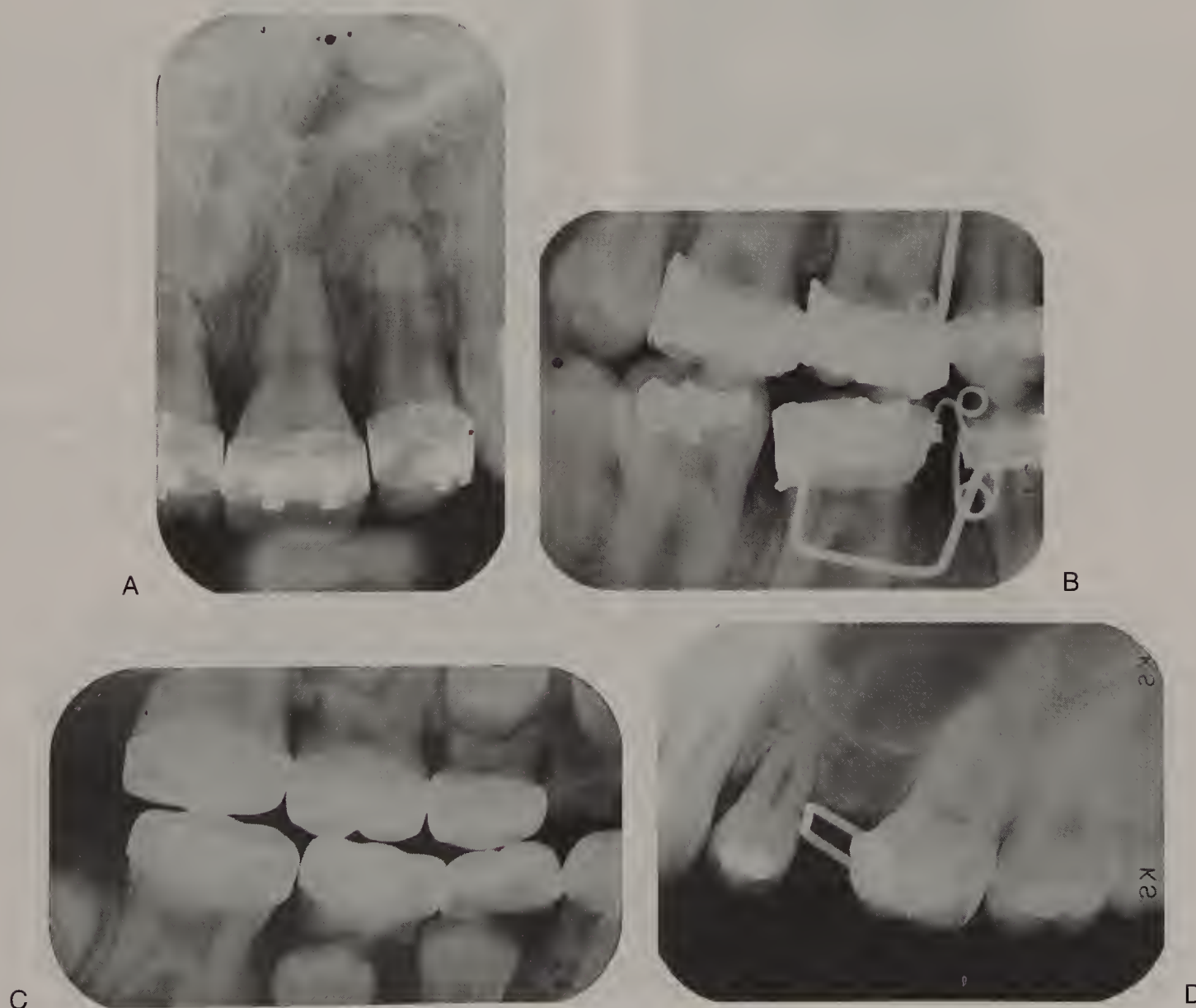
### Restorative Materials (Fig. 14-28)

The most important outcome after the evaluation of a restorative material is to identify any defects radiographically that may cause the material to fail. Defective restorations may actually contribute to the recurrence of disease, such as caries along deficient margins of restorations, and alveolar bone loss beneath an overhang or an open contact. Some older restorative materials and cements no longer in use may be present in older patients. For example, a 50-year-old patient could have a 30-year-old tooth-colored restoration in a central incisor that may mimic a carious lesion on the radiograph. These older tooth-colored materials are radiolucent on the radiograph, whereas newer tooth-colored materials are radiopaque. Principal among these esthetic restorative materials are older resins, porcelain veneer gold crowns, porcelain crowns, and silicates. Cements include those used as subbases or for crown cementation. Radiolucent materials in current use (such as temporary crowns and

bridges, denture bases, and denture teeth) are invariably made of acrylic. Radiopaque materials include tooth-colored composite restorations, sealants, pins, cements, bases, amalgam, gold foil, cast gold, nonprecious alloys, and porcelain fused to metal crowns. Aluminum temporary crowns and stainless steel full-faced and open-faced crowns are also seen in children.

### Orthodontic/Pediatric Materials (Fig. 14-29)

Some of the main advantages of direct bonded orthodontic brackets include more pleasing esthetics than bands, easier and faster placement than bands, and no need for separating wires to open contacts. However, many orthodontists still prefer to use bands, especially in combination with direct bonded brackets. A principal disadvantage of bands is that caries, such as interproximal caries, cannot be detected beneath them. Other orthodontic materials include wires, springs, space maintainers, fixed retainers, inclined planes, habit-breaking



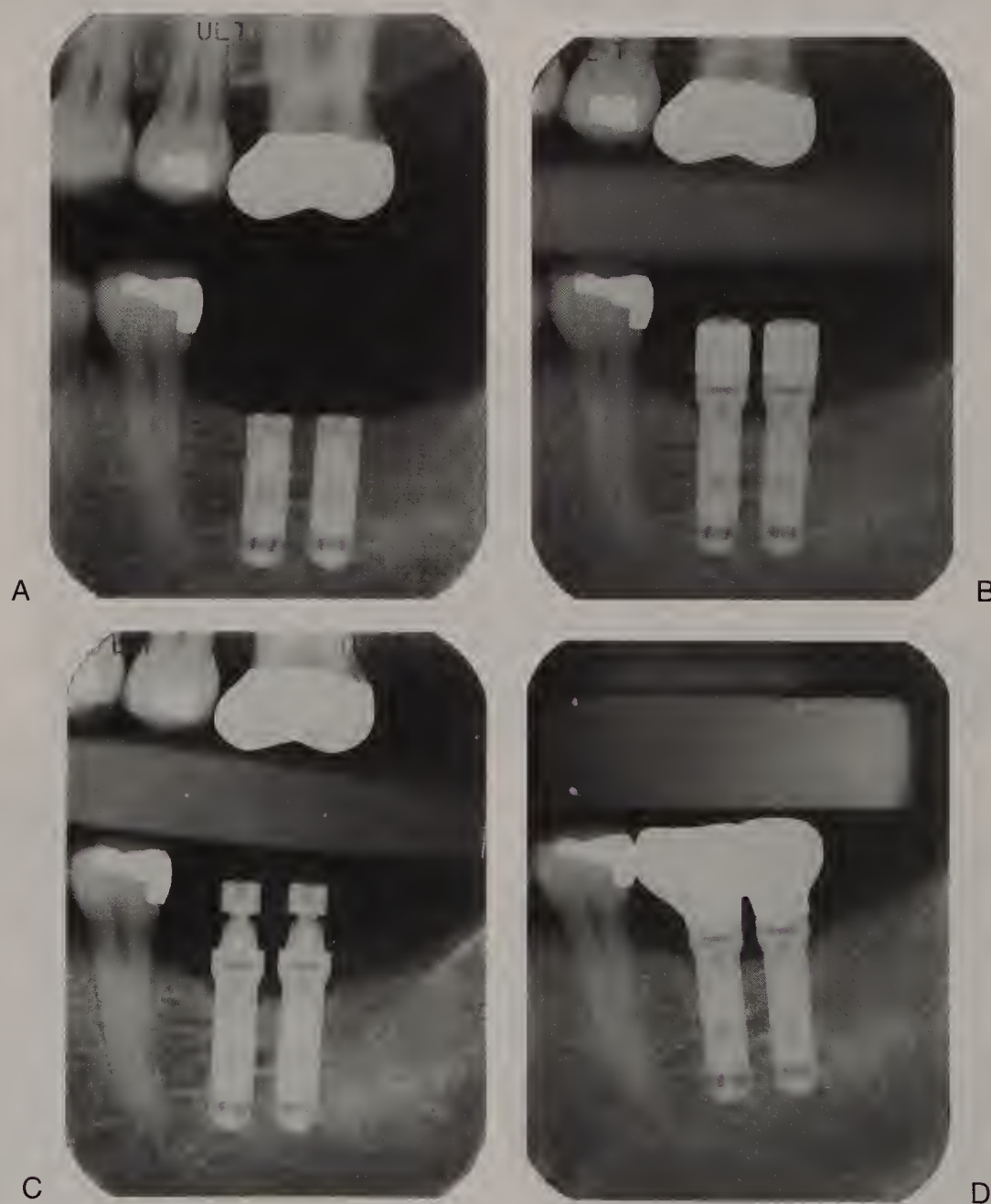
**Figure 14.29 Orthodontic/Pediatric Materials.** (A) Stainless steel bands and brackets. (B) Bands, stainless steel wires, and brackets. (C) Stainless steel crowns. (D) Space maintainer and stainless steel band.

appliances, and similar materials including radiopaque cement for bands. Pediatric materials include most other materials in addition to sealants, stainless steel crowns, and space maintainers.

### Trauma/Oral Surgery Materials (Figs. 14-30–14-32)

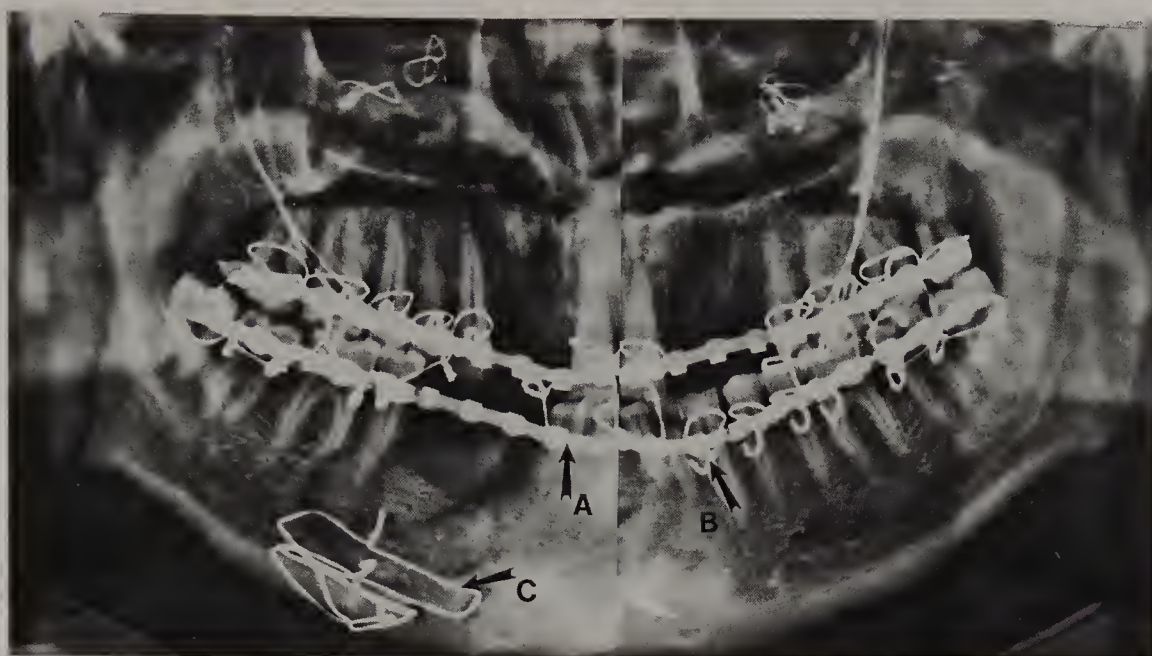
Some of the most commonly encountered foreign materials are associated with implants (Fig. 14-30). These include the implant itself or the fixture, the healing caps (used for 3 to 6 months after placement), the post that screws into the implant after removal of the healing cap, and the final restoration that is usually some type of casting either as a single unit or as a part of a fixed bridge. In the evaluation of implants, the persistence of bone right to the edge of the implant and minimal vertical loss of bone at the neck or cervical portion of the implant are

important. Other materials include wires, plates, and screws used after trauma or orthognathic survey (Fig. 14-31) and transplanted bones, such as ribs, to fill surgical defects. Patients with a retrognathic profile may sometimes have an acrylic button implanted to fill out the chin. Other foreign materials often seen in U.S. patients include broken surgical burs and instrument tips (Fig. 14-32B), radiopaque automobile glass fragments, pellets, birdshot, bullets, and explosive fragments. These may provide information about the patient's history. Amalgam fragments may sometimes cause an amalgam tattoo (presence of amalgam fragments in oral tissue). The diagnosis is confirmed by the presence of very minute to large-sized amalgam fragments around the cervical portion of a full crown, within the crestal portion of the alveolar bone, or within the soft tissues including the tongue or cheek (Fig. 14-32A).



**Figure 14.30 Implant Materials.** (A) Implants and healing caps. (B) Implants and appliance. (C) Prepared with screw tips. (D) Crowns screwed in place.





**Figure 14.31 Trauma/Oral Surgery Materials.** (A) Winter arch bars, (B) stainless steel wires holding arch bars in place, and (C) surgical wires stabilizing fractures.

### Prosthetic Materials (Fig. 14-33)

Any removable prosthetic device, such as a complete or partial denture, should usually be removed before taking radiographs. This is because any metallic or porcelain part of these prostheses may obscure the image of other structures, such as abutment teeth or alveolar bone. Sometimes “flippers” or temporary partial dentures are left in; because they are often all-plastic, only the wrought wire clasp may be visible. Fixed bridges may involve only one missing tooth or an entire arch. These fixed bridges involve materials mentioned previously in the restorative section.

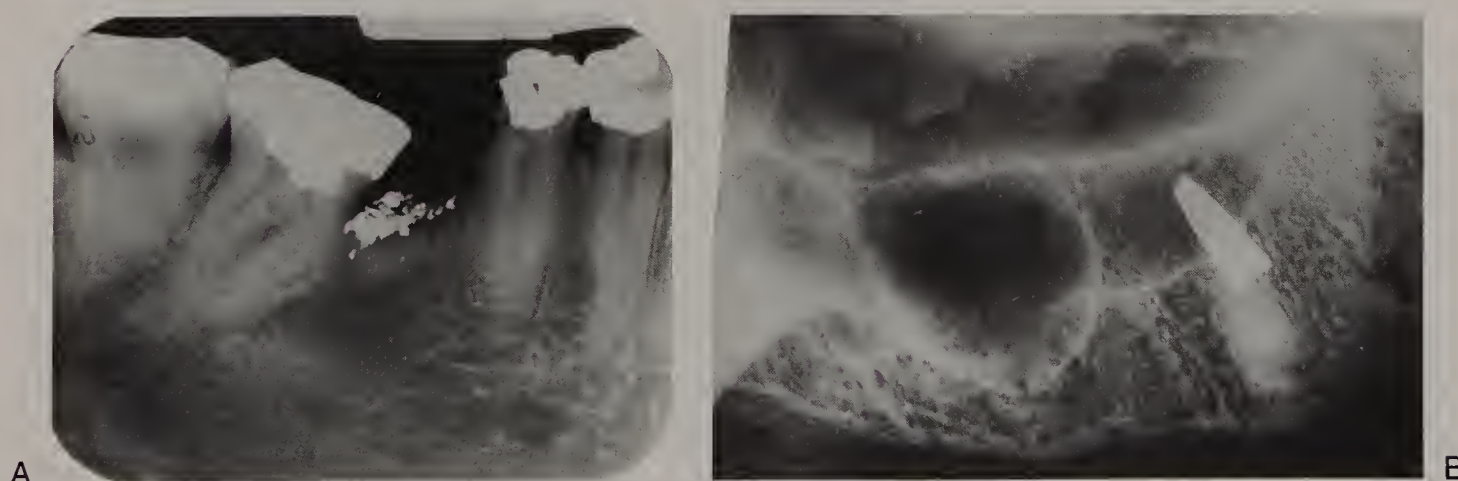
### Periodontal/Hygiene Materials (Fig. 14-34)

Materials relating to periodontal/hygiene procedures are seen infrequently. These materials may include stainless steel wires used for tooth splinting, broken scalers, curette

tips, or prophylaxis paste containing radiopaque materials such as zirconium. Films contaminated with stannous fluoride cause black fingerprints on the processed film. Metallic measuring devices are sometimes placed within periodontal pockets or bony defects to more accurately assess the periodontal problem.

### Radiographic Materials (Fig. 14-35)

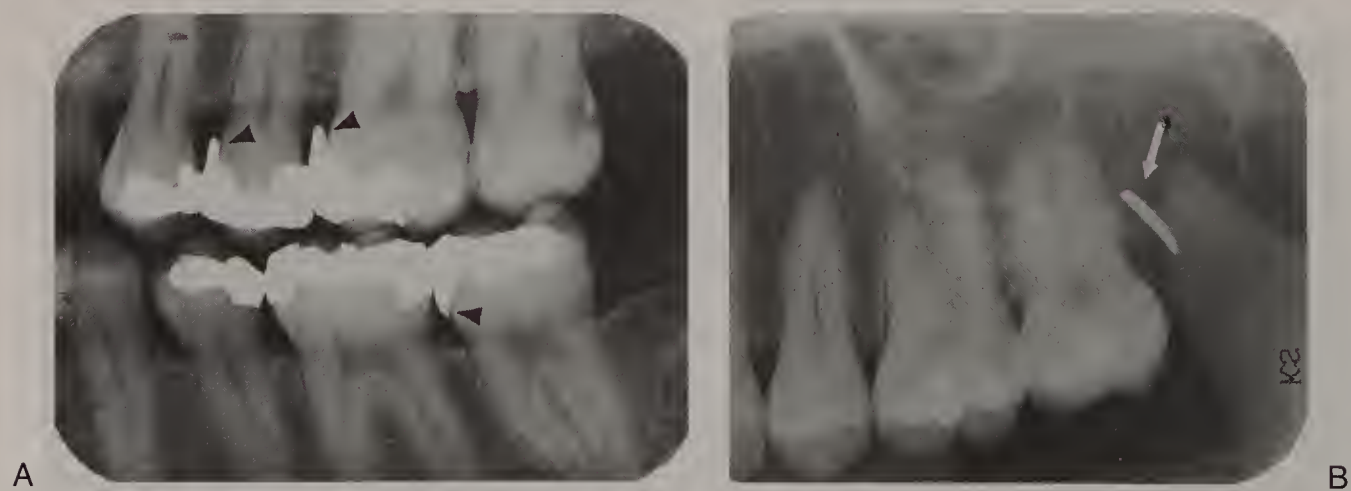
Most radiology equipment is now made of heat-sterilizable plastic materials and disposable materials made of paper, plastic, or Styrofoam that are primarily radiolucent. Occasionally, metallic biteblocks, attachments of metallic positioning rods, and film-holding devices (such as hemostat forceps) may be seen on the radiograph. Additionally, various radiographic artifacts mentioned elsewhere may be radiolucent or radiopaque.



**Figure 14.32 Trauma-Related Materials.** (A) Amalgam fragments of amalgam tattoo. (B) Elevator tip in maxillary sinus. (Note the retained root tip.)

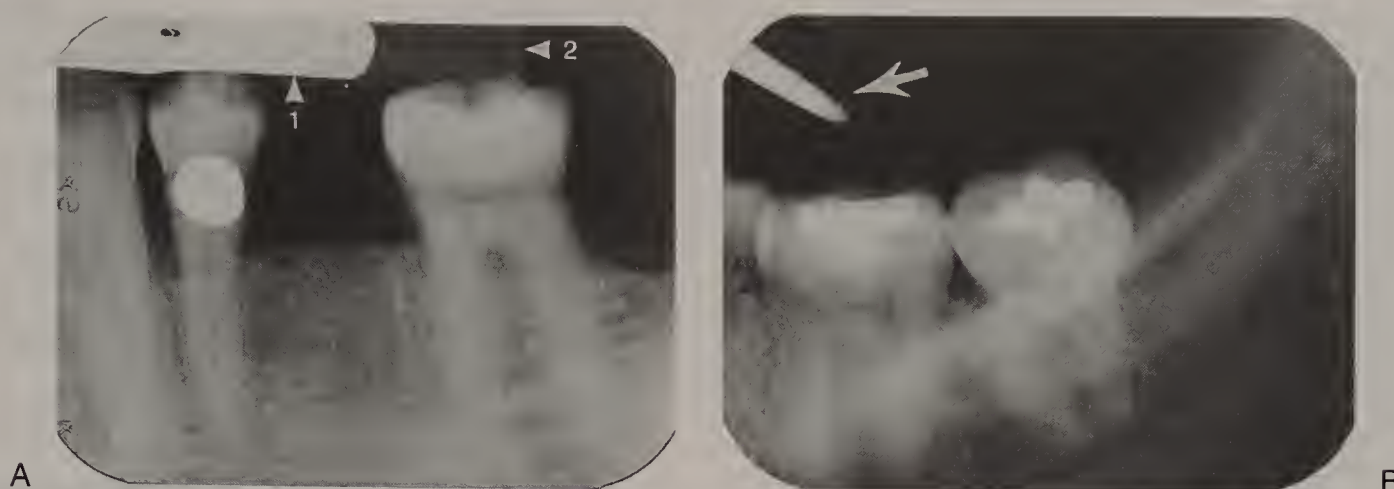


**Figure 14.33 Prosthodontic Materials.** (A) Anterior porcelain denture teeth with metal pins and radiotransparent acrylic denture base. (B) Acrylic temporary partial denture with radiotransparent plastic tooth and wrought wire clasp. (C) Cast chrome-cobalt partial denture framework, porcelain posterior denture tooth, and radiotransparent acrylic. (D) Posterior cast gold three-unit fixed bridge.



**Figure 14.34 Periodontal/Hygiene Materials.** (A) Overhangs. (B) Broken scaler tip.





**Figure 14.35 Radiographic Materials.** (A) Metal (arrowhead 1) and plastic biteblock (arrowhead 2). (B) Hemostat tip (arrow) used to hold film.

### OTHER MATERIALS (FIG. 14-36)

The above discussion includes the most commonly seen materials. However, others may be encountered, including retained injected radiopaque materials for sialogram (radiogram of salivary glands and ducts) or the opacification (making opaque) of lesions such as cysts in soft tissues or the maxillary sinuses. Also, jewelry in the ears, nose, tongue, and lips may be seen in radiographs, as well as eye-glass frames and some types of wigs. Unusual foreign objects, such as a thumbtack in the nose, straight pin in a salivary duct, or broken syringe needle, have all been reported.



**Figure 14.36 Other Materials.** Glass eyeglass lens and metal frame (arrow).

### WORKSHOP/LABORATORY EXERCISES

#### EXERCISE 14.1 NORMAL INTRAORAL ANATOMY AND MATERIALS

##### Materials and Equipment Needed

1. The mounted half- or full-mouth survey from the previous workshop on the paralleling technique or a duplicated set of full-mouth radiographs on a patient from the instructor.
2. Plastic orthodontic tracing sheets.
3. Sharp pencil and paper.

##### Instructions

- Step 1: Using transparent tape, attach the orthodontic tracing sheet on top of the full-mouth survey.
- Step 2: Use the viewbox and magnifying lens.
- Step 3: Using neat tracings and numbered arrows, identify as many anatomical landmarks and materials as you can.
- Step 4: On a separate sheet of paper, name the landmarks that correspond to the numbered arrows.

**Note to Instructors:** This workshop can be simplified if several different full-mouth surveys are each duplicated on a single panoramic-sized duplicating film. Label each original set with numbered arrows using a fine sharp pen. Ask the students to identify the numbered arrows on a separate sheet of paper and include structures and materials. This will eliminate the tracing and simplify correction.

## CASE-BASED PROBLEM-SOLVING

You are trying to sort out which structures in the mandible are within the bone, which ones are on the buccal surface, and which ones are on the lingual surface. Create a table that locates these structures by region, including anterior, premolar, and molar/retromolar areas. Indicate which are radiolucent and which are radiopaque.

asked to do the mandible as a bone, and half can be asked to do the maxilla. Then have the students trade with classmates who have done a different jaw (upper or lower) and critique the table.

## REVIEW QUESTIONS

1. Which of the following structures appear radiopaque on the radiograph?

1. Nasal fossa.
2. Mylohyoid ridge.
3. Maxillary sinus.
4. External oblique ridge.
5. Coronoid process.

- A. 2, 4, and 5.
- B. 1, 3, and 4.
- C. 1, 4, and 5.
- D. 1, 2, and 5.
- E. 1, 2, and 3.

2. What is the hamular process?

- A. A hooked bony projection of palatine bone.
- B. A bony projection of the medial pterygoid plate.
- C. A bony projection of the lateral pterygoid plate.
- D. A hooked bony projection of maxillary tuberosity.
- E. A bony projection of the coronoid process of the mandible.

3. Which of the following can mimic a periapical radiolucent lesion on a dental radiograph?

1. Apical foramen of tooth not closed in an immature tooth.
2. Mental foramen.
3. Nasopalatine foramen.
4. Greater palatine foramen.
- A. All of the above.
- B. 1, 2, and 4.
- C. 1, 2, and 3.
- D. 3 and 4.
- E. 1 and 2.

4. Which of the following is usually a sign of active eruption of a tooth?

- A. The lamina dura forms a continuous line around the tooth root.
- B. The lamina dura is perforated by many small openings.
- C. There is widening of the periodontal ligament space.
- D. There is a thickening of the lamina dura at the root apex region.

5. Match the following terms with the proper definitions:

### Column A

1. Fossa \_\_\_\_\_

2. Canal \_\_\_\_\_

3. Foramen \_\_\_\_\_

4. Sinus \_\_\_\_\_

5. Septum \_\_\_\_\_

6. Suture \_\_\_\_\_

7. Cortical \_\_\_\_\_

8. Cancellous \_\_\_\_\_

### Column B

A. Hole or opening in bone

B. Broad shallow depression in bone

C. Cavity, recess, or hollow space in bone

D. Passageway through bone

E. Sponge-like bone

F. Bony partition that separates two spaces

G. Immovable joint found between bones

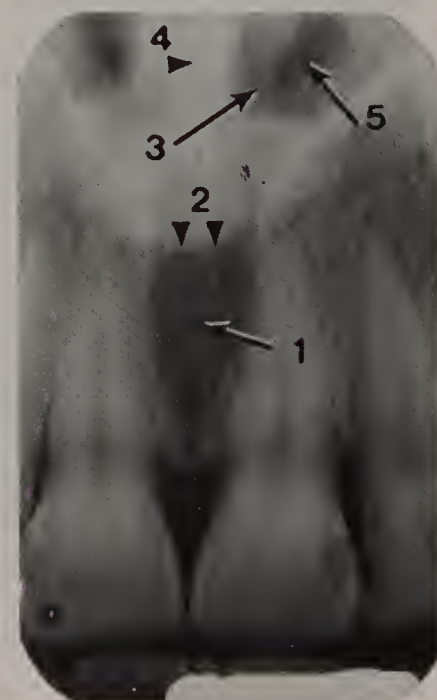
H. Hard or compact bone

6. Which of the following affects the form of the alveolar crest?

- A. Tooth inclination.
- B. State of eruption.
- C. The shape of the interproximal tooth surfaces.
- D. All of the above.

## CASE-BASED QUESTIONS

### CASE 14.1





**QUESTION**

1. Identify the anatomical structures by matching the columns.

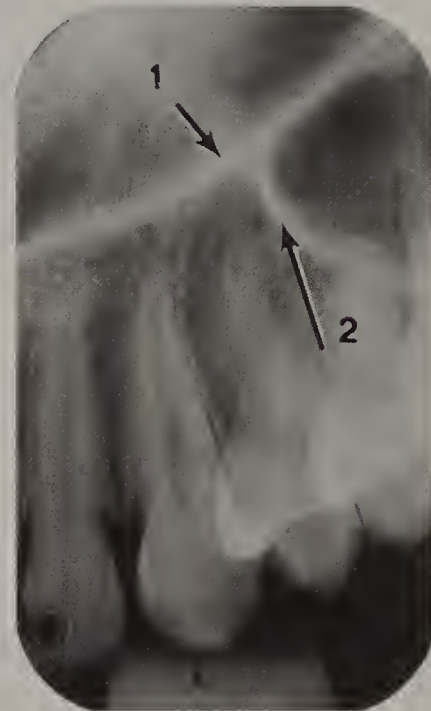
| Column A      | Column B            |
|---------------|---------------------|
| Arrow 1 _____ | A. Nasal fossa      |
| Arrow 2 _____ | B. Nasal septum     |
| Arrow 3 _____ | C. Tip of nose      |
| Arrow 4 _____ | D. Incisive foramen |
| Arrow 5 _____ | E. Nasal mucosa     |

**CASE 14.2****QUESTION**

1. Identify the radiopaque line indicated by the arrow.
- Mylohyoid ridge.
  - External oblique ridge.
  - Mental ridge.
  - Retromolar triangle.
  - Buccinator ridge.

**CASE 14.3****QUESTION**

1. Most likely, what is the dark area identified by the arrowhead in this radiograph?
- Periapical cyst.
  - Tumor of some kind.
  - Mylohyoid fossa.
  - Submandibular gland fossa.
  - Sublingual gland fossa.

**CASE 14.4****QUESTION**

1. The landmark known as the inverted-Y is well demonstrated. It is composed of which structures?
- Inferior border of nasal cavity
    - Anterior border of maxillary sinus.
  - Floor of orbit.
    - Inferior border of nasal cavity.
  - Inferior border of left nasal cavity.
    - Anterior border of right nasal cavity.
  - Floor of maxillary sinus.
    - Floor of orbit.
  - Palatal extension of maxillary sinus.
    - Anterior border of maxillary sinus.

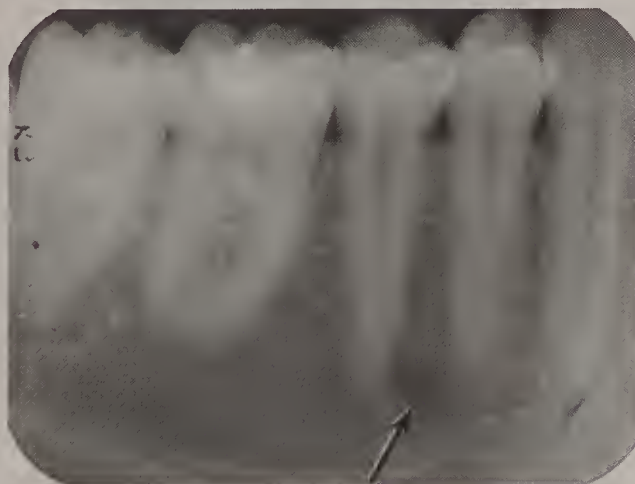
### CASE 14.5



#### QUESTION

1. In all probability, what is the dome-like structure (arrow) above the roots of the molars on this radiograph?
  - A. Mucocele.
  - B. Sinusitis.
  - C. Mucous retention cyst (phenomenon).
  - D. Radicular cyst.
  - E. Osteoma.

### CASE 14.6



#### QUESTION

1. Identify the radiolucent circle identified by the arrow in this radiograph. The premolars are vital.
  - A. Medullary space.
  - B. Lingual foramen.
  - C. Apical granuloma.
  - D. Mental foramen.
  - E. Nasopalatine foramen.

### CASE 14.7



#### QUESTION

1. In all probability, what are the white radiopacities in this radiograph (arrows)?
  - A. Cementomas.
  - B. Osteomas.
  - C. Tori.
  - D. Exostoses.
  - E. Foreign bodies.

### CASE 14.8





**QUESTION**

1. What are the several dark lines within the edentulous alveolar bone? The patient has no signs or symptoms.

- A. Fracture lines.
- B. Medullary spaces.
- C. Nutrient canals.
- D. Trabecular spaces.
- E. Osteomyelitis.

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# Radiologic Diagnosis of Periodontal Disease

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Understand the limitations of the radiograph in the evaluation of periodontal disease.
2. Understand the benefits of the radiograph in the evaluation of periodontal disease.
3. Recognize the presence of etiologic factors in radiographs.
4. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

|                        |                              |                          |                            |
|------------------------|------------------------------|--------------------------|----------------------------|
| alveolar bone height   | digital subtraction          | horizontal bone loss     | periodontal ligament space |
| bone defects           | radiography                  | infrabony pocket         | (PDLs)                     |
| bone loss              | faulty restorations          | localized bone loss      | pocket formation           |
| bruxism                | food packing                 | localized juvenile       | ramping                    |
| calculus               | furcation involvement        | periodontitis (LJP)      | root mobility              |
| cementoenamel junction | generalized bone loss        | Nabors probe             | root morphology            |
| (CEJ)                  | hemiseptum                   | occlusal trauma          | triangulation              |
| clenching              | Hirschfeld calibrated silver | osseous crater           | vertical bone loss         |
| crestal bone           | points                       | overhanging restorations |                            |
| crown-root ratio       |                              |                          |                            |

## INTRODUCTION

Periodontal diseases are conditions that affect the surrounding and supporting tissues of the teeth. The most common periodontal diseases are caused by microbiological infections associated with local accumulation of bacterial plaque, pathogens, periodontal flora, restorations, and calculus. Periodontitis is characterized by gingival inflammation, periodontal pocket formation, destruction of the periodontal ligament and alveolar bone, and gradual loosening of the teeth. It is associated with apical migration of the junctional epithelium on the root surface. Hoag and Pawlak (1990) report that the incidence of periodontitis is approximately one in four for adults. The incidence of periodontal disease with pocket formation is about 4 in 10 adults at 50 years of age.

## ROLE OF THE RADIOGRAPH IN PERIODONTAL DISEASE

There are limitations to the use of the radiograph in the diagnosis of periodontal disease. Radiographs give a two-dimensional representation of three-dimensional anatomical structures. The radiographic image lacks the third dimension of depth, which results in bone and tooth structures being superimposed over each other. However, if the limitations of the radiograph are recognized, the radiograph can still be considered an important diagnostic aid in the initial examination and diagnosis of patients with periodontal disease. To minimize the limitations of radiography, the intraoral radiograph must be taken with the long beam indicating device (BID) paralleling technique. This provides a radiograph that is the most anatomically accu-

rate. Also, it is important that a high-kilovoltage (80 to 90 kVp) technique be used, because radiographs with long-scale contrast are produced. Such images are superior to lower-kVp images in the interpretation of bony lesions because of the varying degrees of opacities and lucencies.

Although the radiograph provides crucial information regarding the presence of periodontal disease, it does not provide data concerning the activity or rate of periodontal destruction at the time of the examination. Sequential radiographic examinations performed after bone destruction has occurred can demonstrate disease activity retrospectively, because succeeding radiographic examinations of the patient can be compared both visually and more accurately by digital subtraction techniques. Early et al. (1979) estimated that a 30 to 50% change in bone mineral content is needed before bone loss can be detected in the radiograph. Small amounts of alveolar bone loss are difficult to see when dental radiographs are compared visually. Webber et al. (1982), Jeffcoat (1984), Jeffcoat et al. (1987), and McHenry et al. (1987) reported that small osseous changes can be detected by subtracting all unchanged bony structures from a set of dental radiographs, leaving only the area of change in the resultant subtraction radiograph. Lesions with less than 5% bone loss can be detected by digital subtraction radiography. Digital subtraction can also be used to detect bone regeneration as a result of periodontal therapy.

The digital subtraction radiograph may be used routinely in the dental office in the future. In digital subtraction, one image of an anatomical region from, for example, the previous year can be superimposed on a second image of the same anatomical region from the current year. The superimposition of the two images is done in the computer using special software. When one image is subtracted from the other, only the differences between the two images are seen. Thus, even minute changes in alveolar bone density can be detected and quantified.

## LIMITATIONS OF THE RADIOGRAPH

With respect to periodontal disease, the role of the radiograph is misunderstood, and the limitations of radiographs must be understood. Some of the important limitations are listed below.

### Presence or Absence of Periodontal Pockets

Because the periodontal pocket is a pathologically deepened gingival sulcus, the only reliable method of locating a periodontal pocket and evaluating its extent is by careful periodontal probing. The periodontal pocket is composed of soft tissue, so it will not be visible on the radiograph (Fig. 15-1A, B); however, if a radiopaque material such as gutta percha root canal points or **Hirschfeld calibrated silver points** are inserted into the pocket, the base of the pocket can usually be recorded on the radiograph (Fig. 15-1C).

### Early Bone Loss

In a study by Pauls and Trott (1966), interseptal bony defects smaller than 3 mm could not be seen on radiographs by the use of visual methods. The sensitivity of radiographs in quantifying early bone destruction is only fair. The status of bone on facial and lingual aspects of the teeth is difficult to evaluate because the dense tooth structures are superimposed over the bone. Ramadan and Mitchell (1962) reported that by the time periodontal bone destruction becomes detectable on the radiograph, it has usually progressed beyond the earliest stage. Therefore, the very earliest signs of periodontal disease must be detected clinically.

### Early Furcation Involvement

Furcation involvement is detected by clinical examination, which includes careful examination with a specialized probe such as the Nabors probe. Radiographs are helpful but usually show less bone loss than is actually present



**Figure 15.1 Absence of Periodontal Pockets on Radiograph.** (A) Radiograph of a patient with 10-mm pockets on the palatal surface of maxillary premolars. (B) Photograph of the patient in A showing 10-mm pockets on lingual surfaces of premolars by periodontal probes (arrows). (C) Silver points were used on mandibular first molar to assess base of periodontal pockets.





**Figure 15.2 Furcation Involvement.** Radiograph showing furcation involvement (arrows) of lower first and second molars.

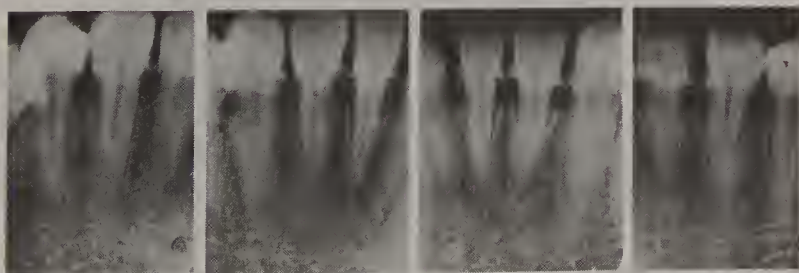
(Fig. 15-2). The furcation area of a tooth should be examined clinically, even if the radiograph shows a very small radiolucency or an area of diminished radiodensity at the furcation. Variations in the alignment of the x-ray beam may obliterate the presence or extent of furcation involvement. The facial and lingual aspects of the alveolar bone will often be superimposed over the furcation.

#### Dental Calculus

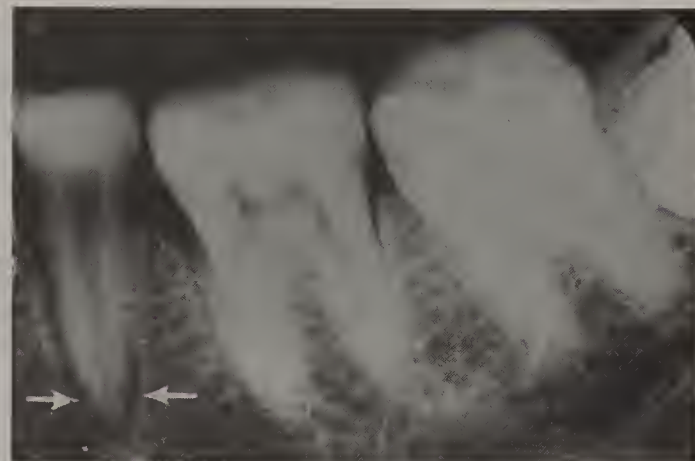
Radiographs may be useful in detecting subgingival calculus, which appears as a radiopaque line that increases in density with increased mineralization. The detection of calculus radiographically will depend on its degree of mineralization and on the angulation of the x-ray beam. The radiograph may show heavy calculus deposits and calculus spurs or spicules interproximally (Fig. 15-3), sometimes even on the facial and lingual surfaces; however, it cannot be relied on for the thorough detection of calculus. Here the radiograph is an adjunct to the clinical examination.

#### Tooth Mobility

Radiographs do not record tooth mobility. However, in most cases, a widening of the periodontal ligament space (PDLs) on the radiograph does indicate an increase in mobility (Fig. 15-4). In such instances, the PDLs are wider around the mobile tooth or teeth than the remainder of the teeth. Traumatic defects manifest themselves more



**Figure 15.3 Dental Calculus.** Interproximal spur-like calculus in lower anteriors.



**Figure 15.4 Periodontal Ligament Space (PDLs) Widening.** The lower second premolar PDLs is widened (arrows), and the tooth is mobile.

readily in the faciolingual aspects of the supporting structures, because in the mesiodistal aspects the contact areas of the adjacent teeth provide added stability. Because the tooth is superimposed over the faciolingual structures, a widened PDLs on these surfaces cannot be seen on the radiograph. Such changes will require a thorough clinical assessment of mobility for the final diagnosis.

#### Morphologic Characteristics of Bone Deformities

The presence of osseous defects or bone deformities may be suggested on the radiograph, but careful periodontal probing and surgical exposure are necessary to determine the shape and dimensions of bone deformity. Because the radiograph lacks depth, it will not accurately record the true picture of a bone deformity (e.g., showing the number of remaining walls of an infrabony pocket).

#### BENEFITS OF THE RADIOGRAPH

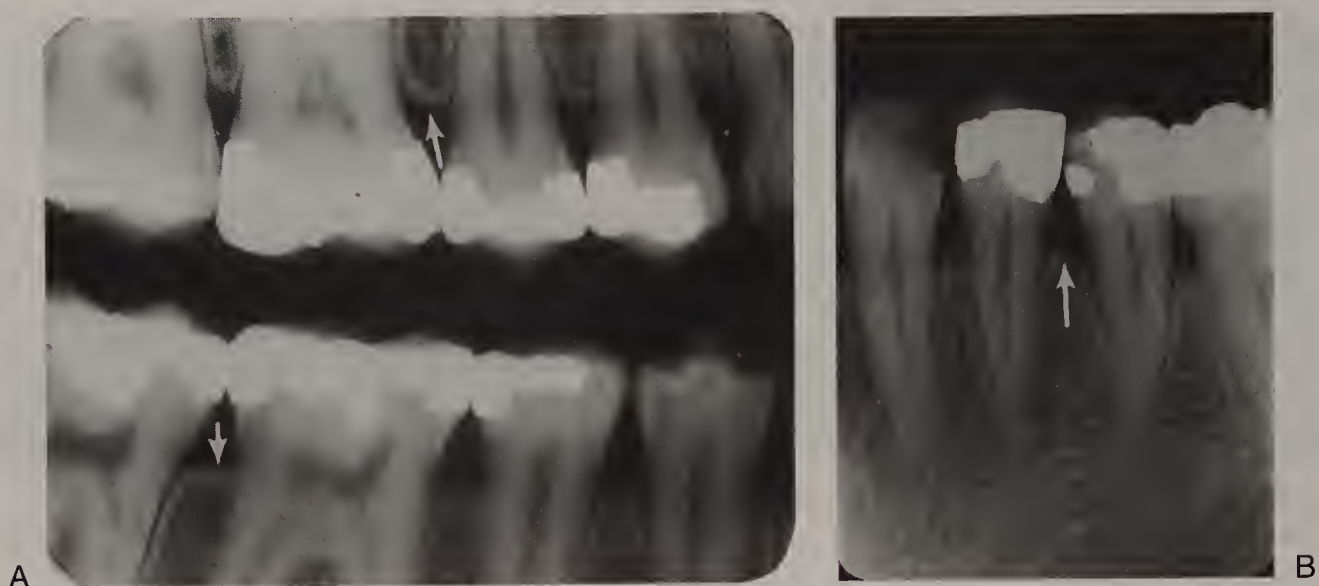
Despite its limitations, the periodontal examination is incomplete without accurate radiographs, which can show most bony changes in association with periodontal disease when viewed under good lighting conditions. The remainder of this chapter will be devoted to the benefits of the radiograph in the diagnosis of periodontal disease.

#### Early Radiographic Changes in Periodontitis

Although the radiograph is not sensitive enough to detect the earliest signs of periodontal disease, it is still an essential part of the clinical examination. Glickman (1972) listed the following sequence of early radiographic changes that occur in periodontitis:

##### EARLY PERIODONTITIS

1. Crestal irregularities.
2. Triangulation (funneling).
3. Interseptal bone changes.



**Figure 15.5 Crestal Irregularities.** (A) Normal interidental alveolar crestal bone (arrows). The coronal border of the alveolar bone (alveolar crest) extends normally to approximately 1.5 mm from the CEJ of the teeth. (B) Note fuzziness and break of continuity of lamina dura at crest of alveolar bone between first and second premolars (arrow).

**Crestal Irregularities.** One of the first radiographic signs of periodontitis is the indistinctness and interruption in the continuity of the lamina dura (radiopaque) seen along the mesial or distal aspect of the interdental alveolar crest (Fig. 15-5). This bone resorption results from extension of the inflammation into the interdental bone, with an associated widening of the periodontal space and a reduction in the mineralized tissue per unit of bone at the septal margin.

**Triangulation (Funneling).** Triangulation is the widening of the PDL space by the resorption of bone along either the mesial or distal aspect of the interdental (interseptal) crestal bone. The sides of the triangle are formed by the alveolar bone and root surfaces, the base is toward the tooth

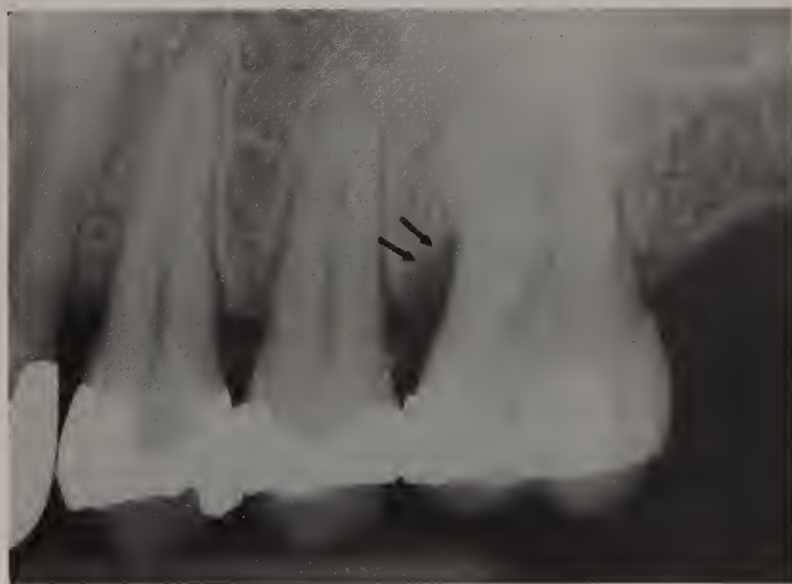
crown, and the apex of the triangle is pointed toward the root (Fig. 15-6). This is an early sign of bone degeneration and necessitates a search for possible etiologic factors, such as plaque, calculus, gingivitis, or food impaction.

**Interseptal Bone Changes.** One of the earliest radiographic signs of periodontitis is the finger-like radiolucent projections extending from the crestal bone into the interdental alveolar bone. These projections are a result of a deeper extension of the inflammation from the connective tissue of the gingiva. They represent widened blood

passage of inflammatory fluid and cells into the bone. It results in a reduction of mineralized tissue per unit area (Fig. 15-7). When all the alveolar bone support is lost and the tooth seems to “float in air” on the radiograph, it is called the “terminal stage” of chronic destructive periodontitis (Fig. 15-8). Reactive sclerosis (radiopaque) can sometimes be seen at the margin of the remaining bone in terminal, chronic destructive periodontitis. Reactive sclerosis is a defense mechanism by the host bone whereby more bone is laid down at the margins of benign bone diseases, causing the area to appear more radiopaque in the radiographic image.

#### Evaluation of Bone Loss

The radiograph is used indirectly to determine the amount of bone loss attributed to periodontal disease. Actually, the radiograph indicates the amount of bone remaining and not the amount of bone loss. The amount of bone loss is the difference between the remaining coronal (pertaining to crown of tooth) height and the assumed normal coronal bone level for the patient. In a normal individual, the alveolar bone height is located 1 to 1.5 mm apical (toward apex of tooth) to the cemento-enamel junction (CEJ). The evaluation of bone loss is made primarily

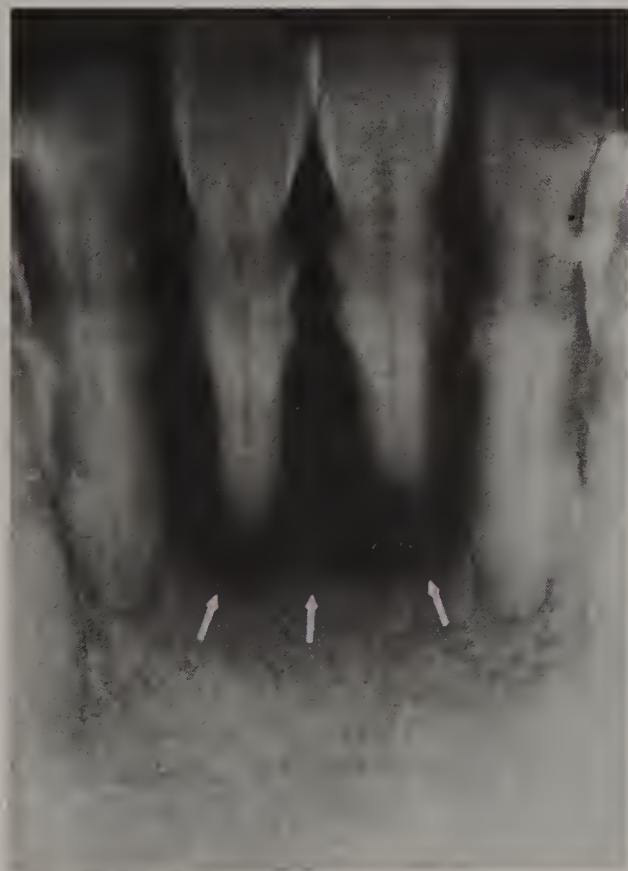


**Figure 15.6 Triangulation (Funneling).** Note the wedge-shaped radiolucencies on the mesial aspects of the first molar (arrows). Spur calculus can be seen on distal of second premolar.





**Figure 15.7 Interseptal Bone Changes.** Note the increased bone resorption along endosteal margins of medullary spaces, which results in increased radiolucency of interseptal bone (*white arrows*). Also note the gross amounts of interproximal deposits of calculus (*black arrows*).



**Figure 15.8 Chronic Destructive Periodontitis.** Terminal stage of chronic destructive periodontitis (*arrows*). The teeth seem to be hanging in the air.



**Figure 15.9 Localized Bone Loss.** Localized bone loss between maxillary molars. Note the deficient contact between the molars providing an excellent food packing area.

by examining the interproximal septal bone on the radiograph. Of course, bone loss occurs on all surfaces, but the thickness of the tooth tends to obscure facial and lingual bone loss on the radiograph. If the bone loss occurs in isolated areas, it is described as **localized bone loss** (Fig. 15-9). When the bone loss is evenly distributed throughout the dental arches, it is called **generalized bone loss** (Fig. 15-10). The inflammation of periodontitis may spread from the gingiva into the alveolar bone and periodontal ligament, and reach the pulp through the root apices or accessory pulp canals near the apex or the furcation of a tooth. In these cases, retention of the tooth will depend on a combined periodontal/endodontic treatment plan (Fig. 15-11). If the alveolar bone loss from periodontitis is severe in the posterior maxillary molar region, the radiograph is useful in determining the approximation of the crestal bone level to the floor of the maxillary sinus. This is especially important if bone surgery is being planned in this region.

**Direction of Bone Loss.** The direction of bone loss or bone destruction, whereby areas previously occupied by healthy bone become radiolucent due to pathologic dissolution of the bone, is determined using the CEJ as the plane of reference.

**Horizontal Bone Loss.** When the bone loss occurs on a plane that is parallel to a line drawn from the CEJ of a tooth to that of an adjacent tooth, it is called **horizontal bone loss** (Fig. 15-12).

**Vertical Bone Loss.** When there is a greater degree of bone destruction on the interproximal aspect of one tooth than on the adjacent tooth, the bone level is angular or not parallel to a line joining the CEJs. This type of bone loss is called **vertical or angular bone loss** (Fig. 15-13). Vertical bone loss usually consists of one or many **infrabony pockets**, because the base of the pocket is usually located apical to the crest of the surrounding bone. Traditionally,



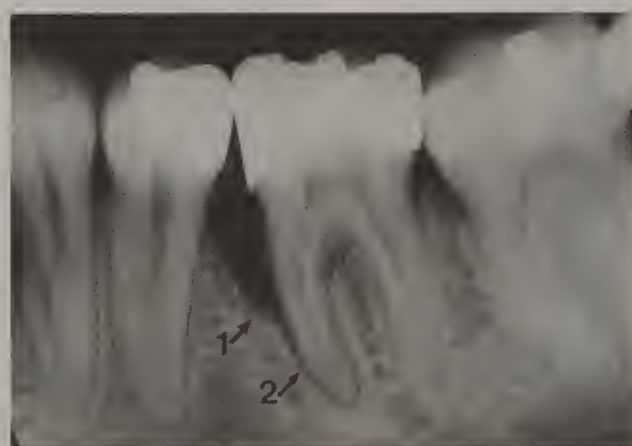
**Figure 15.10 Generalized Bone Loss.** Generalized bone loss in maxilla and mandible revealed in a panoramic radiograph.



**Figure 15.11 Combined Periodontal-Endodontic Pathoses.** Radiograph of nonvital second molar, which is periodontally involved.



**Figure 15.12 Horizontal Bone Loss.** Horizontal bone loss occurs on a plane parallel with a line drawn from the CEJ of one tooth to that of an adjacent tooth (white arrows). Note trifurcation involvement of maxillary first molar and gross amounts of interproximal calculus between first and second molars (black arrows).



**Figure 15.13 Vertical Bone Loss.** (1) Vertical bone loss occurs when there is greater bone loss on the proximal of one tooth than the adjacent tooth. (2) Thickened PDL space.





**Figure 15.14 Localized Juvenile Periodontitis (LJP).** (A) Classic arch-shaped anterior alveolar bone destruction found in LJP. (B) A 17-year-old girl with LJP. Clinically, there were few signs and symptoms of inflammation. *Upper radiographs: patient at age 13. Lower radiographs: patient at age 17.* (Note the severe bone loss between premolars and molars.)

horizontal bone loss was thought to be a result of a uniform resorptive response when inflammation from local irritating factors was the sole cause; vertical bone loss resulted from a more complex etiology, such as systemic disease, with a combination of occlusal trauma and local irritation. Proof of these theories have not been demonstrated conclusively. Thus, patterns of bone loss are now less important in the clinical diagnosis of periodontal disease than they were once thought to be.

**Localized Juvenile Periodontitis (LJP).** Vertical bone loss around the first molars and incisors in an otherwise healthy adolescent with little or no accumulation of plaque and little or no clinical inflammation represents the classic diagnostic features of localized juvenile periodontitis (LJP). The classic radiographic finding in LJP is an arch-shaped loss of alveolar bone extending from the distal surface of the second premolar to the mesial surface of the second molar. Also, there is almost always a distolabial migration of the maxillary incisors with diastema formation (Fig. 15-14). The rate of bone loss is three to four times faster than in typical adult periodontitis. The definitive etiologic factors of LJP are not known, but most authorities believe that the principal cause is bacterial, with the possibility of an altered host response.

#### Evaluation of Bone Height

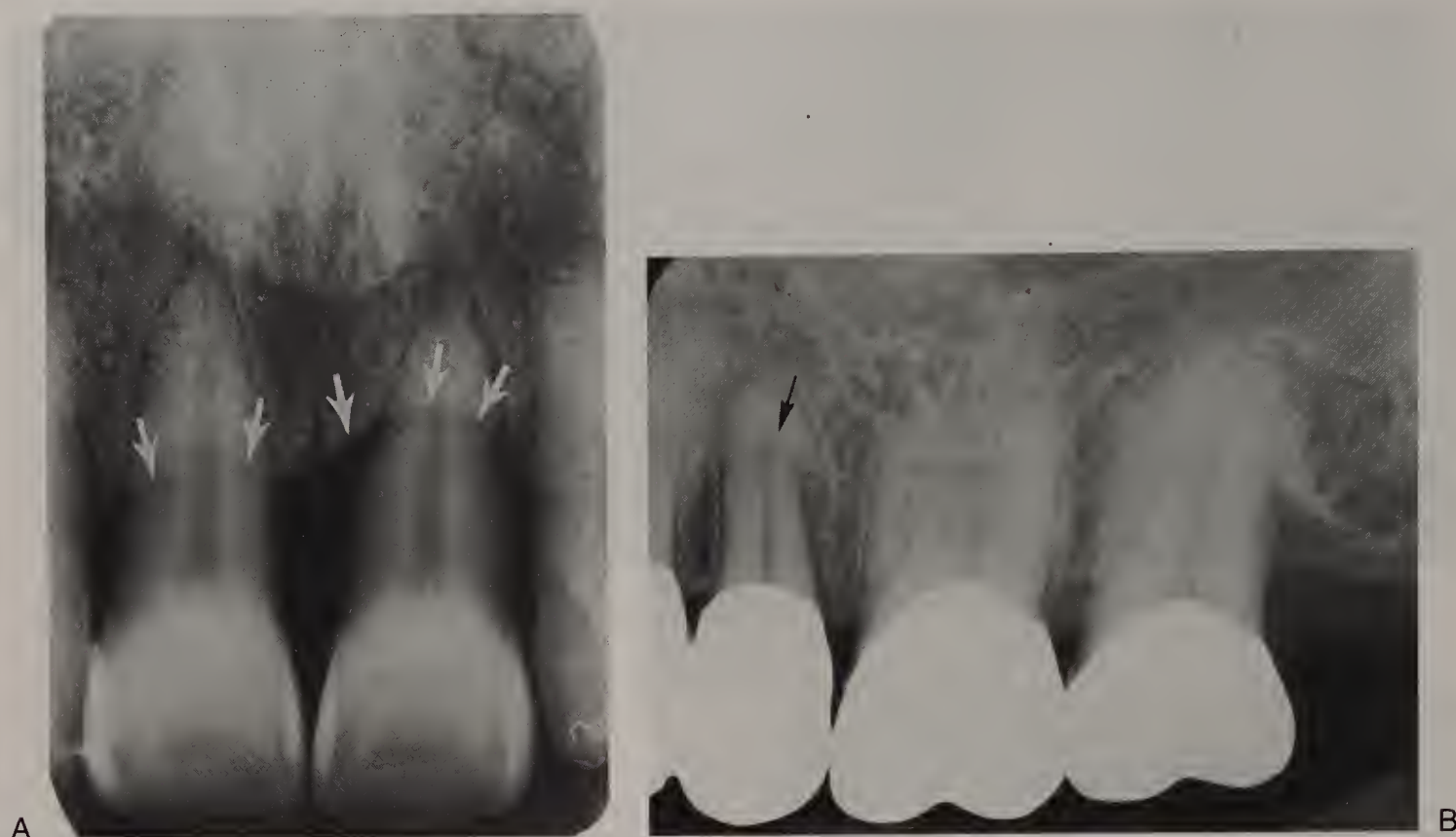
Because the density of the tooth obscures the coronal bone level of the alveolar bone on the facial and lingual surfaces, it is difficult to assess bone loss on the facial and lingual surfaces of teeth.

At times it is possible to estimate facial and lingual bone levels by using two procedures in combination:

1. Tracing the lamina dura line coronally until it loses its maximal opacity. This provides a rough estimate of the true height of the interseptal bone. The bone coronal to this level is the facial bone that has been cast coronally by excessive vertical angulation. This is especially true if the bisecting angle technique has been used. (The relationship of the buccal and lingual cusps of the teeth to each other should be checked.)
2. Starting at the apex of the tooth, the trabecular pattern of the bone on the root of the tooth should be traced coronally until it terminates at some level on the tooth root. A line running across the tooth will be noted. This line separates the denuded portion of the root from the root portion covered by bone (Fig. 15-15). The line usually represents the lingual height of the alveolar crest because of its greater detail. This line will join the terminal portion of the maximal coronal lamina dura opacity, as described in the first procedure.

#### Evaluation of Bone Defects

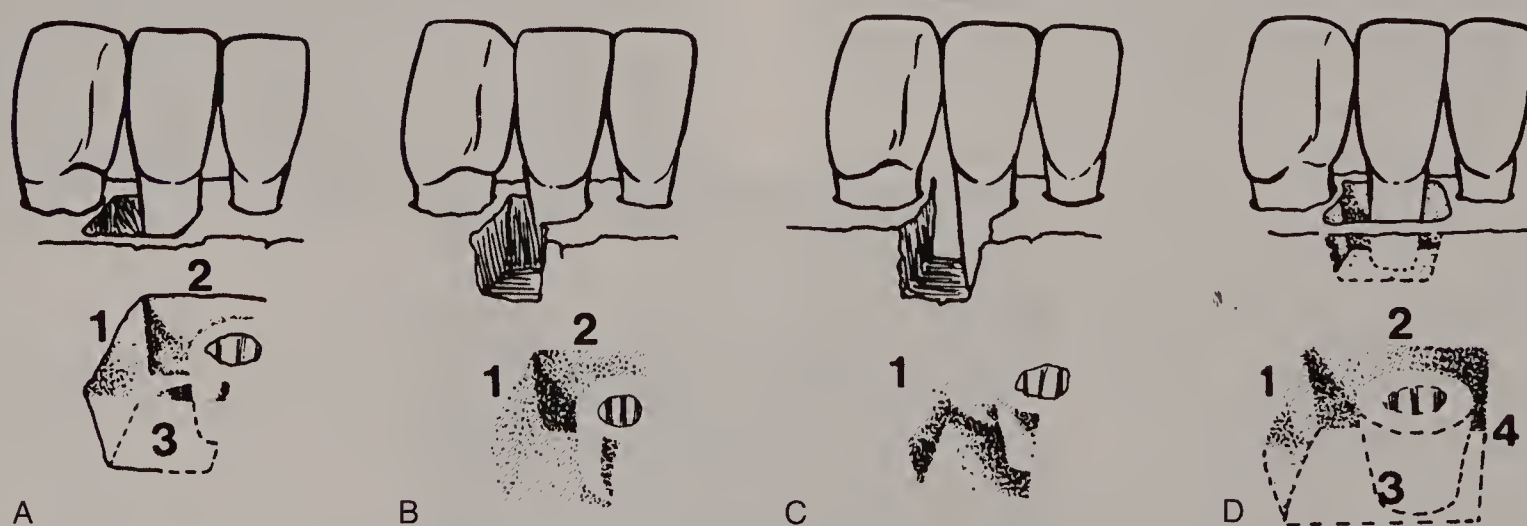
There are different types of bone deformities produced by periodontal disease. The accurate radiograph will usually show a bone defect in the interseptal bone, but its exact form or shape can be determined only by careful periodontal probing and/or by direct vision during surgical exposure. In most instances, the bony defect in periodontal disease is angular or vertical with an accom-



**Figure 15.15 Evaluation of Bone Height.** (A) Note that the trabecular pattern of the central incisors can be observed as the eye scans apically from the arrows. Below the arrows, the root appears denuded of bone. This is the true line of the bone height. (B) Note the severe bone loss on lingual surface of the maxillary second premolar. This is most likely bone level on the lingual surfaces because of its clarity (black arrow).

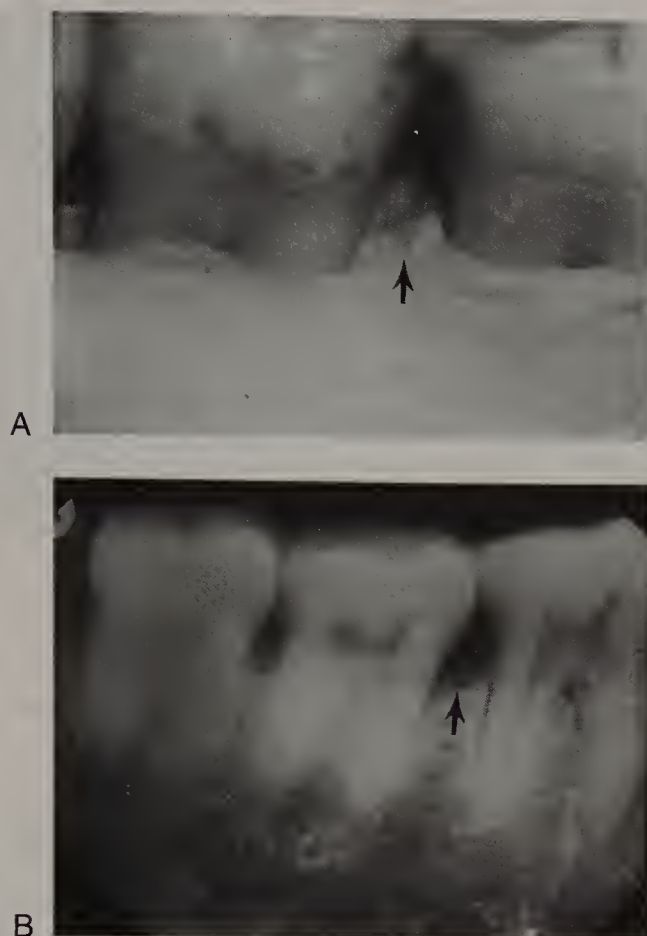
panying infrabony pocket. As suggested by Goldman according to the number of bony walls associated with the infrabony pocket. Infrabony pockets may be classified as one-walled, two-walled, three-walled, or four-walled bony defects (Fig. 15-16).

**One-Wall Infrabony Pocket or Defect.** In the one-wall angular defect, one bony wall of the interseptal bone remains after the mesial or the distal portion of the interseptal bone has been destroyed. It is called the “hemiseptum defect” and is identical to vertical or angular bony deformities (Figs. 15-16C and 15-17). Sometimes

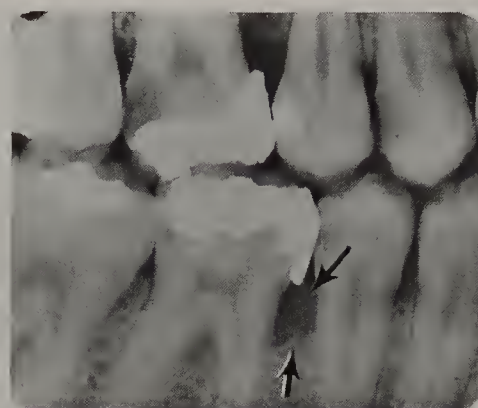


**Figure 15.16 Bony Defect.** (A) Three-wall bony defect. (B) Two-wall bony defect. Another type of two-wall bony defect is the osseous crater where the facial and lingual walls are intact but the interdental alveolar crest has been resorbed, forming a crater in the bone. (C) One-wall bony defect. This is also called the hemiseptum defect in which one wall of the interdental septum remains after the facial and lingual walls have been destroyed. Ramping is another form of one-wall defect when a facial wall is left standing and the interdental septal wall slopes toward the destroyed wall, forming a ramp-like appearance. (D) Four-wall bony defect completely surrounds the tooth.





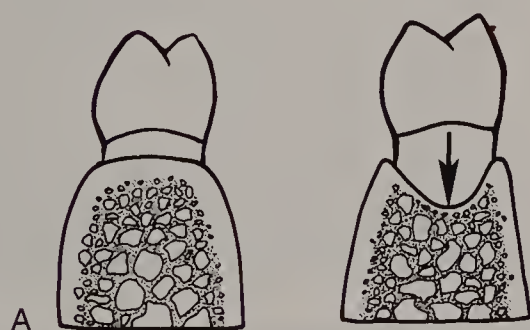
**Figure 15.17 One-Wall Vertical Angular Bony Defect (Hemiseptum Appearance).** (A) One-wall hemiseptum defect between mandibular first and second molars of dry specimen. (B) Radiograph of A showing one-wall hemiseptum defect between first and second molars.



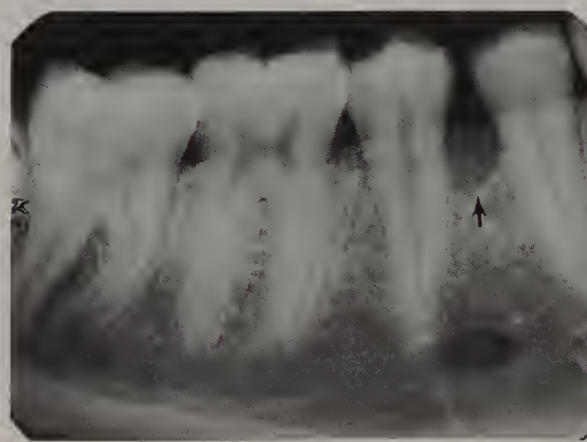
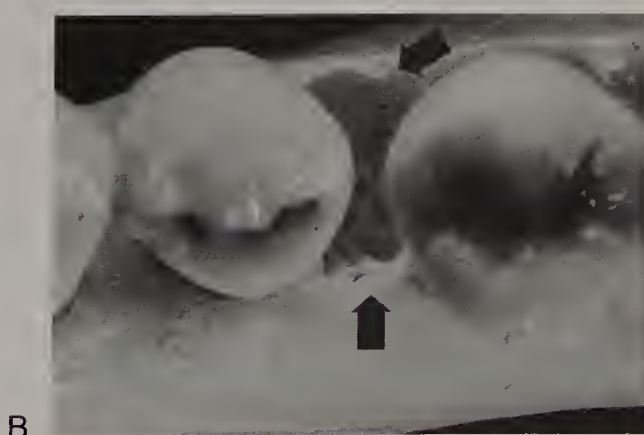
**Figure 15.18 One-Wall Bony Defect (Ramp-Like Appearance).** The defect has formed a ramp-like appearance (arrows), because the inter-dental septal bone slopes down from the facial/lingual wall crest of bone toward the crest of the destroyed facial/lingual bone. In this case, probing confirmed that the lingual wall was destroyed, and the ramping sloped down from intact facial wall toward the lingual crest of bone.

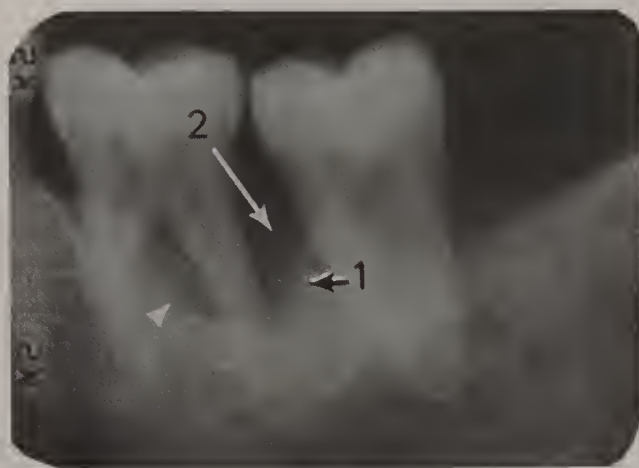
the one-wall defect will take the form of a ramp when the facial or lingual cortical bone is destroyed (Fig. 15-18). This defect is called “ramping.”

**Two-Wall Infrabony Pocket (Defect).** An osseous crater is a concavity in the crest of the interdental bone confined within the facial and lingual walls (Fig. 15-19). It is a two-wall infrabony pocket deformity. Manson and Nicholson (1974) found that the craters constitute approximately one-third of all defects (35.2%) and two-thirds (62.0%) of all mandibular defects; they also were twice as common in the posterior segments compared with the anterior segments. A less common two-wall defect occurs when the facial or lingual cortical plate of bone is missing (Figs. 15-16B and 15-20). When the remaining facial or lingual wall



**Figure 15.19 Osseous Crater (Two-Wall Bony Defect).** (A) Diagram of an osseous crater between two mandibular premolars. (Left) Normal bone contour. (Right) Osseous crater within interdental septal bone (arrow). (B) Osseous crater between two premolars in dry specimen. (C) Radiographic appearance of osseous crater between first and second premolars.





**Figure 15.20 Less Common Two-Wall Bony Defect.** Radiograph of less frequently seen two-wall infrabony defect found here on the distal of the first molar. (1) Distal wall and (2) lingual wall were intact, with furcation involvement (white arrowhead) confirmed by probing.

is very thin or if a high-contrast low-kilovolt peak technique is used, this defect may not be seen on the radiograph. The remaining thin bony wall will be “burnt-out” and erased from the radiograph (Fig. 15-21).

**Three-Wall Infrabony Pocket or Defect (Intrabony Pocket).** The three-wall defect is an infrabony defect surrounded by bony walls on three sides, with the tooth root forming the fourth wall. The infrabony defect is not a circumferential defect because there is an osseous wall on each side of the root; however, the defect may extend around the root and stop on the buccal or lingual aspect instead of the interproximal surface. Defects with three bony walls occur most often in the mandibular molar region but can occur wherever bone is thick enough to have cancellous bone between the alveolar bone and cortical plate (Fig. 15-16A).

**Four-Wall Infrabony Pocket (Defect).** The circumferential defect is the four-wall defect that completely surrounds the root of the tooth (Fig. 15-16D).

### Furcation Involvement

Extension of the periodontal pocket between the roots of multirooted teeth is called **furcation involvement**. The mandibular first molars are the most common sites of furcation involvement, and the maxillary first premolars are the least common locations. The number of furcation involvements increases with age. Examination of the extent of the furcation involvement is made by exploration with a Nabors periodontal probe or dental explorer inserted into the roof of the furcation. Visualization can be facilitated by use of warm compressed air. Radiographs can be helpful in locating furcation involvement; however, the furcation involvement will not be seen unless the bone resorption extends apically beyond the furca. The mandibular molar furca is much more sharply defined than the maxillary molar furca, mainly because the palatal root is not superimposed over the furca as with the maxillary molar (Fig. 15-22).



**Figure 15.21 Radiograph of Two-Wall Bony Defect With Burnt-Out Lingual Wall.** Radiograph of two-wall infrabony defect on mesial of molar with mesial wall (black arrow) and lingual wall (white arrow). The lingual remaining wall in this case is irregular and thin as well as “burnt out” and erased from the radiograph. This lingual wall was confirmed by probing.

In using the radiograph to aid in the detection of furcation involvement, the following rules should be kept in mind:

1. If there is a slight thickening of the PDLs in the furcation area, the area should be investigated clinically. It is a general rule that furcation involvement is often greater than the radiograph shows.
2. If there is severe bone loss on the mesial or distal surface of a multirooted tooth, furcation involvement should be suspected.

## RECOGNITION OF ETIOLOGIC FACTORS

The primary cause of inflammatory periodontal diseases is the accumulation and growth of bacterial plaque on the teeth near the gingival margin or in the sulcus or pocket. However, the periodontal tissue response to the bacteria is influenced by local, immune, and systemic factors.

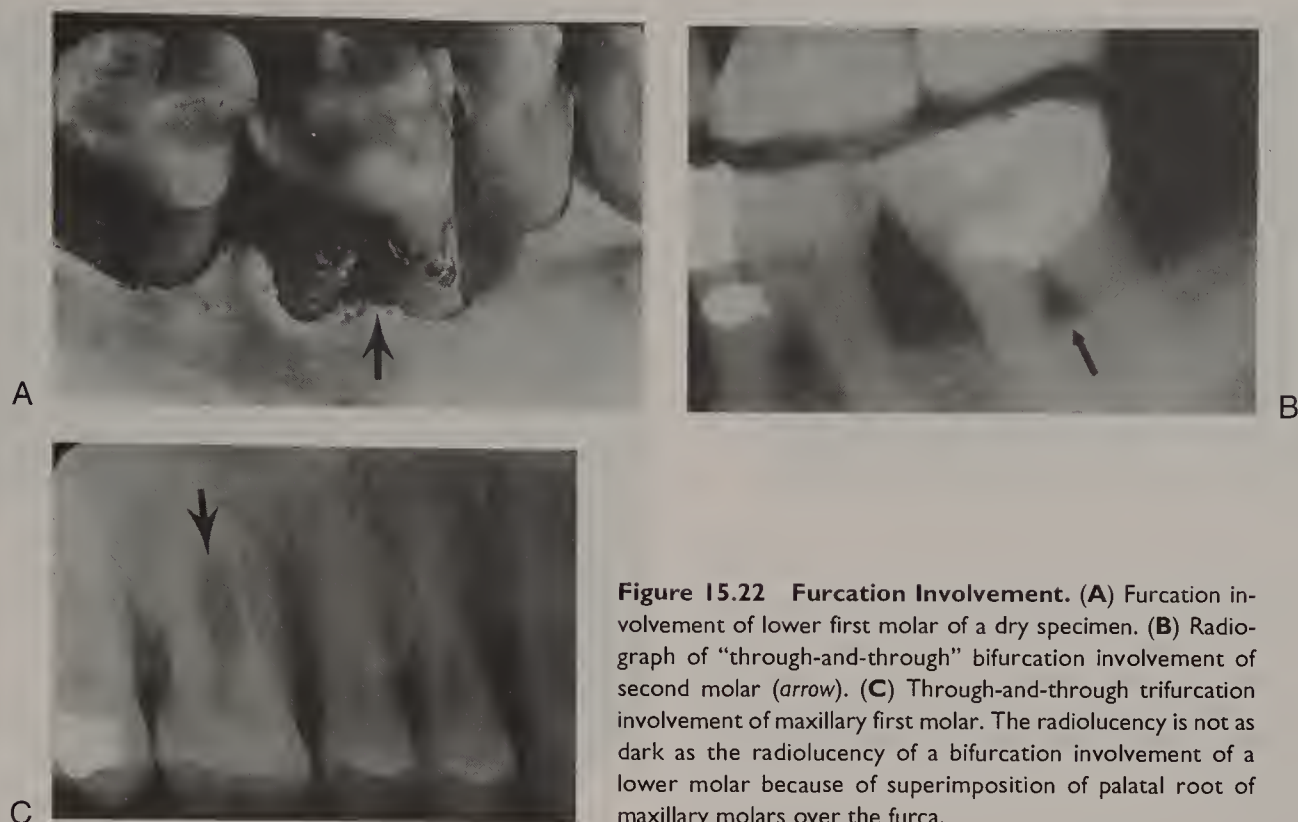
**Local factors** are found in the immediate environment of the periodontal tissues and can be divided into **local irritating** and **functional factors**. Local irritating factors are separated into **local initiating** and **local predisposing factors**. Bacterial plaque is the **local initiating factor** because it causes gingival inflammation when it accumulates on the teeth adjacent to the gingiva.

**Local predisposing factors**, such as **overhanging restorations**, **calculus**, and **food retention areas**, create a dento-gingival environment that favors the accumulation of bacterial plaque. **Local functional factors**, such as **bruxism** and **occlusal trauma**, create occlusal forces that are associated with destruction of the periodontal ligament and alveolar bone but do not affect the inflammatory process directly.

### Detection of Local Predisposing Factors

Several local predisposing factors may be detected on the radiograph: **calculus deposits**, **faulty restorations**, and





**Figure 15.22 Furcation Involvement.** (A) Furcation involvement of lower first molar of a dry specimen. (B) Radiograph of “through-and-through” bifurcation involvement of second molar (arrow). (C) Through-and-through trifurcation involvement of maxillary first molar. The radiolucency is not as dark as the radiolucency of a bifurcation involvement of a lower molar because of superimposition of palatal root of maxillary molars over the furca.

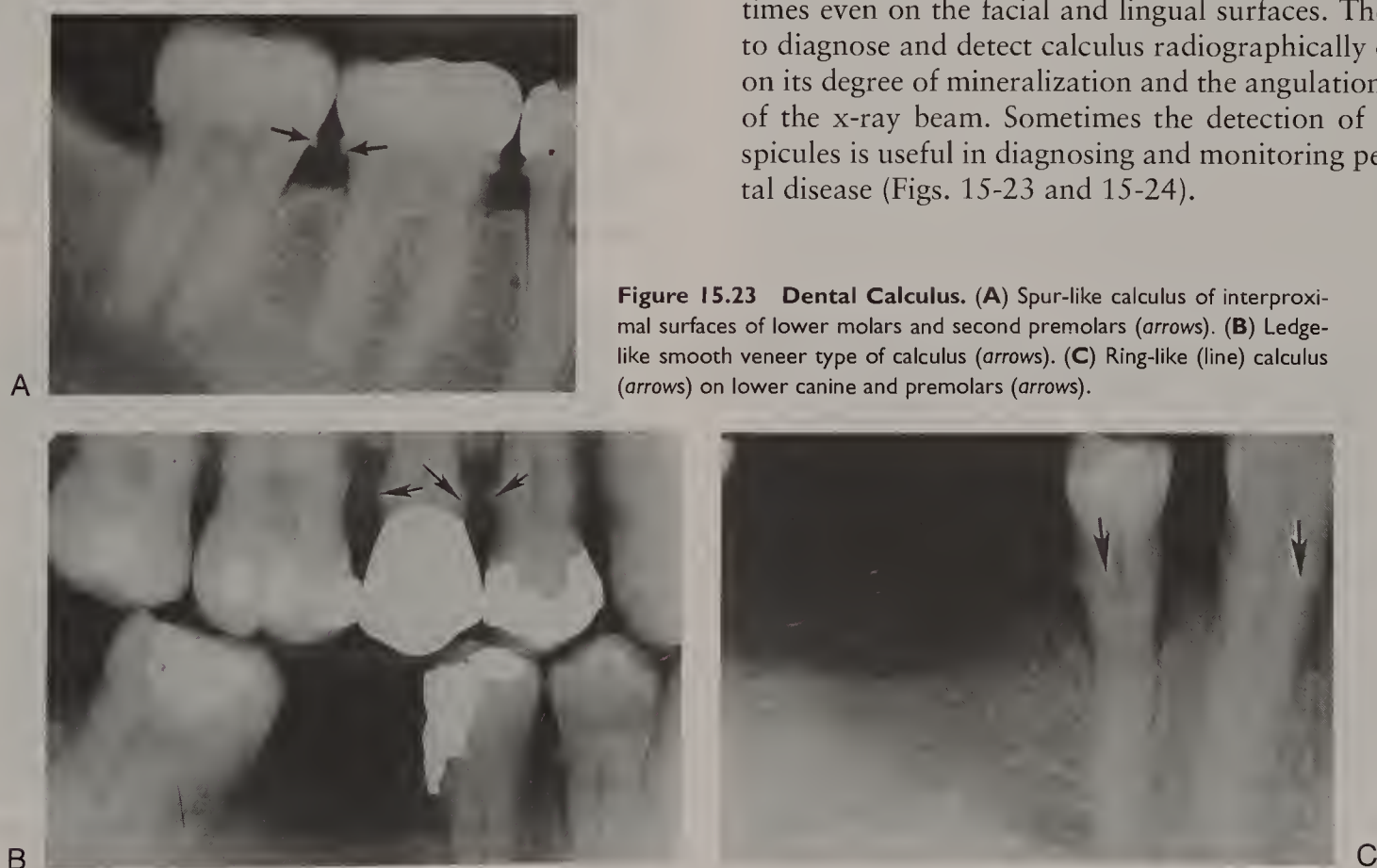
food packing areas. The radiograph plays no role in determining the cause of the predisposing factors in periodontal disease, it only detects them.

**Dental Calculus Deposits.** Calculus is bacterial plaque that has been mineralized. It can form on all tooth sur-

supragingival (salivary) and subgingival (serumal).

The primary etiologic role of calculus in periodontal tissues is that it acts as a holding mechanism for nonmineralized bacterial plaque and keeps the bacterial plaque in direct contact with the tissue.

**Dental Calculus Detection.** The radiograph shows heavy radiopaque calculus deposits interproximally and sometimes even on the facial and lingual surfaces. The ability to diagnose and detect calculus radiographically depends on its degree of mineralization and the angulation factors of the x-ray beam. Sometimes the detection of calculus spicules is useful in diagnosing and monitoring periodontal disease (Figs. 15-23 and 15-24).



**Figure 15.23 Dental Calculus.** (A) Spur-like calculus of interproximal surfaces of lower molars and second premolars (arrows). (B) Ledge-like smooth veneer type of calculus (arrows). (C) Ring-like (line) calculus (arrows) on lower canine and premolars (arrows).



**Figure 15.24 Gross Amounts of Dental Calculus.** (A) Photograph of an 88-year-old woman with a huge amount of calculus clinging to a tipped lower molar tooth and more in the posterior maxilla. (B) Radiograph of the calculus clinging to the tipped lower molar tooth of the patient in A.

**Faulty Restorations.** Inadequate dental restorations and prostheses are common causes of gingival inflammation, periodontitis, and alveolar bone resorption.

Some problems with restorations and prostheses include the following:

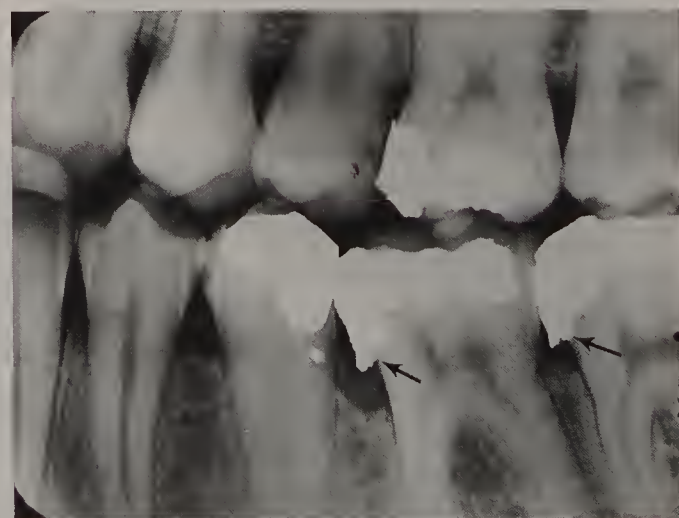
1. Overhanging margins of dental restorations (Fig. 15-25).
2. Open interproximal contacts of dental restorations (Fig. 15-26).
3. Deficient margins of crowns and aesthetic porcelain restorations.
4. Fixed and removable prostheses that are improperly adapted.
5. Overcontoured restorations and pontics that create excessive buccolingual contours and inadequate interproximal embrasure spaces.
6. Clasps of partial dentures that retain plaque adjacent to the gingiva or exert excessive occlusal forces.

Some factors leading to food impaction include the following:

1. Wear from attrition, opening contact points (Fig. 15-27).
2. Loss of occlusal support by extraction of adjacent teeth, which will open contacts by shifting the teeth.
3. Opening of the contact areas by caries (Fig. 15-28).
4. Supraeruption of teeth, opening contact points when opposing teeth are not replaced.
5. Partially impacted teeth, producing food-lodging areas around the impaction.
6. Improperly constructed restorations.

### Local Functional Factors

**Periodontal Occlusal Traumatism.** Periodontal occlusal trauma gives rise to a degenerative lesion that develops



**Figure 15.25 Overhanging Restorations.** Overhanging restorations on mesial surfaces of first and second molars (arrows).

**Food Packing Areas.** Food impaction is the forceful wedging of food through occlusal pressure into the interproximal spaces. The absence of tooth contact or presence of an unsatisfactory interproximal relationship is conducive to food impaction. As the teeth wear down and the flattened surfaces replace normal convexities, the wedging effect of the opposing cusp into the interproximal space is exaggerated and food impaction results. Cusps that tend to forcibly wedge food interproximally are known as “plunger cusps.”





**Figure 15.26 Open Interproximal Contact.** Plunger maxillary molar cusp causes food wedging between lower first and second molar, followed by caries and periodontal bone destruction.



**Figure 15.28 Caries and Open Contact.** Large carious lesion on distal of first molar has created a food packing area, which has contributed to the severe amount of destruction of alveolar bone supporting the first molar.

when occlusal forces exceed the adaptive capacity of the supporting periodontal tissues. Clinically, it is characterized by breakdown of the periodontal ligament fibers, resorption of bone, widening of the PDLs, and loosening of the teeth. The diagnosis of periodontal or occlusal trauma is made from clinical mobility tests, tooth percussion, probing, palpation, observation of wear patterns, observation of masticating movements, and the history of the patient's oral habits (bruxism, clenching). The radiograph is used only as a supplemental aid in determining periodontal or occlusal traumatism.

The radiographic signs of trauma from occlusion include the following:

1. The increased width of the PDLs of the mesiodistal surfaces due to resorption of the lamina dura.
2. Vertical or angular bone destruction.



**Figure 15.27 Attrition and Open Contact.** Severe attrition has caused a loose contact and food packing area between second premolar and first molar, with resultant periodontal destruction of alveolar bone.

**Crown-Root Ratio and Root Morphology.** Tooth stability is influenced by the amount of leverage placed on the periodontium. The type of leverage is dependent on the amount of tooth that is within bone (clinical root) in relation to the amount of tooth not within bone (clinical crown). An increase in length of the clinical crown produces unfavorable leverage on the periodontium (Fig. 15-29). In any patient the clinical root may be short or spike-like because of a morphologic variation in the normal anatomy of the root. Some Hispanic-Americans have significantly shortened roots as a result of the shovel-shaped incisor syndrome; any patient may have shortened roots from excessive orthodontic forces. If there is a loss of alveolar bone surrounding these short or spike-shaped teeth, the leverage exerted on the periodontium becomes exceedingly great (Fig. 15-30).

#### Activity of the Destructive Process

The approximate activity of the destructive process of periodontal disease can be evaluated by comparing stan-



**Figure 15.29 Clinical Crown-Root Ratio.** Note poor clinical crown-root ratio of lower first and second premolars (arrows).



**Figure 15.30 Spiked Roots.** Note short, spiked roots of maxillary premolars with thickened PDLS and overhanging restoration on distal of second premolar.

standardized radiographs taken over regular intervals. When the interdental septal bone crest is rough and irregular and the alveolar bone below the crest is devoid of any suggestion of bone opacity, it is most likely that the resorptive process is active (Fig. 15-31A). Nutrient canals indicate active and even rapid bone resorption. If a smooth surface of the alveolar bone with condensation of remaining alveolar bone is seen in the presence of bone loss, a static destructive process or slowly destructive process is indicated (Fig. 15-31B).

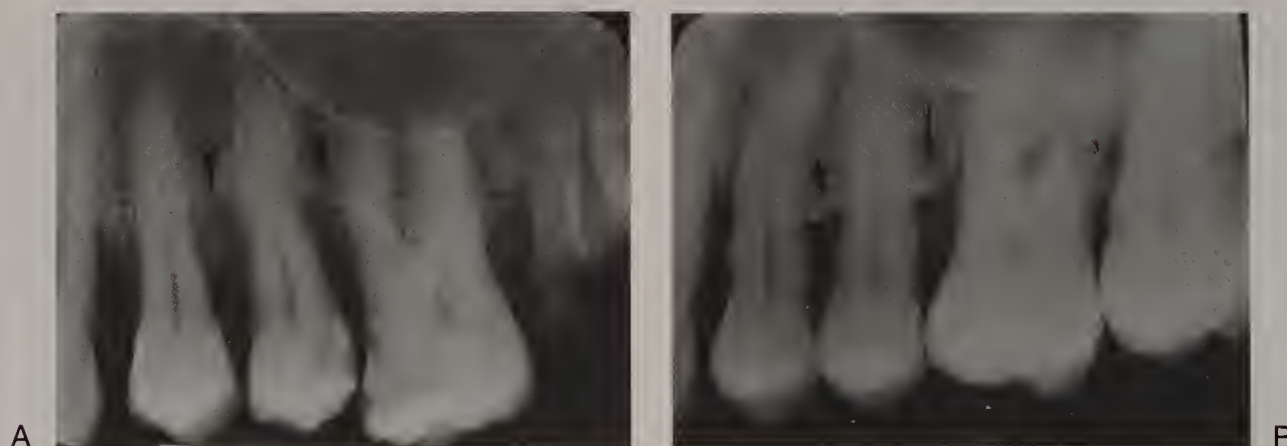
### Prognosis

The prognosis cannot be estimated until all available information has been secured. Radiographic information is part of the diagnostic data that are used in determining the prognosis. The prognosis is reasonably good if the destructive process is not generalized, the past bone response to local irritants has been good, only a limited amount of bone has been lost, the destructive activity is minimal, correctable etiologic factors can be identified

(radiographs can only identify certain local predisposing irritants and cannot determine etiology), occlusal deformities can be corrected, the location of the periodontal pocket is favorable (a patient with deep pockets and little bone loss has a better prognosis than a patient with shallow pockets and severe bone loss), the number and distribution of remaining teeth is favorable for the adequate support of a prosthesis (the crown-root ratio of abutment teeth is favorable), the patient's general health is good, the patient's teeth are normal in size and shape (not short and spike-shaped), and the patient is motivated to save the remaining teeth and is capable of performing all routine and specialized home care procedures as dictated by the extent and distribution of the periodontal disease.

### REVIEW QUESTIONS

1. Identify information that cannot be obtained from radiographs concerning the diagnosis of periodontal disease.
  1. Root length and shape.
  2. Existence or absence of periodontal pockets.
  3. Morphology (shape) of bone deformities.
  4. Clinical crown to clinical root ratio.
  5. Approximate gross amount of bone destruction.
  6. Position of maxillary sinus in relation to periodontal deformity.
  7. Position or condition of structures on the facial and lingual aspects of the tooth.
  - A. 1, 3, 4, 5, and 6.
  - B. 2, 3, and 7.
  - C. 1, 2, 3, 6, and 7.
  - D. 3, 4, 5, 6, and 7.
  - E. 1, 2, 3, 5, and 7.



**Figure 15.31 Activity of Destructive Process.** (A) Radiograph of patient with appearance of an actively destructive process. (B) Radiograph of a patient with a static destructive periodontal disease. The crests of the interseptal alveolar bone between first and second premolars are smooth and radiopaque.



2. Which of the following are benefits of the dental radiograph in periodontal diagnosis?
  1. The position of the septal bone between the teeth is usually recorded in one plane.
  2. The clinical crown to clinical root ratio is documented.
  3. Root length and root morphology are recorded.
  - A. 1 and 2.
  - B. 1, 2, and 3.
  - C. 2.
  - D. 1 and 3.
  - E. 2 and 3.
3. Which of the following statements are true concerning periodontitis?
  1. Juvenile periodontitis is a localized periodontitis occurring in teen-agers and young adults.
  2. A normal crown-root ratio is 1:2.
  3. Calculus plays a primary inflammatory role in initiating periodontal disease.
  4. The crater bone deformity is the most common osseous deformity in periodontitis.
  5. The infrabony osseous deformity is a three-wall infrabony pocket.
  - A. 1 and 3.
  - B. 2 and 4.
  - C. 1, 2, 3, and 5.
  - D. 1, 3, 4, and 5.
  - E. 1, 2, 4, and 5.
4. What is the most common cause of periodontal disease?
  - A. Overhanging restorations.
  - B. Dental calculus.
  - C. Bacterial plaque.
  - D. Malocclusion.
  - E. Habitually grinding the teeth.
5. Which of the following radiographic techniques using D speed film will most minimize the limitations of use of the radiograph in diagnosing periodontal disease?
  1. High kVp technique.
  2. Low kVp technique.
  3. Long BID bisecting angle technique.
  4. Long BID paralleling technique.
  5. Short BID bisecting technique.
  - A. 1 and 4.
  - B. 2 and 3.
  - C. 1 and 3.
  - D. 2 and 4.
  - E. 1 and 5.
6. What is the most reliable method of locating periodontal pockets?
  - A. Long BID paralleling radiograph.
  - B. Short BID bisecting angle radiograph.
  - C. Hirschfeld calibrated silver points placed in the pocket before x-ray exposure.
  - D. Probing with periodontal instrument.
  - E. Gutta percha root canal placed in the pocket before x-ray exposure.
7. The use of the radiograph in diagnosing a mobile tooth is limited to which of the following?
  - A. A tooth PDL thickening is in mesiodistal aspects of contact areas.
  - B. A tooth PDL thickening is in faciolingual aspects of supporting structures.
  - C. A tooth PDL thickening is in all aspects of tooth root.
  - D. Mesiodistal calculus on tooth. Early alveolar bone loss on mesiodistal aspects of tooth.
8. The Nabors probe is used for which of the following?
  - A. Detection of calculus.
  - B. Tooth mobility.
  - C. Early bone loss.
  - D. Depth of periodontal pocket.
  - E. Early furcation involvement.
9. Triangulation or "funneling" is defined as which of the following?
  - A. Indistinctness of continuity of lamina dura on mesial or distal aspect of tooth.
  - B. Widening of PDL by resorption of bone along either mesial or distal aspect of crestal bone.
  - C. Interseptal bone changes.
  - D. Vertical bone loss.
10. What is vertical bone loss?
  - A. It occurs when bone loss is present on a plane that is parallel to a line drawn from CEJ of a tooth to that of an adjacent tooth.
  - B. It occurs when there is a greater degree of bone destruction on interproximal aspect of one tooth than adjacent tooth.
  - C. It is the same as a three-wall infrabony pocket or defect.
  - D. It is a furcation involvement.
  - E. It is usually a consequence of localized juvenile periodontitis.

11. What is the most common osseous defect of periodontal disease?
  - A. Hemiseptum defect.
  - B. Ramping defect.
  - C. Osseous crater.
  - D. Furcation involvement.
  - E. Horizontal bone defects.
12. Which of the following is the most important radiographic consideration in planning to use certain teeth as bridge abutments?
  - A. Interproximal calculus deposits.
  - B. Food packing areas.
  - C. Periodontal functional factors.
  - D. Crown-root ratio.
  - E. Activity of the periodontal destructive process.
13. Which of the following is a local predisposing factor in periodontal disease?
  - A. Calculus deposits.
  - B. Open interproximal contacts.
  - C. Overhanging restorations.
  - D. Overcontoured dental restorations.
  - E. All of the above.
14. What are the radiographic signs of trauma from occlusion?
  1. Increased width of PDLS on mesiodistal surfaces of a tooth.
  2. Increased width of PDLS on faciolingual surface of a tooth.
  3. Vertical bone loss.
  4. Horizontal bone loss.
  - A. 1, 2, 3, and 4.
  - B. 1, 2, and 3.
  - C. 1 and 4.
  - D. 1 and 3.
  - E. 1, 3, and 4.
15. Open contacts are due to which of the following?
  - A. Caries.
  - B. Attrition.
  - C. Plunger cusps.
  - D. Supraeruption of teeth.
  - E. All of the above.

## CASE-BASED QUESTIONS

**CASE 15.1**

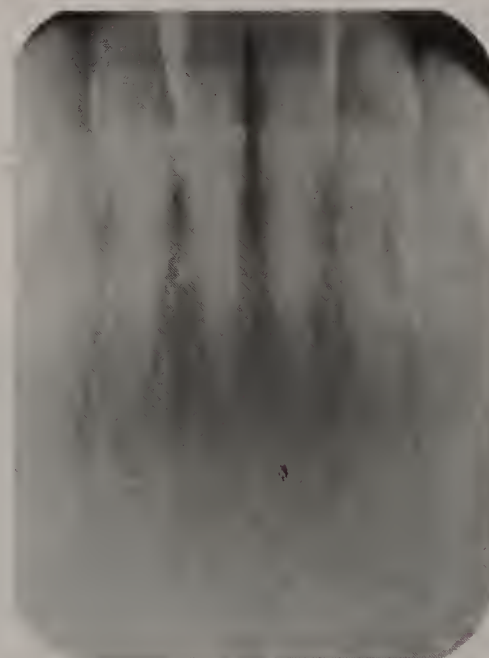
This patient is an older man with calculus.

**QUESTION**

1. In the maxillary molar, the distribution and location of the calculus is:
  - A. Circumferential.
  - B. Subgingival.
  - C. Supragingival.
  - D. Generalized.
  - E. A and B.

**CASE 15.2**

This 45-year-old woman has moderately severe horizontal bone loss and calculus.





**QUESTION**

1. The presence of prominent nutrient canals indicates:
  - A. Hyperemic and bleeding gingiva.
  - B. A good host response.
  - C. The patient is prone to posttreatment infection.
  - D. Rapidly destructive periodontitis.

**CASE 15.3**

This patient is a 58-year-old man who has long denied he has any problems; he states that he “doesn’t get cavities.”

**QUESTION**

1. There is a problem with the maxillary first molar. What term best describes its position?
  - A. Supraerupted.
  - B. Elongated.
  - C. Ectopic.
  - D. Infraerupted.

**CASE 15.4**

This patient is a 35-year-old woman who has regularly seen her hygienist and dentist for many years but had to come to a dental school due to financial problems.

**QUESTION**

1. The periodontal problem between the maxillary molars is due to:
  - A. Not replacing the second premolar.
  - B. Open contact.
  - C. An overhang.
  - D. Poorly contoured restorations.
  - E. All of the above.

**CASE 15.5**

This patient is a 50-year-old man who is without any major dental complaint.

**QUESTION**

1. What is the primary cause of the bone destruction at the mesial of the second molar?
  - A. Nonreplacement of the first molar.
  - B. Poor home dental care.
  - C. Juvenile periodontitis.
  - D. Toothpick misuse.

**CASE 15.6**

This 42-year-old woman is not prone to accept regular recalls and feels she has had little need for dental care. Her teeth have always been described by others as “beautiful.”



**QUESTION**

1. Which problems listed below do you think she has?
  - A. Moderate to severe calculus formation.
  - B. Horizontal bone loss.
  - C. Vertical bone defect(s).
  - D. Multiple open contacts of teeth.
  - E. All of the above.

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# Abnormalities of Teeth

## OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Recognize alterations in numbers of teeth on radiographs.
2. Identify alterations in tooth size, shape, and structure on radiographs.
3. Identify acquired defects of teeth on radiographs.
4. Identify alterations in tooth eruption on radiographs.
5. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

|                                    |                           |                            |                          |
|------------------------------------|---------------------------|----------------------------|--------------------------|
| abrasion                           | dental dysplasia          | fusion (synodontism)       | oligodontia              |
| amelogenesis imperfecta            | dentinogenesis imperfecta | gemination (schizodontism) | peg lateral              |
| anodontia                          | dilaceration              | ghost teeth                | regional odontodysplasia |
| anomaly                            | drift                     | hyperdontia                | supernumerary roots      |
| attrition                          | ectopic eruption          | hypodontia                 | supernumerary teeth      |
| concrecence                        | embedded tooth            | impacted tooth             | taurodontism             |
| dens evaginatus (Leong's premolar) | enamel hypoplasia         | macrodontia                | translocation            |
| dens invaginatus (dens in dente)   | enamel pearl (enameloma)  | malformation               | transposition            |
|                                    | erosion                   | microdontia                | variation                |
|                                    | familial                  | migration                  |                          |

## INTRODUCTION

A developmental abnormality is a departure or divergence from what is considered the normal process of growth and differentiation. A developmental disturbance or ab-

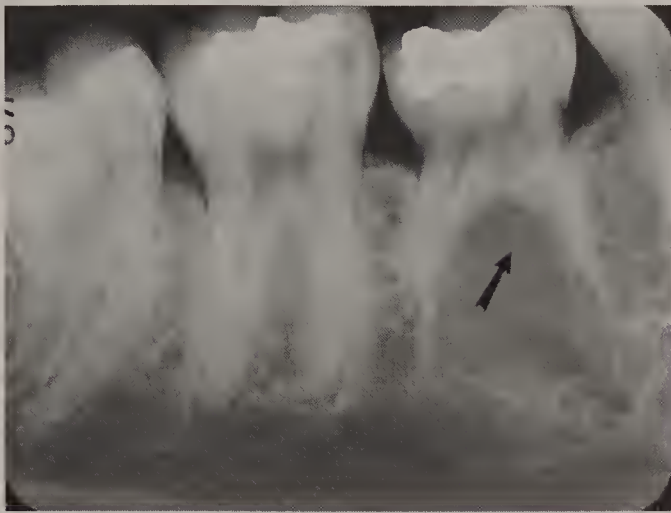
ation is a minor deviation from normal (e.g., enlarged medullary bone space), and anomalies are more severe deviations that do not interfere with function (e.g., peg laterals). Malformations are more severe deviations that do interfere with function (e.g., cleft palates). The most common anomalies are those that affect the teeth; those that result from faulty development of the supporting structures of the teeth are more rare. Anomalies discussed in this chapter may be caused by local conditions, inherited dental disorders, or manifestations of systemic disturbances in this chapter to include defects or alterations in

number, size, shape, structure, and eruption. In addition, acquired defects of teeth such as abrasion, attrition, and erosion are discussed.

## ALTERATIONS IN NUMBER OF TEETH

### ANODONTIA AND HYPODONTIA (OLIGODONTIA)

Anodontia means the absence of all teeth. In true anodontia, all teeth fail to develop; this is an extremely rare occurrence. Acquired anodontia is very common and results from the premature extraction of all teeth. Hypodontia (oligodontia) or partial anodontia means that one or several, but not all, teeth are missing. Hypodontia may be congenital or acquired. The most common congenitally missing permanent teeth are the third molars,



**Figure 16.1 Hypodontia (Oligodontia).** Congenitally missing second premolar with a retained primary second molar (arrow).

followed by the premolars and maxillary lateral incisors. When the second premolar is congenitally missing, a submerged, sometimes ankylosed (fused) second primary molar is present (Fig. 16-1).

### HYPERDONTIA (SUPERNUMERARY TEETH)

Hyperdontia refers to one or more extra teeth, and the problem is congenital only. Approximately 90% of all supernumerary teeth occur in the maxilla. The most common extra tooth is the **maxillary mesiodens** (extra tooth in maxillary midline) (Fig. 16-2). Others include upper fourth molars and mandibular premolars (Fig. 16-3). Upper fourth molars may resemble other maxillary molars or they may be small and conical. These microdontic (small) fourth molars are referred to as **distomolars** when they are distal to the third molar in location and as **paramolars** when they are seen buccal or palatal to the maxillary molars.

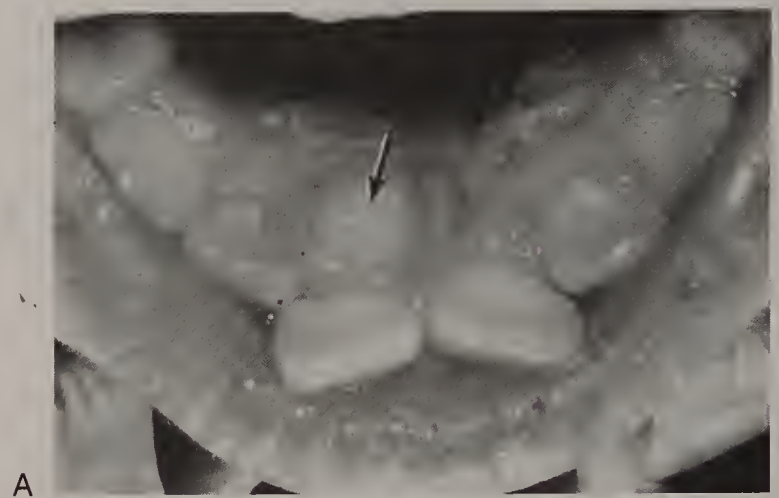
### ALTERATIONS IN TOOTH SIZE

#### MACRODONTIA

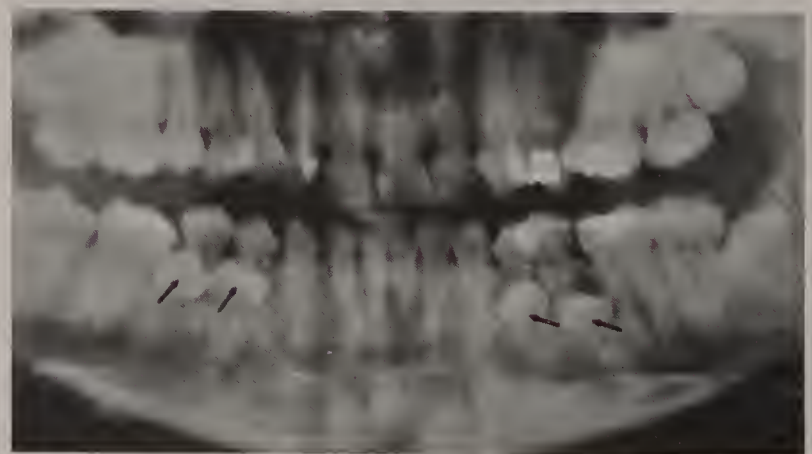
Macrodontia refers to teeth that are larger than normal (Fig. 16-4). This condition may affect all teeth, as may be seen in the pituitary giant, or may be localized and involve one or several teeth. The term macrodontia should not be applied to teeth that are enlarged due to magnification, gemination, or fusion. Relative macrodontia occurs when the teeth appear to be overly large due to micrognathia, in which the jaws are too small to accommodate the teeth.

#### MICRODONTIA

Microdontia means teeth that are smaller than normal. This condition is much more common than macrodontia.



**Figure 16.2 Hyperdontia (Mesiodens).** (A) Erupted mesiodens (arrow) located just posterior to maxillary central incisor. (B) Bilateral mesiodens (arrows).



**Figure 16.3 Hyperdontia (Supernumerary Teeth).** Bilateral unerupted supernumerary premolars (arrows).





**Figure 16.4 Macrodontia.** Extremely long canine tooth.

Generalized microdontia affects all teeth, as may be seen in the pituitary dwarf. Relative generalized microdontia occurs when the teeth appear to be too small to fill all the space provided by the jaws. Microdontia of one or several teeth is more common than the generalized form. The most commonly affected teeth are the maxillary permanent lateral incisors, sometimes known as peg laterals, and the third molars (Fig. 16-5). Peg laterals are usually cone-shaped, and the condition is often bilateral and familial in occurrence. Familial means occurring in or affecting more members of a family than would be expected by chance.

## ALTERATIONS IN TOOTH SHAPE

### GEMINATION (SCHIZODONTISM)

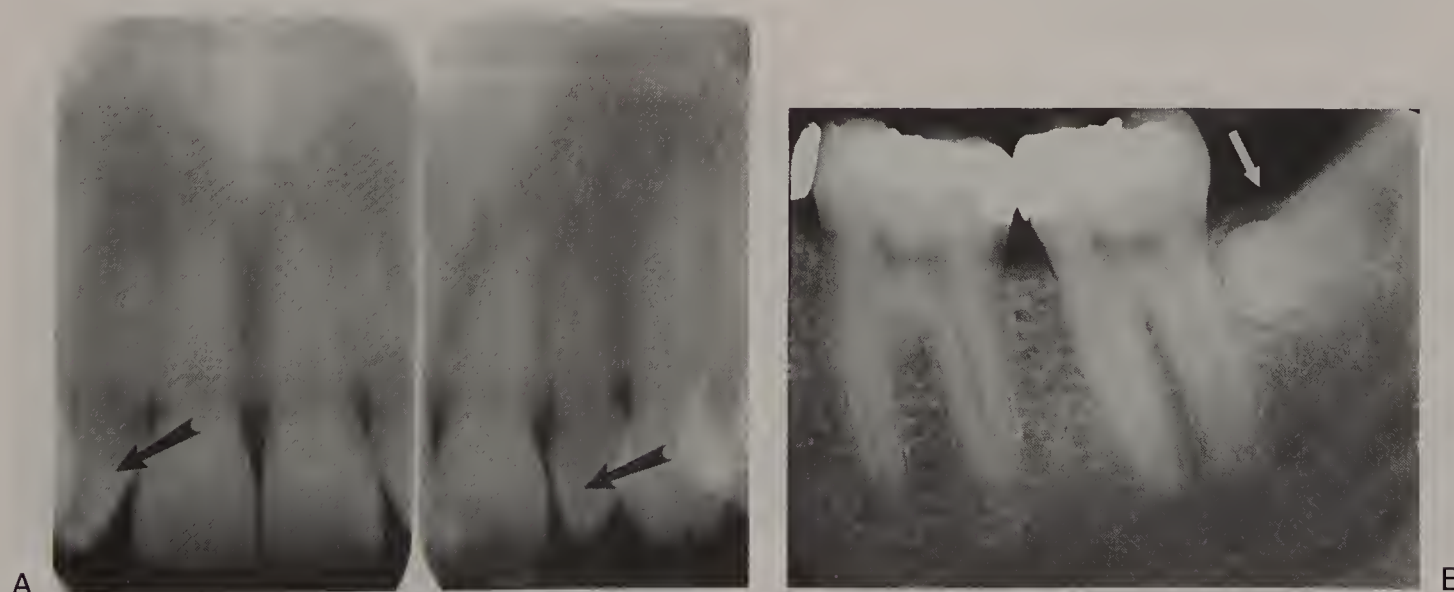
Gemination consists of an aborted attempt by a single tooth bud to divide. It most frequently affects anterior teeth, particularly in the primary dentition. In gemination, the total number of teeth in the arch is normal. Radiographically, the crown is usually enlarged and the incisal edge may be notched. The pulp chamber is often Y-shaped with two coronal portions and a single root canal space (Fig. 16-6).

### FUSION (SYNODONTISM)

Fusion occurs as a result of the union of two adjacent tooth buds by dentin and/or enamel. If fusion occurs between two normal teeth, a reduced number of teeth will be present in the arch. If the union is between a normal tooth and a supernumerary tooth, the distinction between fusion and gemination may be impossible. Fusion occurs mainly in the anterior region, particularly in the primary dentition. The most reliable radiographic sign of this condition is seen when two separate root canal spaces and pulp chambers are seen (Fig. 16-7).

### CONCRESCENCE

Concrecence occurs when there is a union between the roots of two or more teeth by cementum only. In true concrecence, the union occurs during root development and/or eruption. In acquired concrecence, the cemental union occurs after the completion of root formation, often as a result of hypercementosis (Fig. 16-8). It is usually

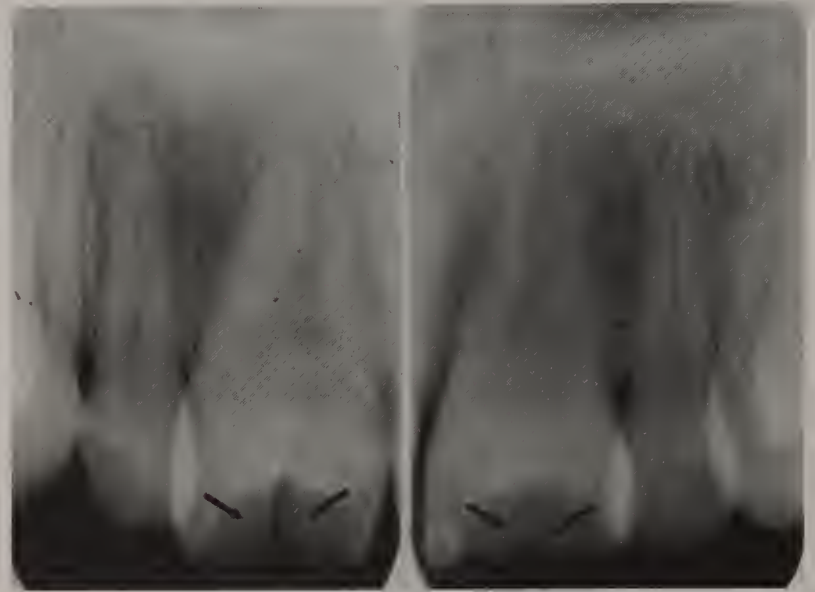


**Figure 16.5 Microdontia.** (A) Bilateral peg laterals (arrows). (B) Microdontic horizontally impacted third molar (arrow).



A

**Figure 16.6 Gemination.** (A) Photograph of a patient with bilateral gemination of maxillary central incisors (arrows). (B) Radiograph of bilateral gemination of maxillary central incisors of the patient in A.



B

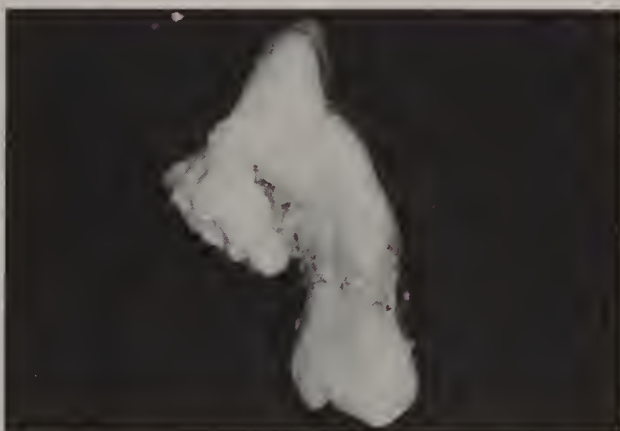


A



B

**Figure 16.7 Fusion.** (A) Fusion between two maxillary molars. (B) Fusion between lateral and central incisors. There is one less tooth in the mandibular incisor region. The fused teeth usually look like two teeth stuck together; often the dentin is confluent joined together as one, as shown here. Note there are two separate pulp chambers and root canals in this radiograph. This makes the diagnosis of fusion much easier.



A



B

**Figure 16.8 Concrecence.** (A) Gross specimen (second and third molars) of concrecence. (B) Radiograph of the gross specimen in A.



seen in the maxillary molar region. Concrescence can cause difficulty with extraction and orthodontic tooth movement.

## DILACERATION

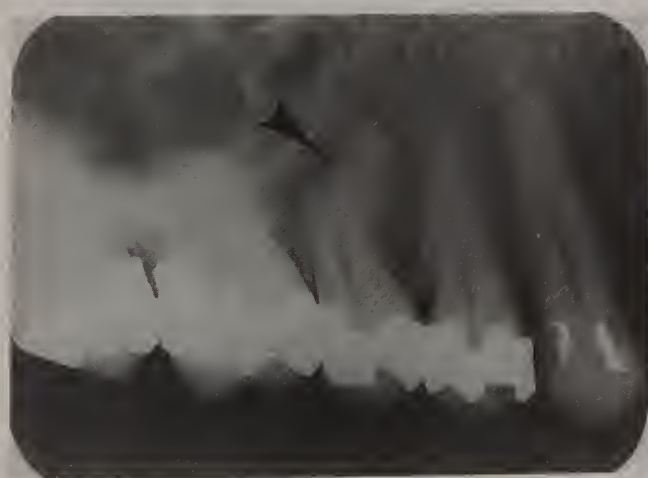
**Dilaceration** is a bent tooth. The root is most frequently involved, and it usually develops as a result of mechanical trauma during root formation and/or eruption. Some common causes include mechanical blockage of the path of eruption by the presence of neoplasms, cysts, supernumerary teeth, or orthodontic treatment. Dilaceration may occur at any location along the root and in any tooth. Dilaceration can result in malpositioning of teeth and can interfere with orthodontic realignment (Fig. 16-9).

## TAURODONTISM

**Taurodontism** (*tauros* meaning “bull,” and *odont* meaning “tooth”) refers to teeth that have an abnormally large pulp chamber and shortened roots, giving them the appearance of a bull. The condition often affects molar teeth, and clinically the teeth appear normal. The pulp chamber appears rectangular and lacks the usual constriction at the cervix. The roots are usually very short, although the overall length of the tooth is invariably normal (Fig. 16-10). Taurodontism may affect either the primary or permanent dentition, although permanent involvement is more common.

## SUPERNUMERARY ROOTS

Extra or supernumerary roots may occur on any tooth but are more frequently seen in mandibular permanent premolars and canines. Radiographic signs of supernumerary roots include double periodontal ligament spaces on one side of the root, the periodontal ligament space crossing



**Figure 16.9 Dilaceration.** Dilaceration of upper right second premolar (arrowhead).

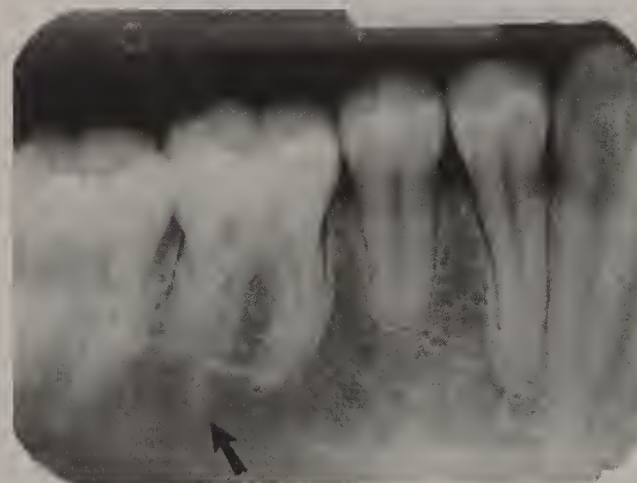


**Figure 16.10 Taurodontism.** Taurodontism of upper right first molar.

roots, and an abrupt diminution in size of the root canal space with branching, producing an inverted-Y shape of the apical portion of the root canal space. The root canal will sometimes branch into two root canals within a single rooted tooth (Fig. 16-11).

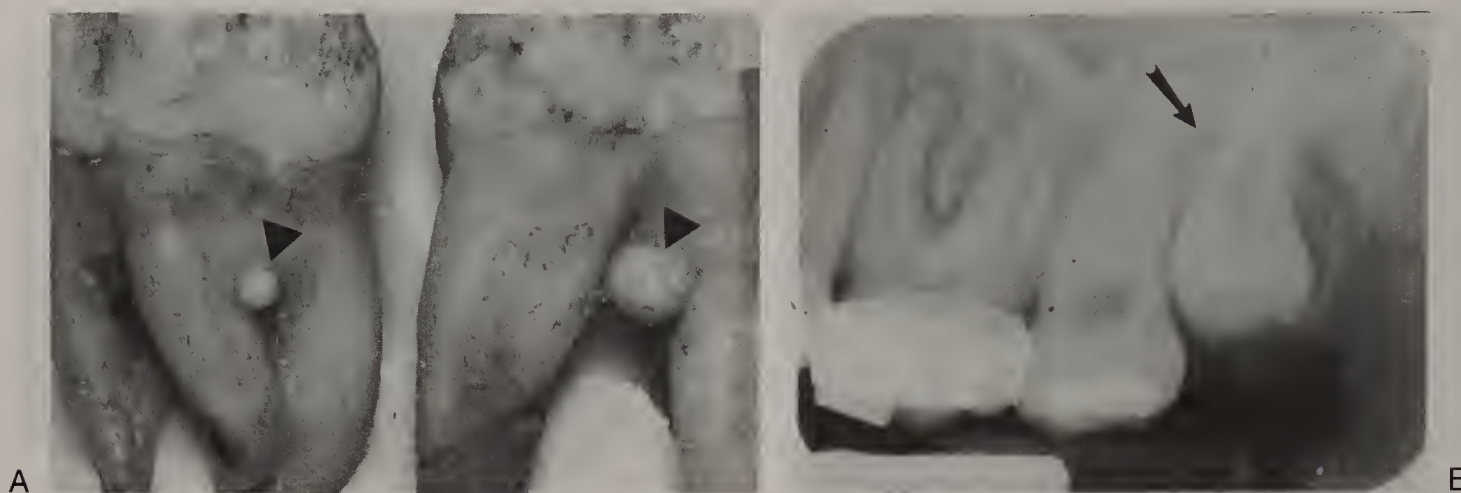


A



B

**Figure 16.11 Supernumerary Roots.** (A) Two-rooted canine (arrows). (B) Three-rooted lower molar (arrow).



**Figure 16.12 Enamel Pearls (Enamelomas).** (A) Enamel pearls in two extracted molars (arrowheads). (B) Enamel pearl on the root of an upper third molar (arrow).

### ENAMEL PEARLS (ENAMELOMAS)

Enamel pearls consist of small, round, or ovoid radiopacities seen in the cervical portion of teeth, often molars. They are usually well defined and show the same degree of radiopacity as enamel. They may be superimposed on the pulp chamber of affected teeth and may be mistaken for pulpal calcifications. Because the enamel pearl is on the outside of the tooth, it will move away from the pulp chamber when off-angle views are taken, whereas pulp stones always remain within the confines of the pulp chamber or root canal space when supplemental views are taken (Fig. 16-12). If the enamel pearl happens to be located at the bifurcation of a molar tooth at the cementoenamel junction, it could lead to a periodontal pocket formation. If the enamel pearl is a predisposing cause of periodontal disease, it may be removed. “Pseudo” enamel pearls are seen at the bifurcation of mandibular first, second, and third molars and are caused by the superimposition of parts of the mesial root on the distal root. The cause is improper horizontal angulation of the beam.

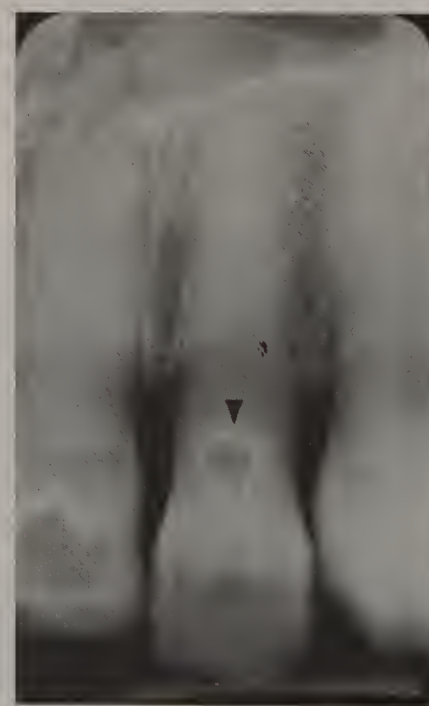
### DENS INVAGINATUS (DENS IN DENTE)

**Dens invaginatus** is a variation that arises as a result of an invagination or infolding of the tooth’s surface before calcification. This condition most frequently affects the coronal portion of the permanent lateral incisors and may occur bilaterally. Dens invaginatus is seen in 1 to 5% of the population. The invagination produces a deep lingual pit, and the underlying pulp is more susceptible to exposure by caries or by mechanical pulpal exposure in the preparation of the tooth. Radiographically, a characteristic teardrop-shaped or hourglass-shaped invagination may be seen, with or without a thin layer of dentin beneath. There is often evidence of carious penetration of the base of the invaginated enamel and varying degrees of periapical disease of pulpal origin at the apex of the tooth

(Fig. 16-13). Sealing of the pits at the earliest age will prevent the development of pulpal problems in many cases.

### DENS EVAGINATUS (LEONG’S PREMOLAR)

The reverse of dens invaginatus is a condition called **dens evaginatus**, which is an outfolding of the enamel organ on the occlusal surfaces of premolar teeth. It forms an enamel-covered, slender supernumerary tubercle (elevation) between the buccal and lingual cusps (Fig. 16-14). The most common complications of this anomaly are pulpal inflammation and necrosis due to caries, attrition, or mechanical exposure during tooth preparation. There may be a pulp horn within the tubercle, especially in younger persons.



**Figure 16.13 Dens Invaginatus (Dens in Dente).** Dens invaginatus (arrowhead) of upper left lateral, demonstrating a teardrop shape.



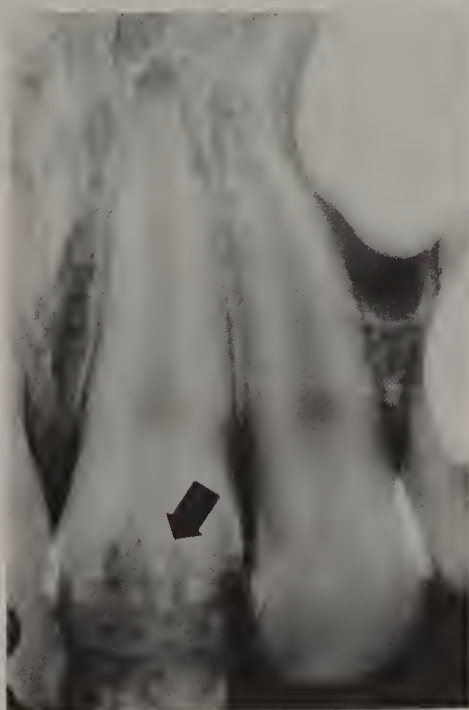


**Figure 16.14 Dens Evaginatus (Leong's Premolar).** (A) Photograph of dens evaginatus (arrowhead) of the occlusal surface of a mandibular second premolar. (B) Radiograph of dens evaginatus (arrowhead).

## ALTERATIONS IN TOOTH STRUCTURE

### ENAMEL HYPOPLASIA

Enamel hypoplasia is an incomplete or defective formation of the organic enamel matrix of the teeth. This causes defects on the surface of the enamel that may range from a white spot to a more severe and generalized mottling, pitting, or grooving (Fig. 16-15). Some unique forms of enamel hypoplasia are due to various specific causes, such as **notched screwdriver-shaped incisors** and **mulberry molars** associated with congenital syphilis, **mottled enamel** due to fluorosis, and **Turner's hypoplasia** (Turner's tooth)



**Figure 16.15 Enamel Hypoplasia (Localized).** Localized pitted type of enamel hypoplasia of permanent maxillary central incisor, probably due to infection or trauma when tooth was developing.

(Fig. 16-16) due to trauma or local inflammation associated with a primary tooth (especially the molars and maxillary incisors). Enamel hypoplasia may be due to various other causes, including nutritional deficiencies and high fevers associated with childhood diseases (Fig. 16-17). In many cases, the condition remains unexplained and is referred to as idiopathic.

### AMELOGENESIS IMPERFECTA

**Amelogenesis imperfecta** is the hereditary form of enamel hypoplasia. There are three types of amelogenesis imperfecta. The **hypoplastic type** is characterized by the presence of a thin layer of normal enamel around the crowns of all the teeth (Fig. 16-18). The **hypomineralized type** consists of a normal amount of enamel that is poorly mineralized (Fig. 16-19). In the hypomineralized type, the enamel may be pitted or chalky and tends to fracture. The **hypomaturation type** is associated with snow-capped cusp tips. For some reason, all these teeth usually have a greater resistance to caries than normal teeth.

### DENTINOGENESIS IMPERFECTA

**Dentinogenesis imperfecta** is a hereditary disorder of dentin that is transmitted as an autosomal dominant trait. (The autosome is any 1 of 22 paired chromosomes in humans, as distinguished from a sex chromosome.) The dentin and the dentinoenamel junction are affected. The teeth have a yellowish-gray opalescent (milky iridescence, like an opal) sheen, and the enamel has a tendency to chip away. In **Type 1**, the condition is associated with osteogenesis imperfecta (a generalized disease of bone), in which case there will be a history of susceptibility to fracture of the long bones, possible deformities due to multiple fractures, and blue sclera ("white") of the eyes. In **Type 2**, there is no association with osteogenesis imperfecta. In **Type 3**, the Brandywine type, the teeth only are affected

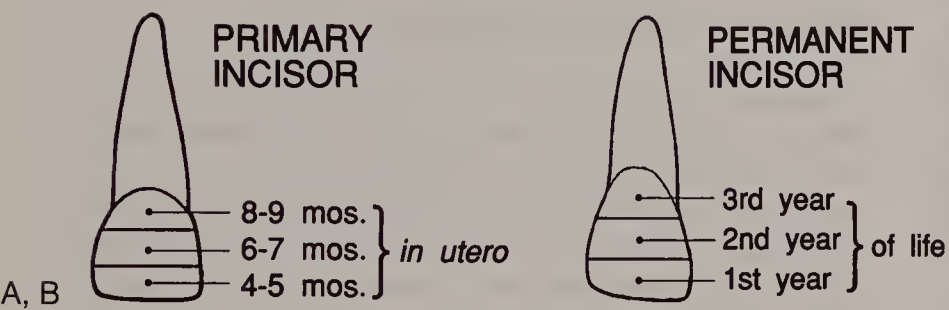
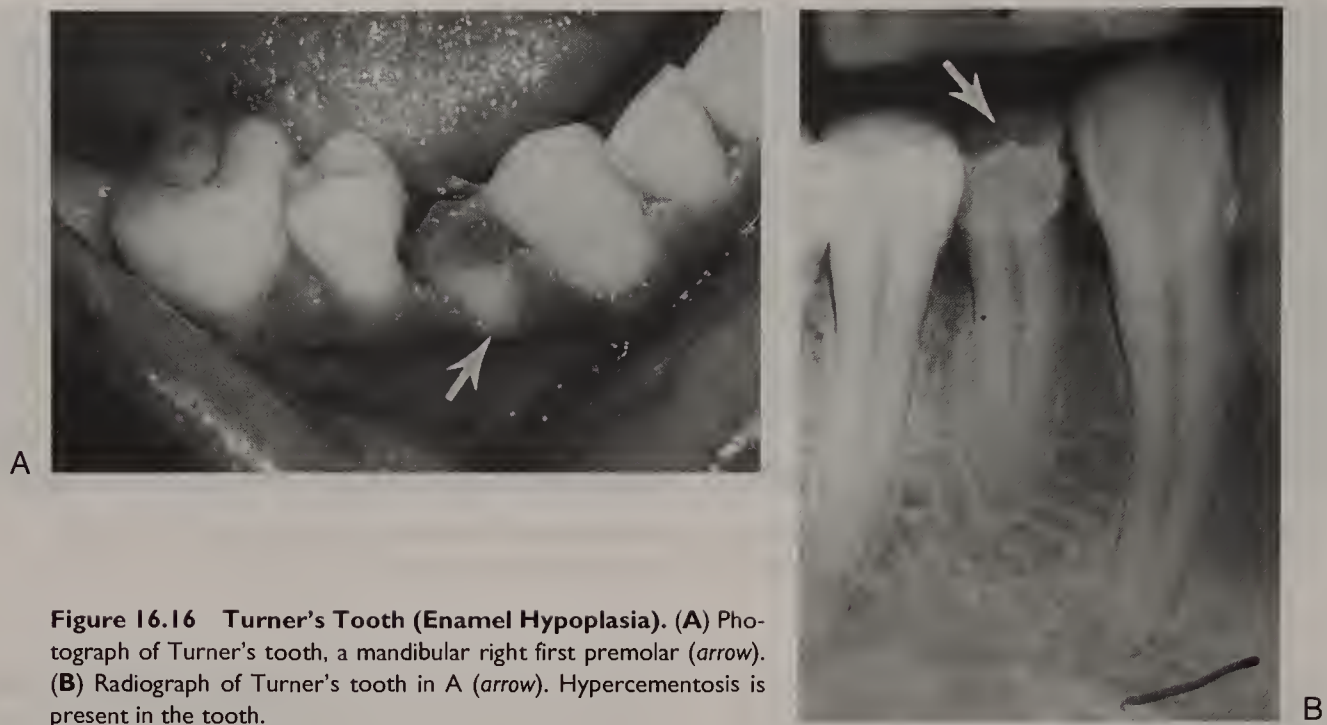
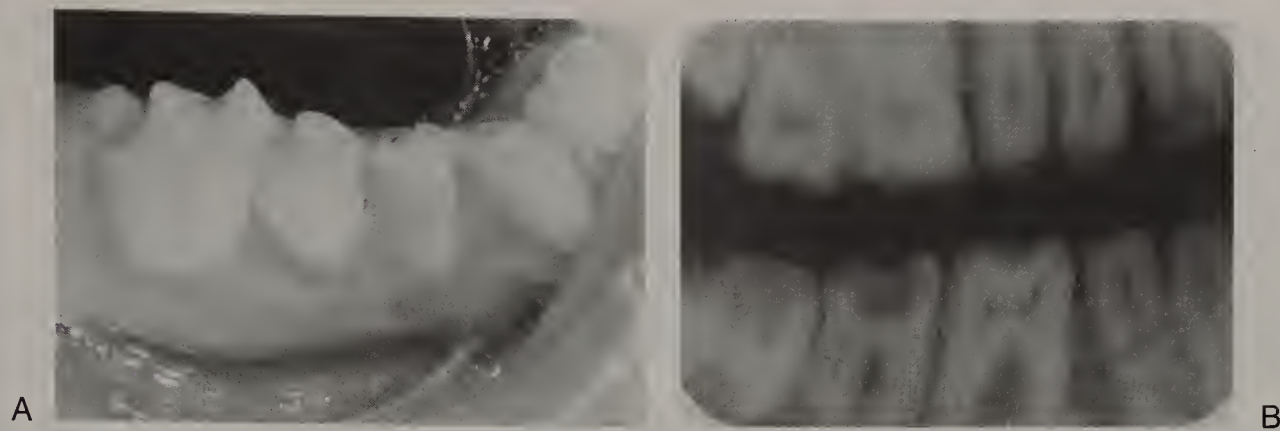


Figure 16.17 Enamel Hypoplasia Due to Serious Nutritional Deficiency or Systemic States. (A) Time frame and area on tooth enamel for **primary** incisors. (B) Time frame and area on tooth enamel for **permanent** incisors. (C) Photograph of anterior teeth with pit type of enamel hypoplasia on all incisors, except the maxillary lateral incisors. If the disturbance takes place in the first year, all incisors except the maxillary lateral incisors will be affected. (D) Enamel hypoplasia occurring late in the first year or early in the second year of life; the tips of the lateral incisors are also affected.





**Figure 16.18 Amelogenesis Imperfecta (Hypoplastic Type).** (A) Photograph of hypoplastic type. (B) Hypoplastic smooth type, right bitewings.

but more generally so. Type 3 occurs only in an inbred population of white, black, and Native American ancestry from Maryland. The radiographic features of dentinogenesis imperfecta include enamel fractures, root fractures, bulbous crowns, short tapered roots, early obliteration of the root canal and pulp spaces, and normal susceptibility to caries. Dentinogenesis imperfecta is a generalized condition affecting all the teeth, including the primary and permanent dentitions (Fig. 16-20). There is a normal susceptibility to caries, and restorations other than crowns tend to fail due to the chipping away of the enamel.

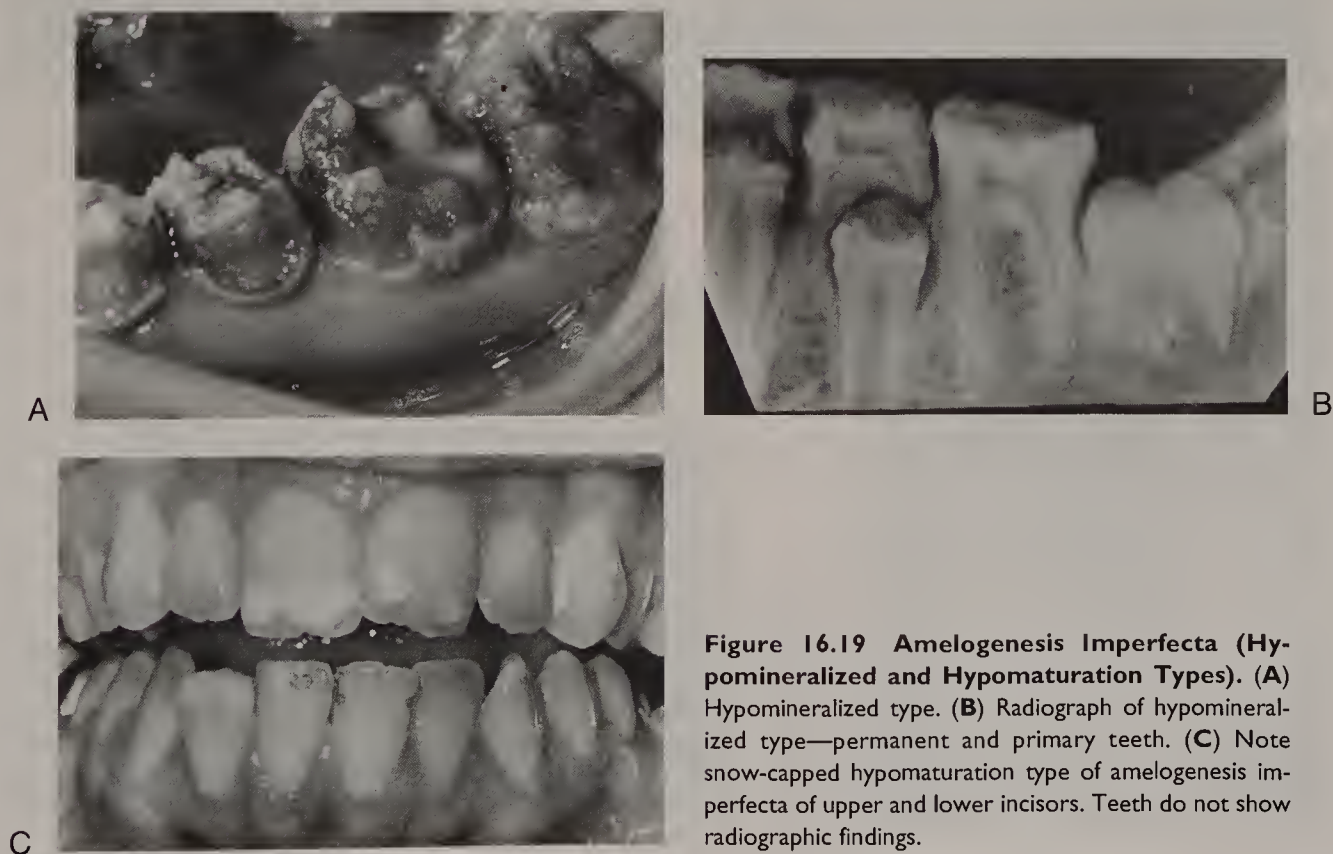
#### **DENTINAL DYSPLASIA (ROOTLESS TEETH)**

Dentinal dysplasia is a rare disturbance of dentin formation characterized by apparently normal enamel forma-

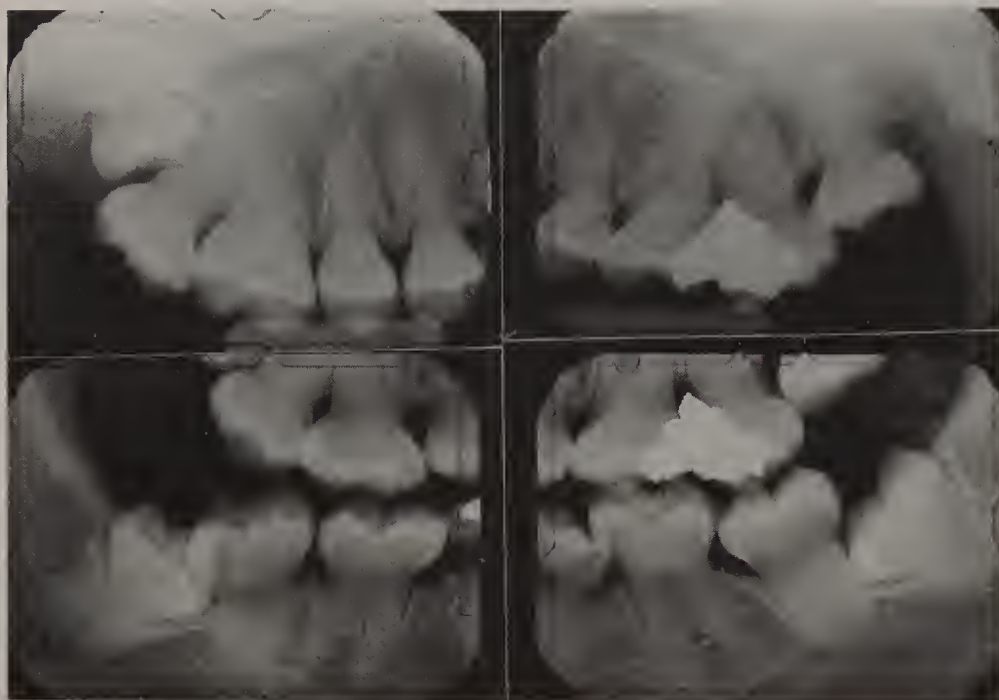
tion with an underlying, bizarre, whorl-like spherical dentinal pattern; partial or complete pulpal obliteration; pulp stones; defectively formed roots; and a predisposition for abscess and cyst formation without an obvious inciting factor, such as pulpal inflammation by caries. Dentinal dysplasia has been subdivided into two types. Type 1 has three subtypes (O'Carroll et al., 1991) and is more common. Type 2, a Shields type (Shields et al., 1973), is characterized by a large pulp chamber and narrowed root canal space (Fig. 16-21).

#### **REGIONAL ODONTODYSPLASIA (GHOST TEETH)**

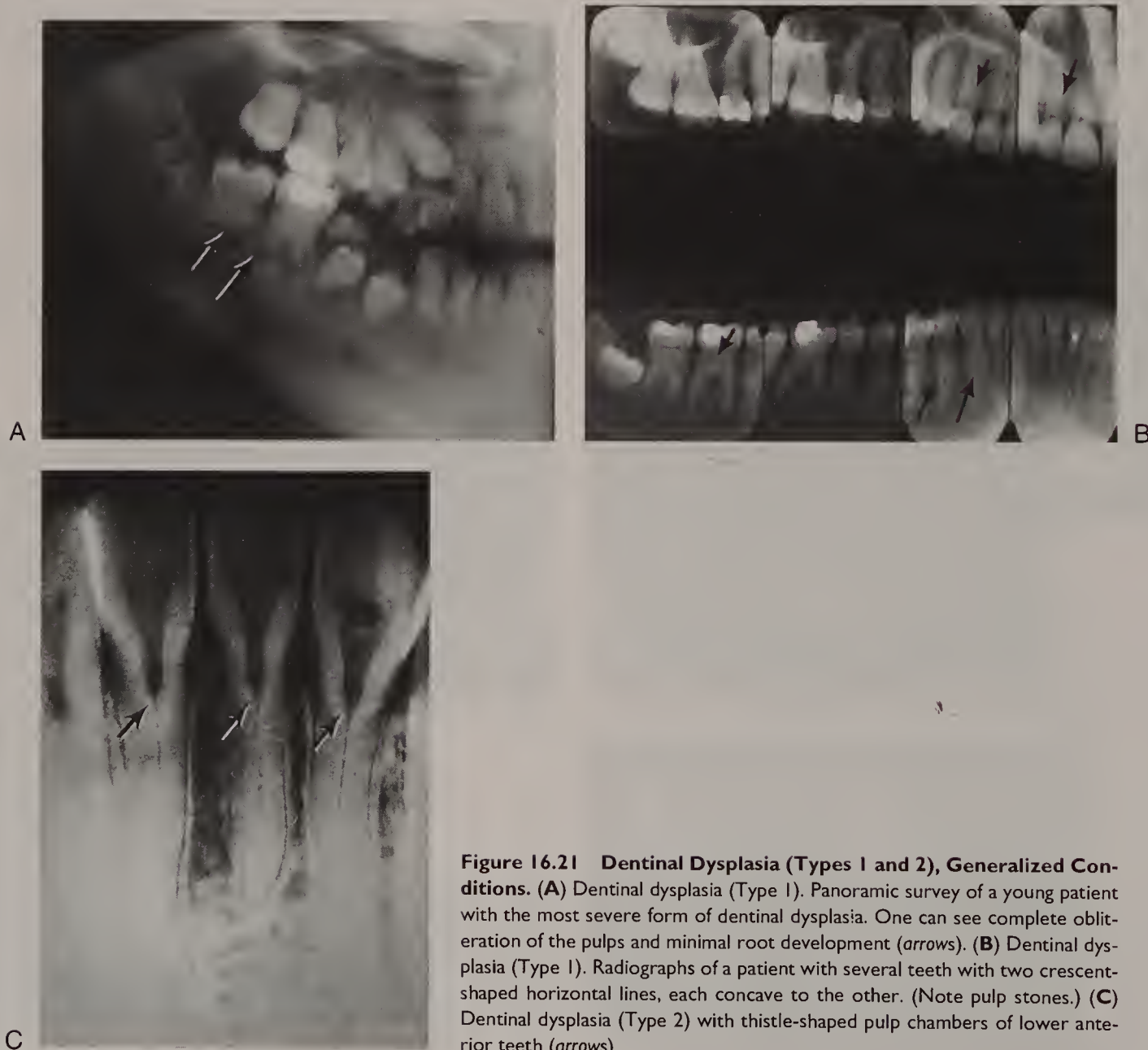
Regional odontodysplasia is a rare developmental anomaly characterized by defective dentin and enamel formation and by calcification within the pulp and dental



**Figure 16.19 Amelogenesis Imperfecta (Hypomineralized and Hypomaturational Types).** (A) Hypomineralized type. (B) Radiograph of hypomineralized type—permanent and primary teeth. (C) Note snow-capped hypomaturational type of amelogenesis imperfecta of upper and lower incisors. Teeth do not show radiographic findings.



**Figure 16.20 Dentinogenesis Imperfecta (Type 2).** This type of dentinogenesis imperfecta does not occur in association with osteogenesis imperfecta. Bitewing and maxillary posterior radiographs of a 21-year-old woman with dentinogenesis imperfecta (Type 2) are shown. Note total obliteration of the pulps, the bulbous crowns, the short and slender roots, and the evidence of early attrition.



**Figure 16.21 Dentinal Dysplasia (Types 1 and 2), Generalized Conditions.** (A) Dentinal dysplasia (Type 1). Panoramic survey of a young patient with the most severe form of dentinal dysplasia. One can see complete obliteration of the pulps and minimal root development (arrows). (B) Dentinal dysplasia (Type 1). Radiographs of a patient with several teeth with two crescent-shaped horizontal lines, each concave to the other. (Note pulp stones.) (C) Dentinal dysplasia (Type 2) with thistle-shaped pulp chambers of lower anterior teeth (arrows).





**Figure 16.22 Regional Odontodysplasia (Ghost Teeth).** The radio-density of teeth in the upper right quadrant is greatly reduced. The demarcation between enamel and dentin is absent. The pulp chambers are widened. These features contribute to the ghost-like appearance of the teeth.

follicle. The etiology has not been determined. The pulp chambers are large, and demarcation between enamel and dentin is absent, giving the so-called ghost-like appearance to the teeth (Fig. 16-22).

The affected teeth are most often localized in the jaws (regional). Eruption may be delayed, partially erupted, or

not erupted at all. Ghost teeth may occur as a solitary finding or as a feature of the Goltz-Gorlin syndrome.

## ACQUIRED DEFECTS OF TEETH

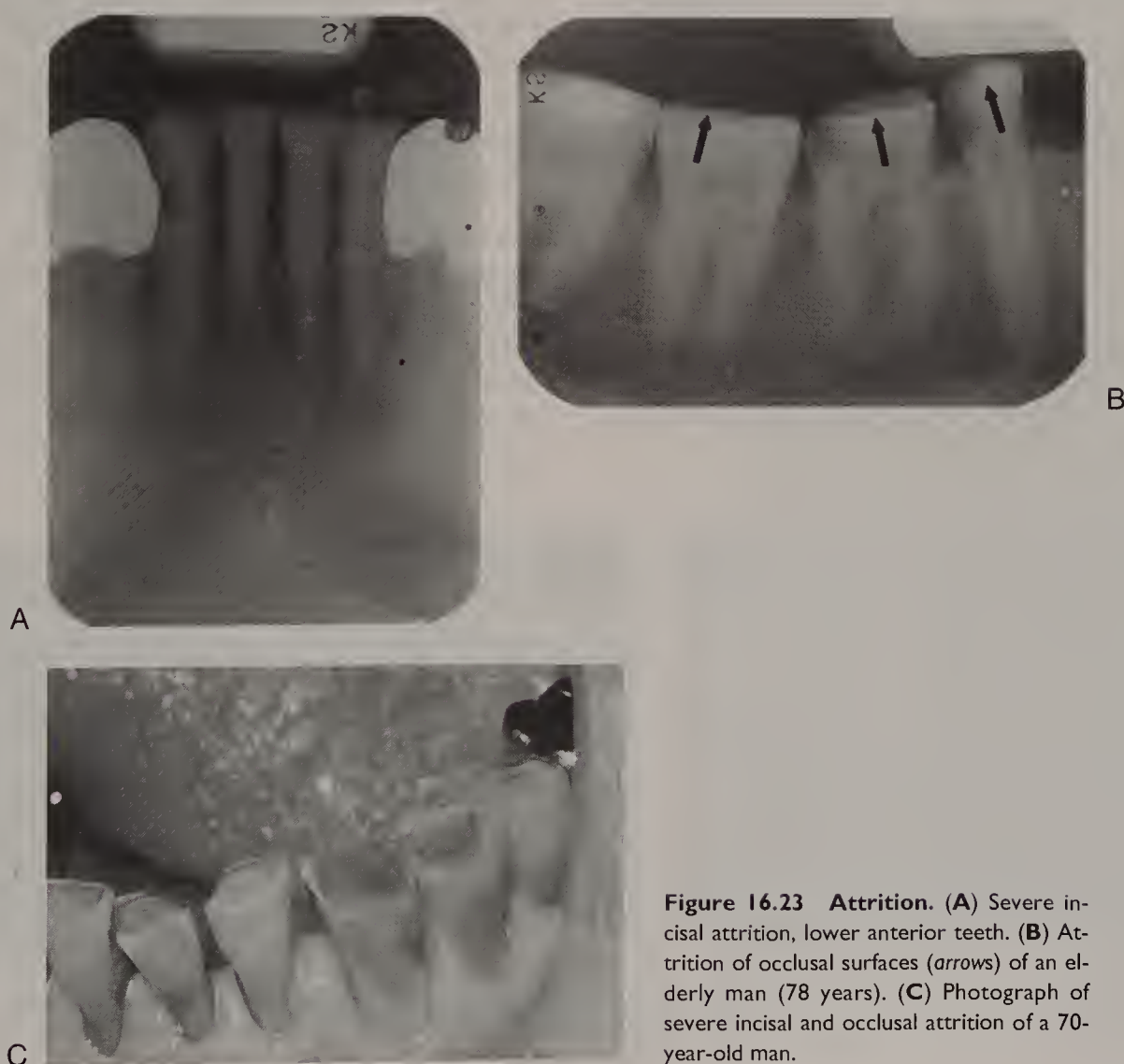
### ATTRITION

Attrition is the physiologic wearing away of tooth structure as a result of normal function. Attrition is usually generalized and most commonly affects the incisal or occlusal surfaces. It is also seen on the interproximal surfaces at the contact points. Attrition that is confined to a

function—such as a grinding, clenching, or bruxism habit—and is referred to as a severe or pathologic attrition. Radiographically, attrition is characterized by a flattening of the involved surfaces causing the teeth to appear worn down (Fig. 16-23).

### ABRASION

Abrasion is the pathologic wearing away of tooth structure by a mechanical process or by the abrasive action of substances other than food. Some types of abrasion in-



**Figure 16.23 Attrition.** (A) Severe incisal attrition, lower anterior teeth. (B) Attrition of occlusal surfaces (*arrows*) of an elderly man (78 years). (C) Photograph of severe incisal and occlusal attrition of a 70-year-old man.

clude **occupational abrasion**, which is seen in seamstresses and tailors who hold needles and pins between their anterior teeth, hairdressers who use their teeth to open hairpins or bobby pins, shoemakers and carpenters who hold nails between their teeth, and others including glassblowers, musicians, sandblasters, and farmers (in these cases, the abrasion is caused by dust). **Habitual abrasion** is seen between the incisal edges of anterior teeth in pipe smokers and from toothbrush and toothpick misuse. **Clasp abrasion** is caused by poorly designed removable partial-denture clasps. **Ritual abrasions** are mostly seen in Third

ing down the anterior teeth to create spaces between them. **Cocaine abrasion** occurs as a result of rubbing cocaine powder into the gingiva as an alternate method of cocaine absorption during bouts of severe nasal mucosal irritation from "line snorting."

Radiographically, the appearance varies greatly with the cause. Hairpins, nails, needles, and similar implements produce notched areas on the incisal edges. Pipe smoking, glassblowing, and similar activities produce an uneven wear pattern conforming to the shape of the object being held. Sandblasters and farmers may show an inordinate degree of interocclusal wear for their chronologic age due to the constant presence of gritty material in the mouth. In toothpick abrasion, the abnormal wear usually occurs beneath the contact points. Toothbrush abrasion produces a characteristic pattern in which there is a well-demarcated horizontal radiolucent line crossing the cervical area in the cervical root area and is sometimes V-shaped in certain radiographic views (Fig. 16-24). Toothbrush abrasion may resemble cervical caries.

## EROSION

**Erosion** is the loss of tooth substance by a nonbacterial chemical process. Clinically, the teeth appear smooth and

glistening, and the underlying yellowish dentin may be exposed and sensitive, particularly to temperature changes. There may be a history of difficulty in retaining restorations. Known causes include chronic vomiting as in bulimia (Fig. 16-25A), chronic regurgitation (vomiting) as in hiatal hernia, excessive intake of acidic carbonated soft drinks, habitual sucking of lemons and acidic candy, use of acidic medications such as a dilute hypochloric acid and some iron preparations, and occupation in industries using acid. The radiographic findings are essentially nonspecific in most instances, although the crowns of the teeth may appear slightly more radiolucent than normal (Fig. 16-25B).

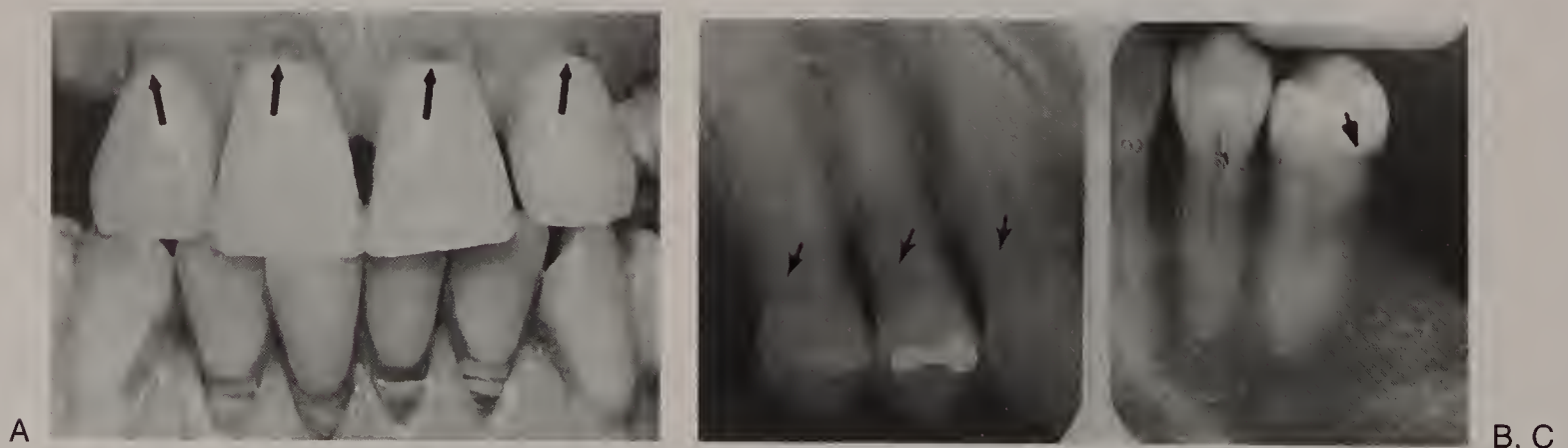
## ALTERATIONS IN TOOTH ERUPTION

### DRIFT AND MIGRATION

**Drift** refers to the movement of an erupted tooth when either mesial or distal contact is lost. **Distal drift** is the most common and is frequently seen in mandibular second premolars (Fig. 16-26). **Migration** refers to an abnormal movement of an unerupted tooth. It usually occurs in a mesial direction and is seen more frequently in the mandible. Migrated teeth usually remain embedded within the jaw (Fig. 16-27).

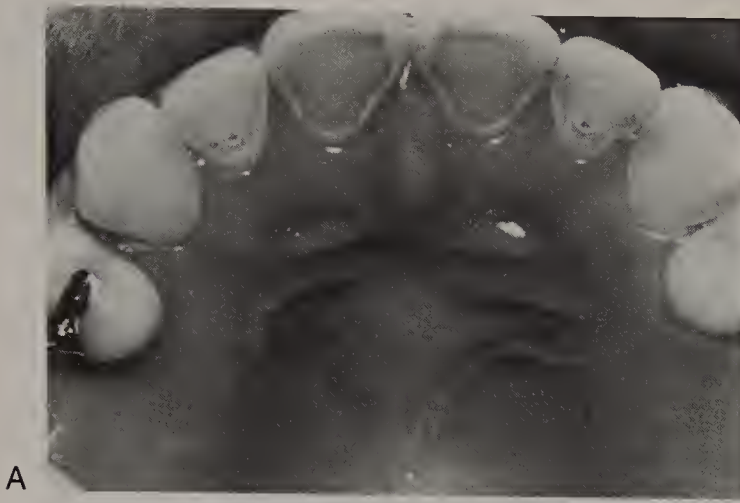
### TRANSLOCATION (TRANSPOSITION) AND ECTOPIC ERUPTION

**Translocation** or **transposition** of teeth occurs when a tooth erupts into the normal position of another or when there is an interchange of position between two teeth. Because the translocated teeth occupy normal positions within the arch, crowding is usually absent and the curvature of the arch remains normal (Fig. 16-28). **Ectopic**



**Figure 16.24 Toothbrush Abrasion.** This condition is caused by brushing back and forth horizontally on the cervical neck of the teeth, rather than using the preferred up-and-down motion. (A) Toothbrush abrasion of maxillary (arrows) and mandibular anterior teeth. (B) Radiograph of toothbrush abrasion of cervical surfaces, right canine and premolars. (C) Note V-shaped toothbrush abrasion on distal of premolar. Sometimes this resembles cervical caries.





A

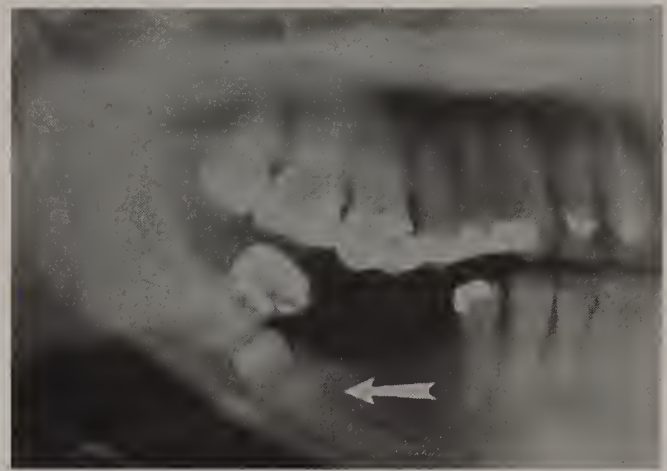


B

**Figure 16.25 Erosion.** (A) Photograph of a 31-year-old woman with bulimia, which causes an abnormal increase in the sensation of hunger. Note erosion on lingual surfaces of the teeth in this patient from excessive vomiting. (B) Radiograph of maxillary central incisor erosion of lingual surfaces of central incisors of a patient with bulimia.



**Figure 16.26 Distal Drift.** Radiograph showing distal drift (arrow) of the erupted second premolar.



**Figure 16.27 Migration of Unerupted Tooth.** Panoramic view of distal migration (arrow) of an unerupted second premolar to mesial root region of erupted second molar.



A



B

**Figure 16.28 Translocation (Transposition).** (A) Photograph of translocation of maxillary canine and lateral incisor. (B) Translocation of maxillary canine and lateral.

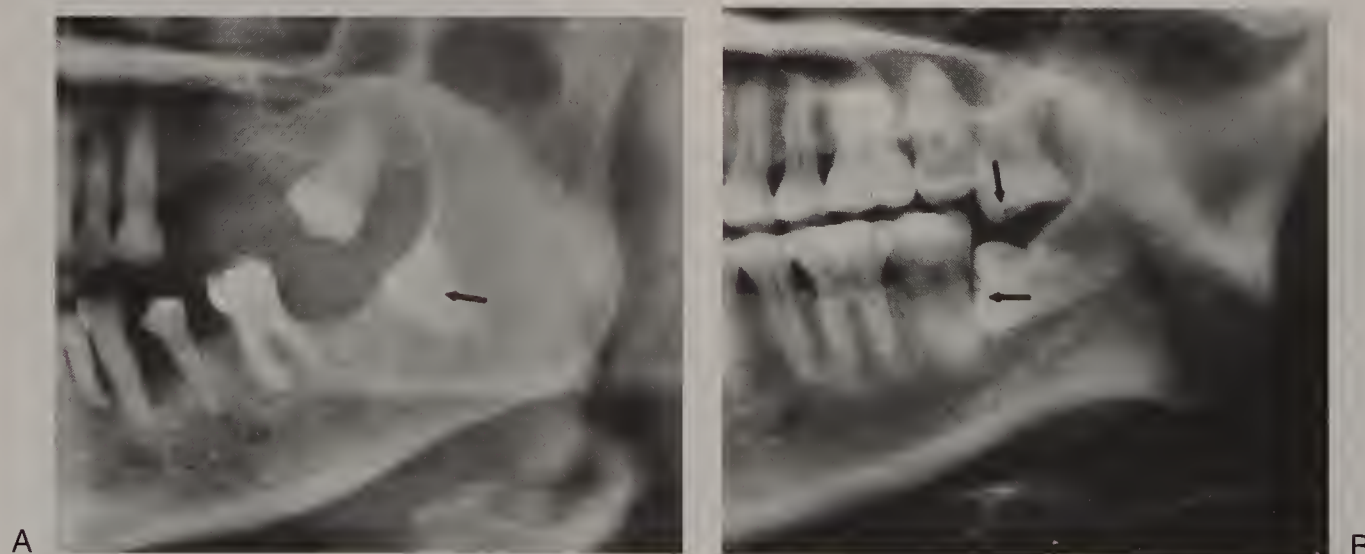


**Figure 16.29 Ectopic Eruption.** (A) Radiograph of double row of anterior incisor teeth with erupting permanent teeth. (B) Double row of lower anterior teeth (permanent and primary teeth) because of prolonged retention of primary incisor teeth and crowding. Permanent teeth have ectopically erupted lingually to primary incisor teeth. In a note there is no resorption of the roots of the primary teeth.

eruption refers to the eruption of a tooth into an abnormal position in the arch. In this instance there may be crowding, and the wayward tooth may be located in a buccal or lingual position, producing a disruption of the even curvature of the arch (Fig. 16-29).

### EMBEDDED AND IMPACTED TEETH

An **embedded tooth** is one that has failed to erupt and remains buried in the bone (Fig. 16-29). An **impacted tooth** is one in which some physical entity has prevented eruption (Fig. 16-30). The third molars and the maxillary canine are the most frequently impacted or embedded, followed by the premolars and supernumerary teeth.



**Figure 16.30 Embedded and Impacted Teeth.** (A) Embedded mandibular third molar that failed to erupt and remains buried in bone. Note tooth is ankylosed to bone, as no periodontal ligament space can be seen. (B) Horizontally impacted lower third molar (arrow) and a supraerupted maxillary third molar (arrow) because there is no antagonist below.



## REVIEW QUESTIONS

- What is the prominent feature in taurodontism?
  - Enamel hypoplasia.
  - Abnormal dentin.
  - Extension of the pulp chamber deep into the root portion of the tooth.
  - Pulp cavity has been obliterated and the entire tooth is more opaque.
- Radiographically, the teeth in amelogenesis imperfecta show what?
  - Dentin with significant disturbances; enamel is normal.
  - Dentin and enamel with significant disturbances.
  - Pulp and dentin are abnormal.
  - Very thin or defective enamel; dentin is normal.
  - None of the above.
- Radiographically, the teeth in dentinogenesis imperfecta show what?
  - Pulp is abnormal; dentin is normal.
  - Dentin only shows disturbances.
  - Enamel is missing; dentin formation is normal.
  - Shortened roots, obliterated root canal, and pulp spaces.
  - None of the above.
- When two teeth appear to be joined by cementum alone, the condition is termed:
  - Fusion.
  - Gemination.
  - Concrescence.
  - Dilaceration.
- An enamel pearl is usually seen:
  - At the cervical region of a tooth.
  - Within the pulp chamber.
  - As a tubercle on the occlusal surface of the tooth.
  - On the lingual of the anterior teeth.
  - On the cusp tips of newly erupted incisors.
- When one tooth takes the place of another in the arch, the condition is termed:
  - Migration.
  - Distal drift.
  - Translocation.
  - Ectopic eruption.
- When teeth are larger than normal, they are termed:
  - Microdontia.
  - Macrodontia.
  - Distomolars.
  - Paramolars.
- The pathologic wearing away of tooth structure by a mechanical process is termed:
  - Attrition.
  - Erosion.
  - Abrasion.
  - None of the above.
- What is Turner's tooth?
  - Hereditary hypoplasia of enamel of dominant character.
  - Hypoplasia of enamel of local origin.
  - Hereditary hypoplasia of enamel of recessive character.
  - Hypoplasia of enamel from congenital syphilis.
  - A tooth characterized by significant hypoplasia and hypocalcification of enamel and dentin.

## CASE-BASED QUESTIONS

### CASE 16.1

This patient is a 20-year-old dental hygiene student and a daughter of an orthodontist.



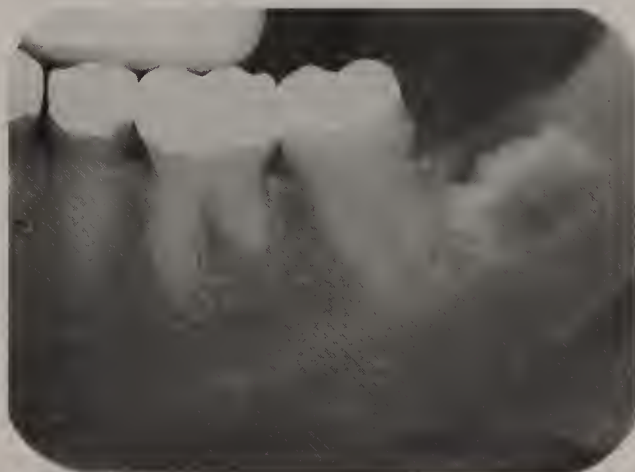
## QUESTIONS

- Which anomaly(ies) is (are) present in the lateral incisor?
  - Dens in dente.
  - Dens evaginatus.
  - Orthodontic root resorption.
  - A, B, and C.
  - A and C.

2. What, if any, procedure for the maxillary lateral incisor should this patient seek from a classmate?
- A better radiograph.
  - A thorough prophylaxis.
  - A sealant for a lingual pit.
  - No procedure is needed.

**CASE 16.2**

This patient is a 14-year-old girl whose teeth have been crowned because the enamel was chipping away and ordinary fillings failed.

**QUESTION**

1. This patient has:
- Amelogenesis imperfecta.
  - Dentinogenesis imperfecta.
  - Dentin dysplasia.
  - Enamel hypoplasia.
  - None of the above.

**CASE 16.3**

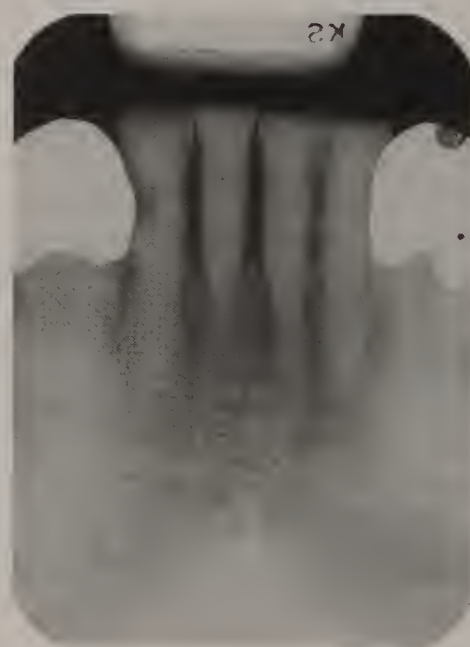
A third-year dental student brought his grandfather (a retired librarian) in for dental treatment.

**QUESTIONS**

1. The condition affecting the four incisor teeth is:
- Attrition.
  - Abrasion.
  - Erosion.
  - Dentinogenesis imperfecta.
2. The problem affecting the right lateral incisor is:
- Caries.
  - Cervical burnout.
  - [Redacted]
  - There is no problem; it is an older radiolucent silicate restoration.

**CASE 16.4**

This patient is 9 years old, and the permanent central incisors have not erupted. The lateral incisors have erupted.

**QUESTION**

1. What is (are) the reason(s) for the noneruption of the central incisors?
- Insufficient arch space.
  - Failure to initiate orthodontic treatment.
  - Extraction of the primary incisors at an early age.
  - Bilateral mesiodens.
  - A, B, and C.

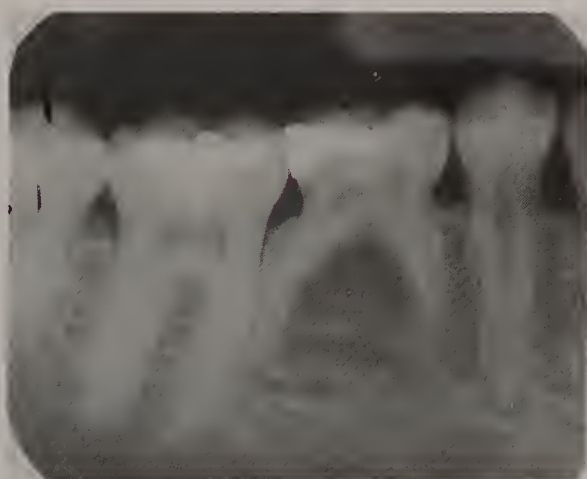


**CASE 16.5**

This patient is a 24-year-old dental student who needs to have his third molars removed.

**QUESTIONS**

1. The term that best describes the shape of the mesial root of the second molar is:
  - A. Tapered.
  - B. Dilacerated.
  - C. Supernumerary.
  - D. Hypoplastic.
2. The distal-buccal attached gingiva adjacent to the first molar appeared bluish. The problem is:
  - A. An intraoral nevus.
  - B. Localized gingivitis and periodontitis due to the poor restoration.
  - C. Chemical (fixer) stains.
  - D. Amalgam tattoo.

**CASE 16.6****QUESTION**

1. What is the anomaly in this radiograph?
  - A. Microdontia
  - B. Taurodontism.
  - C. Congenitally missing tooth.
  - D. Hypercementosis.
  - E. Supernumerary molar.

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# Radiologic Diagnosis of Caries

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. *Identify and interpret caries by type and location.*
2. *Discuss and describe factors influencing caries interpretation.*
3. *Test his or her knowledge by answering the Review Questions.*

## KEY WORDS/PHRASES

|                        |                              |                             |                       |
|------------------------|------------------------------|-----------------------------|-----------------------|
| abrasion               | cementoenamel junction (CEJ) | facial caries               | plaque                |
| acute caries           | cervical burnout             | hypoplasia                  | pulpal caries         |
| arrested caries        | chronic caries               | incipient caries            | rampant caries        |
| attrition              | dental caries                | interproximal enamel caries | recurrent caries      |
| caries progression     | dentinal caries              | lamellar caries             | restorative materials |
| caries-to-normal ratio | dentinoenamel junction (DEJ) | lingual caries              | root caries           |
| cemental caries        |                              | occlusal caries             | secondary caries      |

## INTRODUCTION

A great percentage of the radiologic interpretation done in the dental office is devoted to acquiring information regarding dental caries, periodontal disease, and periapical disease. Because the earliest studies conducted to determine the causes of tooth extraction (Allen, 1944; Brekhus, 1929) reached similar conclusions that caries, periodontal disease, and periapical disease accounted for approximately 93% of tooth loss, it is imperative that the dental health-care worker become competent in the radiologic interpretation of these diseases.

**Dental caries**, or tooth decay, is a pathologic process consisting of localized destruction of dental hard tissues by organic acids produced by the microbial deposits adhering to the teeth. The carious lesions, or the localized destructions of tooth hard tissues, are the signs of the disease. Dental caries is a multifactorial disease with an interplay of three principal factors: (1) the host (primarily

the teeth and saliva), (2) the microflora, and (3) the substrate or diet. In addition, there is a fourth factor: time. When the three essential parameters of dental caries—a susceptible host, cariogenic oral flora, and a suitable local substrate—are present in an individual for a considerable time, dental caries may develop. Carious lesions do not develop without plaque (bacterial mucous mass). When **plaque** contains appreciable portions of highly acidogenic bacteria, such as *Streptococcus mutans*, and is exposed to readily fermentable dietary sugars, it produces sufficient concentrations of acids to demineralize the enamel. Therefore, the pathogenicity of plaque depends on its microbial composition and on the availability of dietary sugars. Characteristically, dental plaque resists removal by the physiologic oral cleaning factors such as saliva and tongue movement; however, plaque is removable by tooth-brushing, if the bristles can reach it. Unlike the sharp decline in caries currently being experienced in Western Europe and North America, caries is increas-

ing rapidly in children in developing Third World countries.

## INTERPRETATION OF CARIES BY TYPE AND LOCATION

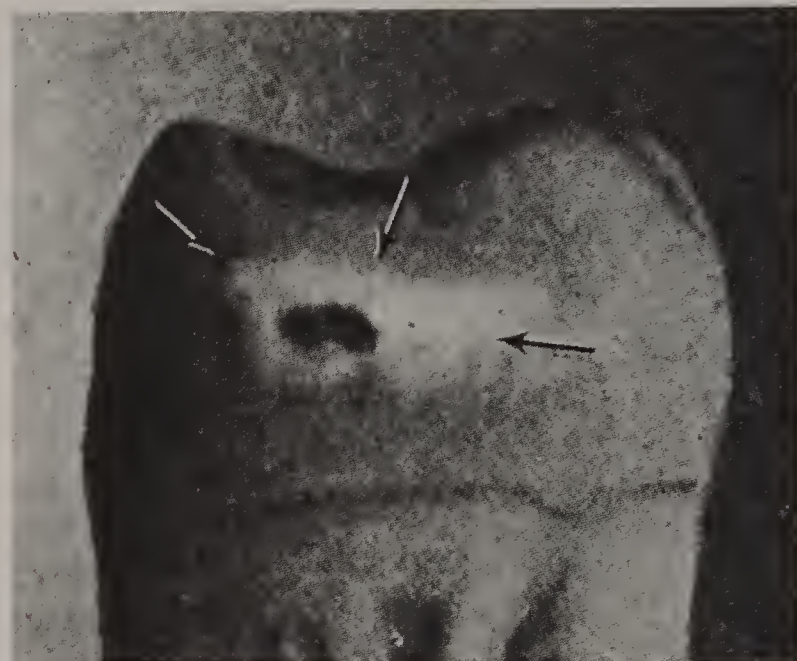
Because dental caries is essentially a process of decalcification, a certain percentage (50%) of the calcium and phosphorus must be destroyed before the decreased density of these minerals can be seen on the radiograph. The classification of the radiographic appearance of caries is discussed according to the following headings: (1) caries location on the tooth (interproximal, occlusal, facial/lingual, pulpal, root, or cemental), (2) recurrent or secondary caries (immediate vicinity of preexisting restoration), and (3) arrested caries (occlusal and interproximal surfaces).

### INTERPROXIMAL ENAMEL CARIES

Interproximal is defined as “between two adjacent surfaces.” The use of confusing and inappropriate terms such as “approximal” and “proximal” should be discouraged. The posterior interproximal enamel carious lesion is the most easily recognized on the radiograph; however, it is the most difficult to detect by use of clinical methods only. In an investigation by Hansen (1980), four times as many posterior interproximal enamel carious lesions were found when posterior bitewings were used when compared with clinical observations alone. **Interproximal enamel caries** usually begins just below the contact point and appears clinically as a chalky, white spot that becomes slightly roughened due to early demineralization (Fig. 17-1). As the carious lesion progresses, it often forms a classic V-shaped radiolucent appearance, with the base of the radiolucent triangle at the surface of the tooth and usually forming a rounded apex pointed toward the **dentinoenamel junction (DEJ)**. Several possible interrelated factors may explain the classic v-shaped configuration of interproximal enamel caries: (1) the carious lesion tends to follow the direction of the enamel rods which are usually aligned at right angles to the DEJ; (2) because the interproximal enamel surface is usually convex, the enamel rods tend to converge at the DEJ; (3) these two factors combined could explain the v-shape of a typical interproximal enamel carious lesion (Fig. 17-2). Nevertheless, there are exceptions to this explanation, as various shapes and sizes of interproximal enamel carious lesions may be seen radiographically (e.g., line-shaped, W-shaped, flame-shaped, half-moon-shaped). According to Newbrun (1989), the determinants of the shape of the carious lesions are still unknown.

#### Lamellar Caries

At one time, the onset of caries was thought to be related to the presence of lamellae in the enamel (proteolytic theory), which were considered pathways of primary inva-

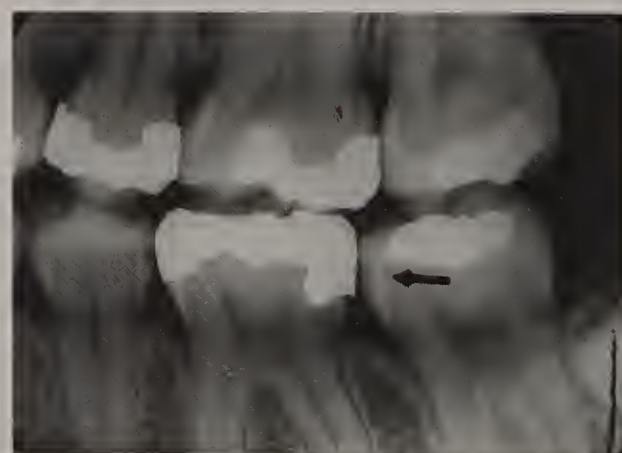


**Figure 17.1 Early Carious Lesion.** Note the white, chalky appearance of the interproximal area with a stained cavitation between the contact point and the cemento-enamel junction of the extracted tooth. (Reprinted with permission from Black AD. *Pathology of Hard Tissues of the Teeth*. 7th Ed. Chicago: Medico-Dental Publishers, 1936:346.)

sion. Because lamellae are in all teeth, inevitably some of them may be involved in carious lesions; hence, they are called **lamellar caries**. Scott and Wyckoff (1949), however, believed that the association between lamellae and carious lesions is random and not a cause-and-effect relationship. Regardless of etiology, lamellar caries appears radiographically as a dark, thin line running completely through the interproximal enamel into the dentin, where the caries then spreads along the DEJ (Fig. 17-3).

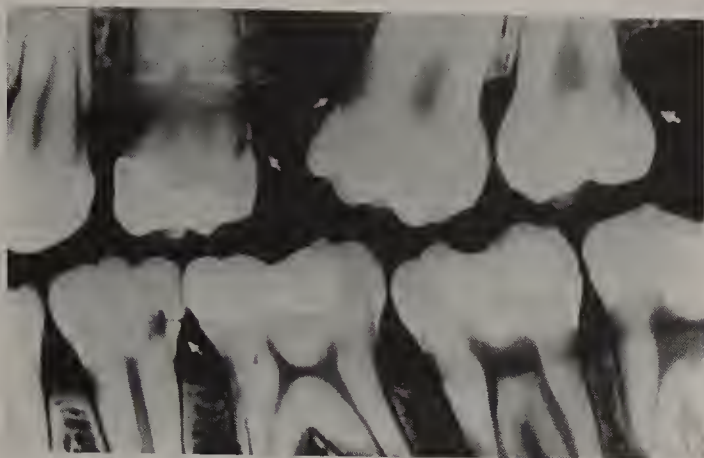
#### Incipient Caries

**Incipient interproximal enamel caries** can be seen on a radiograph as a small, cone-shaped radiolucent area in the

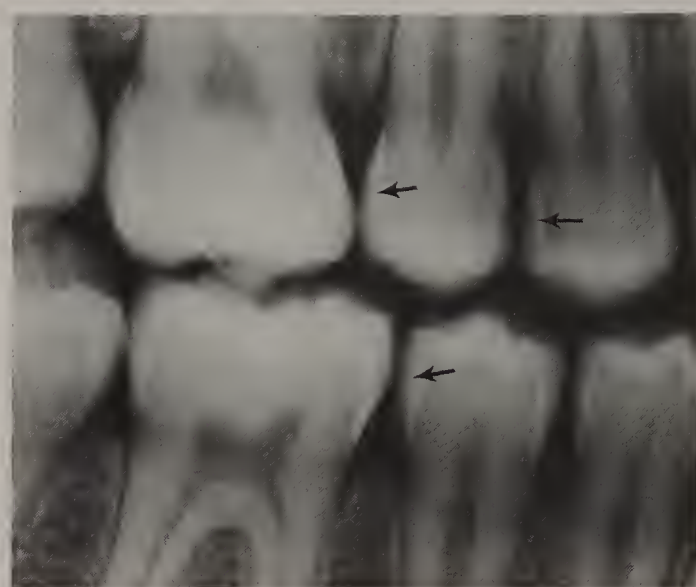


**Figure 17.2 Interproximal Enamel Caries.** Note classic V-shaped caries on mesial surface of the mandibular second molar (arrow). The enamel carious lesion on the distal surface of the mandibular second premolar has a rounded triangular-shaped appearance.





**Figure 17.3 Lamellar Caries.** Bitewing radiograph. Note "line-shaped" enamel caries with dental spread at dentinoenamel junction of distal surface of maxillary mandibular second premolar (arrows). The radiolucencies at mesial of the maxillary second molar and distal of the third molar are areas of cervical burnout.



**Figure 17.4 Interproximal Incipient Enamel Carious Lesion.** Bitewing radiograph revealing incipient enamel carious lesions on distal interproximal surfaces of the premolars (arrows).

outer enamel surface (Fig. 17-4). At this stage, the incipient lesion may be arrested or even reversed by remineralization, if an effective preventive program is enacted. Restoration of an incipient lesion is an elective procedure that is generally not recommended, except in cases of high caries susceptibility.

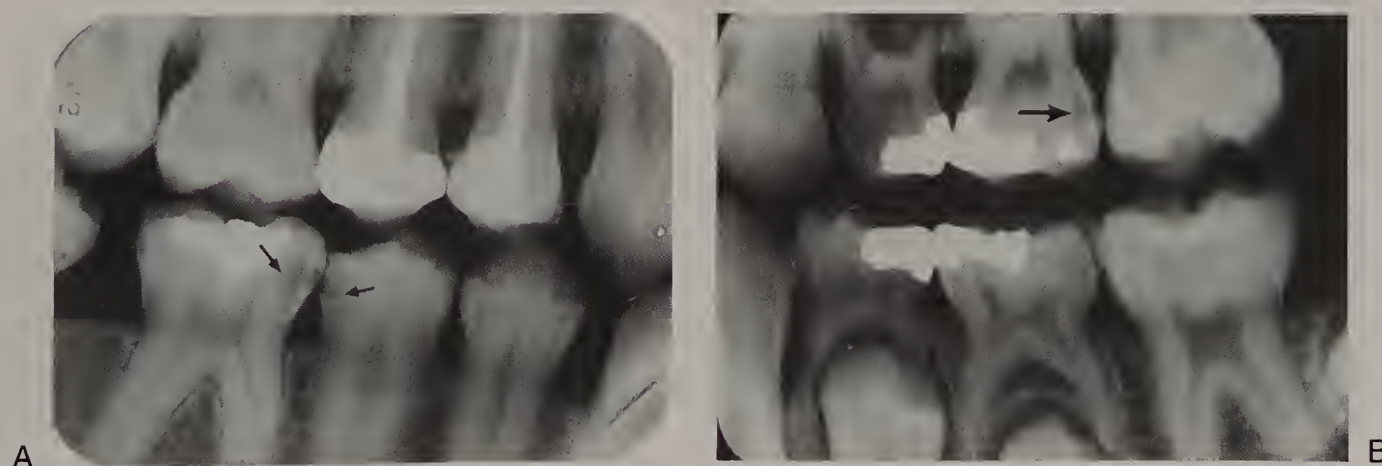
### Dentinal Caries

As the carious lesion reaches the DEJ, it usually first spreads laterally, undermining normal enamel. In the dentin, it spreads much more rapidly toward the pulp, in a form much like a mushroom, with its base on the DEJ (Fig. 17-5). Each of the dentinal tubules enlarge and act as a tract for microorganisms to travel. This leads to eventual destruction of dentinal tubules and the spread of the lesion.

### Interproximal Enamel Caries Progression

There is a need in private practice and teaching clinics for a caries scoring code to classify interproximal enamel car-

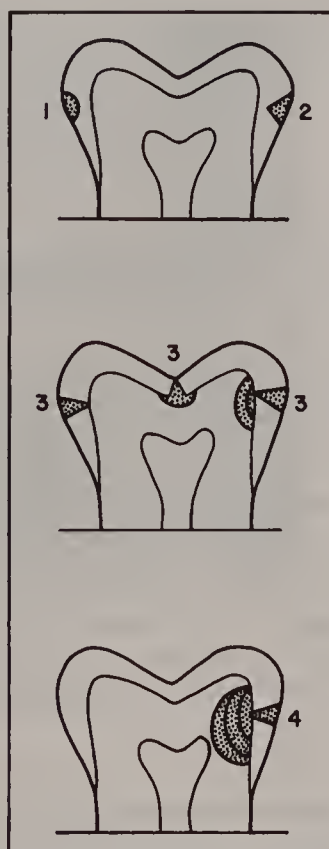
ious lesions according to their radiographic depth of penetration into a tooth. Not all early or incipient interproximal enamel carious lesions detected radiographically should be restored. Recent data have provided evidence that caries progression in many industrialized countries has slowed, leaving adequate time for nonsurgical treatment of interproximal lesions. However, the progression rate of lesions varies among individuals and among lesions within the same individual. On the basis of these observations, it is essential that decisions to treat or not to treat incipient lesions by restorative procedures should be based on combined radiographic and clinical assessments. Therefore, it is important for the dentist and his or her staff to record in the patient's chart as objectively as possible the radiographic findings related to interproximal enamel caries penetration. An example of a caries penetration scoring code is shown in Figure 17-6. Each of the



**Figure 17.5 Dentinal Caries.** (A) Note dental carious lesions in distal surface of mandibular second premolar (arrow) and mesial of mandibular first molar (arrow). (B) Note dental spreading of carious lesion at dentinoenamel junction of distal surface of the upper second primary molar (arrow).

### Classification of Radiographic Caries

- C-1. Enamel caries less than 1/2 way through enamel (sometimes called incipient caries). Do not record these lesions if doubtful of their existence.
- C-2. Enamel caries penetrating at least 1/2 way through enamel, but NOT involving dentino-enamel junction.
- C-3. Caries of enamel and dentin definitely at or through the dentino-enamel junction extending less than 1/2 way to pulp cavity.
- C-4. Caries of enamel and dentin penetrating more than 1/2 way through dentin toward pulp cavity.



**Figure 17.6 Classification of Radiographic Caries.** An example of a caries penetration scoring code illustrating four classes of interproximal caries penetration.

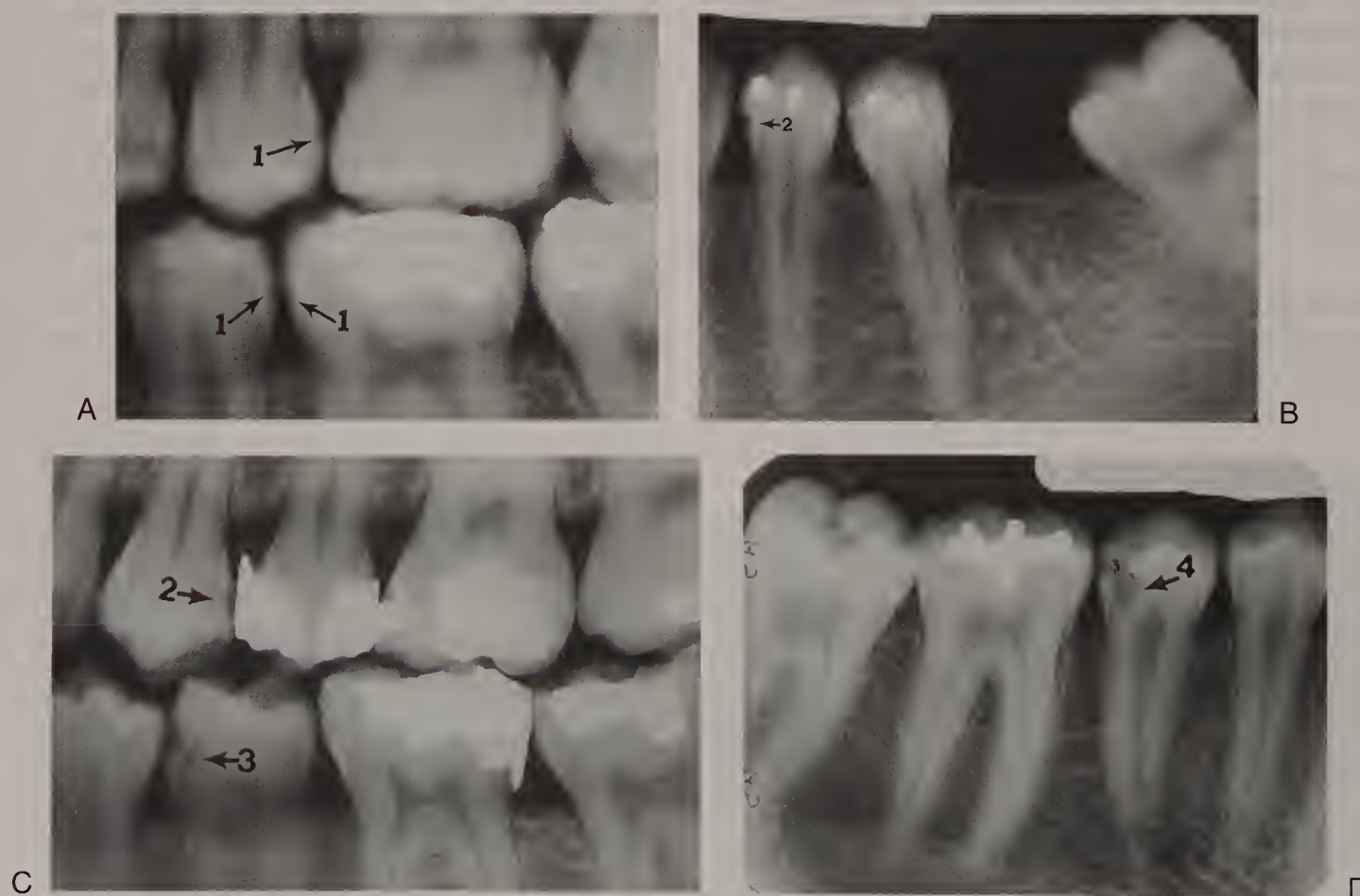
four classes of interproximal enamel caries penetration is illustrated in Figure 17-7.

**Rampant Caries.** Rampant caries is a sudden, rapid, and almost uncontrollable destruction of teeth and involves surfaces of teeth that are ordinarily relatively free of caries. Interproximal and cervical surfaces of anterior teeth, including mandibular incisors that are usually relatively caries free, may be attacked. Rampant caries is most often observed in the primary teeth of young children, in the permanent teeth of teenagers (11 to 19 years of age), and in adult patients with xerostomia (Fig. 17-8).

**Acute and Chronic Caries.** In most cases of acute caries (a condition commonly seen in young adults between the ages of 15 and 25 years), there is a rapid penetration through the enamel, and the initial entrance of the carious process remains small (Fig. 17-9). In chronic caries (commonly seen in adults older than 25 years of age), there is a slower progression of the lesion, and it has a larger entrance at the surface of the enamel (Fig. 17-10).

### OCCLUSAL CARIES

Occlusal caries is the most prevalent location of caries in the oral cavity. It usually occurs early in life, before smooth surface lesions appear. The irregular pit and fissure



**Figure 17.7 Four Classes of Interproximal Caries Penetration.** (A) Distinct Class 1 (incipient) carious lesions identified by arrows. (B) Class 2 carious lesions on mesial of lower first premolar (arrow). (C) Class 3 carious lesion on mesial surface of rotated lower second premolar. Class 2 carious lesion on distal surface of upper first premolar. (D) Class 4 carious lesion on mesial surface of lower second premolar (arrow).





**Figure 17.8 Rampant Caries.** Teenage girl with rampant caries in all her teeth. Maxillary incisors have large carious lesions.

sure surfaces of the premolar and molar teeth are inherently more prone to occlusal caries because of their physical characteristics, which result in poor self-cleansing fissures. Enamel caries that begins in the pits and fissures of the occlusal surfaces of teeth appears radiographically opposite to that of the interproximal enamel carious lesion, in that the apex of the triangle is toward the outer surface of the tooth and the base of the triangle is at the DEJ (Fig. 17-11). Occlusal caries is usually not seen radiographically until it has reached the DEJ and has spread in all directions. This is because the great mass of enamel tissue superimposed over the occlusal enamel lesion hides the lesion on the radiograph. Caries of the occlusal surface is usually initially seen as a radiolucent dark line or area in the dentin just under the occlusal enamel surface (Fig. 17-12). Therefore, the radiograph is not always a reliable diagnostic aid for the detection of occlusal enamel caries. It can only alert the clinician to occlusal surfaces that should be examined more thoroughly. A mirror and the sharp ex-



**Figure 17.9 Acute Caries.** Note the small entrance of the carious lesions as shown by arrows.

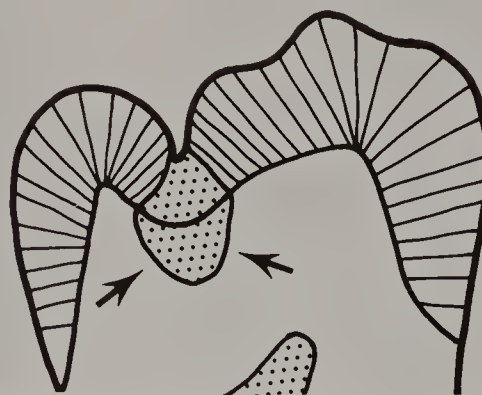


**Figure 17.10 Chronic Caries.** Note the large entrance of carious lesion as shown by arrows.

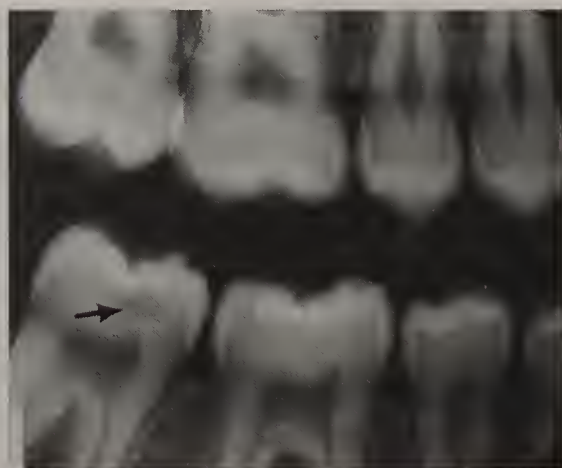
plorer (currently controversial) are the traditional diagnostic aids in the detection of occlusal caries. According to some, probing with a sharp explorer exacerbates the spread of caries—most specifically, pit and fissure lesions.

### FACIAL/LINGUAL CARIES

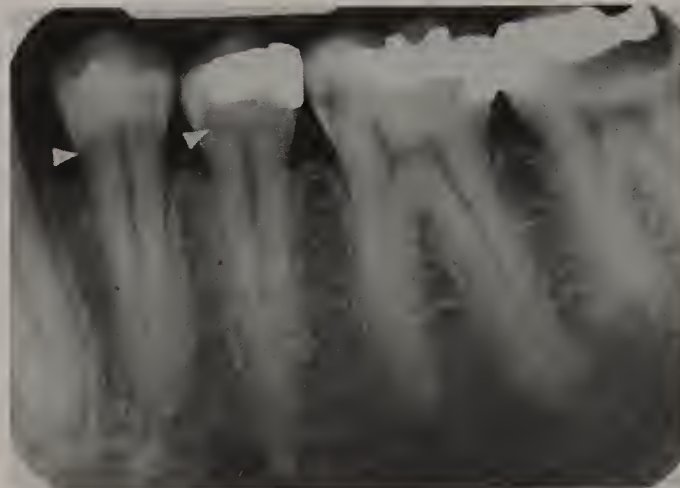
Smooth surface caries on the facial and lingual surfaces of the teeth begins in the pits, fissures, or cervical region of the tooth. Caries developing in pits on the facial and lingual surfaces appears on the radiograph as round radiolucent dots on the tooth surface. Many times, it is like looking into a small “black hole.” The periphery of the black hole is especially well demonstrated if the pit or fissure is on the lingual surface, because this surface is the closest to the film (Fig. 17-13). Cervical caries on the facial or lingual surfaces extend laterally toward the interproximal surfaces, forming a typical crescent-shaped, semilunar cavity, although the cavity may also be round or oval (Fig. 17-14). Facial and lingual caries almost always seems to produce a wide-open cavity shape unlike the carious lesion found in interproximal and occlusal caries, which has a more narrow area of penetration.



**Figure 17.11 Occlusal Caries.** Diagram showing the features of occlusal caries in posterior teeth (arrows).



**Figure 17.12 Occlusal Caries.** Note occlusal caries in mandibular second molar (arrow).



**Figure 17.14 Cervical Caries.** Note cervical facial caries on first and second premolars.

### PULPAL CARIES

The extent and/or proximity of the caries to the pulp chamber can be evaluated with only a limited degree of reliability from radiographs. This limitation stems in large part from the fact that the dental radiograph is a two-dimensional image of a three-dimensional tooth. The radiograph has length and width but lacks the dimension of depth. However, the radiograph does provide some diagnostic information, and as long as it is applied with some reservation, it has a place in the evaluation of **pulpal caries**. If on the radiograph a carious lesion appears to have progressed right to the edge of the pulp chamber and not in the pulp, the dentist should be forewarned of a possible pulp exposure during caries excavation (Fig. 17-15). Overangulation of the x-ray beam can create an appearance of pulp exposure or abnormal apical periodontal ligament space widening, which is seen in advanced pulpitis. In addition, overexposure of the film causes “burnout” of dentin between the pulp and carious lesion by enlarging the carious lesion. Moreover, the radiograph does not have depth, so a large carious lesion can be su-

perimposed over the pulp, when in reality the caries has not penetrated the pulp.

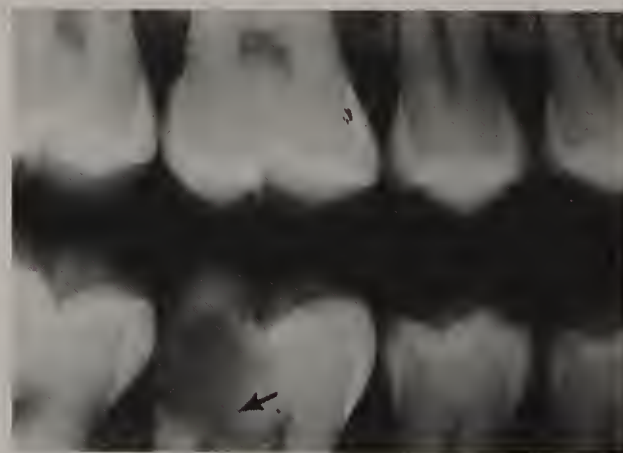
### ROOT OR CEMENTAL CARIES

Root caries is known by a variety of terms including **cemental caries**, **radicular caries**, and **senile caries**. Sumney et al. (1973) reported that root caries is usually seen as a shallow (less than 2 mm deep), ill-defined, softened area that is often discolored and characterized by destruction of cementum with penetration of underlying dentin. As it progresses, the lesion extends more circumferentially (circular in area) than in depth. Root caries starts at or near the **cementoenamel junction (CEJ)** and appears only after the cementum is exposed.

When root surfaces are exposed to the oral environment as a result of gingival recession, plaque retention areas increase, particularly along the CEJ. Cemental or root caries start as small lesions along the CEJ and eventually



**Figure 17.13 Facial/Lingual Caries.** Note the round, black hole appearance of lingual caries on lower second molar.



**Figure 17.15 Pulpal Caries.** Large carious lesion of the lower first molar that has probably reached the pulp; however, the carious lesion could be superimposed over the pulp chamber and give an impression of a pulpal penetration.





**Figure 17.16 Root or Cemental Caries.** Root or cemental caries with characteristic cupped-out appearance, as seen between two molars. Note the loose contact and food packing area between the teeth.

coalesce and spread over the entire tooth surface. The surface becomes soft on probing, with a leathery consistency. Cementum has a laminated appearance microscopically. When microbial plaque deposits are retained on the cementum for long periods, cemental caries is produced, which tends to progress laterally between the layers undermining the cementum. The radiographic appearance of root caries is described as saucer-shaped or having a cupped-out appearance. Root caries is usually located in the region of the interproximal CEJ (Fig. 17-16). Although it does not usually involve the enamel, it may undermine the enamel by spreading underneath it. Root caries may at times be misinterpreted as cervical burnout, which is normally seen in the cervical region of the teeth as a radiolucent triangular area on the interproximal surfaces of the posterior teeth and as a radiolucent band on the anterior teeth.

Root caries frequently occurs in the elderly for three reasons:

1. Cementum seems to be less resistant to caries than enamel and may be exposed more often in the elderly because of gingival recession.
2. The elderly have many more loose contacts between adjacent teeth because of attrition, periodontal disease, or poor restorations, which cause food packing areas.
3. Older persons often have xerostomia (dry mouth) for various reasons (salivary gland atrophy, drugs).

## RECURRENT OR SECONDARY CARIES

Recurrent or secondary caries develops at the margins or in the vicinity of a restoration and may indicate an unusual susceptibility to caries, poor oral hygiene, a deficient cavity preparation, a defective restoration, or a combination of these factors. It is usually due to a “leaky margin,” produced by one of the above factors. Mjor (1981) reported that clinical studies based on dentists’ re-

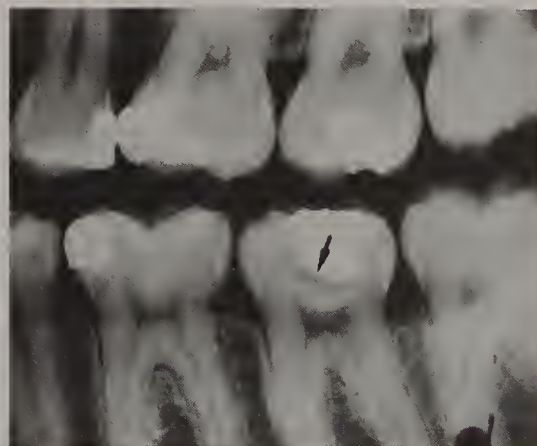


**Figure 17.17 Recurrent or Secondary Caries.** There is recurrent caries on the mesial surface of the lower second premolar (arrow).

ports show that 60% of all replacements of amalgam restorations are due to recurrent (secondary) caries. Recurrent caries is seen under the restoration as a dark, radiolucent area (Fig. 17-17). Incomplete removal of dentinal caries before placing the restoration is also seen on the radiograph as a radiolucent area under the restoration. A radiopaque layer of dentin will sometimes be seen under the radiolucent carious lesion under the restoration (Fig. 17-18). At times, a flame-shaped, radiopaque area can be seen in the dentin immediately adjacent to a restoration (Fig. 17-19). It was previously thought that these radiopaque areas in dentin under carious lesions and restorations represented defensive reactions. It is now thought that they represent partially demineralized dentin containing tin or zinc that has leached out from amalgam or cement restorations due to changes in pH.

## ARRESTED CARIES

Incipient and even more advanced carious lesions may become arrested if there is a significant shift in the oral



**Figure 17.18 Recurrent or Secondary Caries.** Note the radiolucent caries lesion under the radiopaque restoration. This is most likely from incomplete removal of dentinal caries before placement of the restoration.



**Figure 17.19 Radiopaque Dentin.** Note flame-shaped radiopacity underneath margins amalgam restorations of molar and premolars. This is thought to represent tin or zinc ions from the amalgam that have been released into partially demineralized dentin.

environment from factors that cause caries to those that tend to slow the caries process. According to Backer (1966), clinical longitudinal studies suggest that **incipient enamel caries** can remain dormant for long periods and that some carious lesions may be reversed by remineralization. Most typically, the arrested incipient carious interproximal lesion is seen on teeth where the adjacent tooth has been extracted, so the local environmental conditions have changed completely. Clinical exploration of the lesion reveals that it is the same hardness as normal enamel. Therefore, these lesions are defined as remineralized carious lesions. Radiologically, these areas may appear as small radiolucent areas. Another form of arrested caries is seen in large occlusal carious lesions that become static or stop progressing for some reason. The appearance of arrested occlusal caries is an open cavity revealing yellow, brown, or black exposed dentin that has a polished, eburnated (hard) surface. The carious lesion most likely becomes arrested because microorganisms cannot

be retained on the polished surfaces of the lesion. The radiographic appearance of arrested caries is one in which the crown of the tooth is absent, with a dark, radiolucent area on a roughened top surface of a destroyed tooth. A white sclerotic line under the radiolucent area may be present as a defensive measure of the pulp to wall-off the carious lesion (Fig. 17-20).

## FACTORS INFLUENCING INTERPRETATION OF CARIES

### RADIOGRAPHIC UNDERESTIMATION OF CARIES SIZE

#### Radiographic Appearance of Caries and Demineralization

A sufficient amount of calcium and phosphorus must be removed from the tooth for the carious lesion to be seen on the radiograph. Early et al. (1979) estimated that it takes approximately 50% of the calcium and phosphorus in a localized area of a tooth or bone to be absorbed before a radiolucency will be revealed on the radiograph. Therefore, the actual depth of penetration of the carious lesion is further advanced clinically and microscopically than the radiograph indicates.

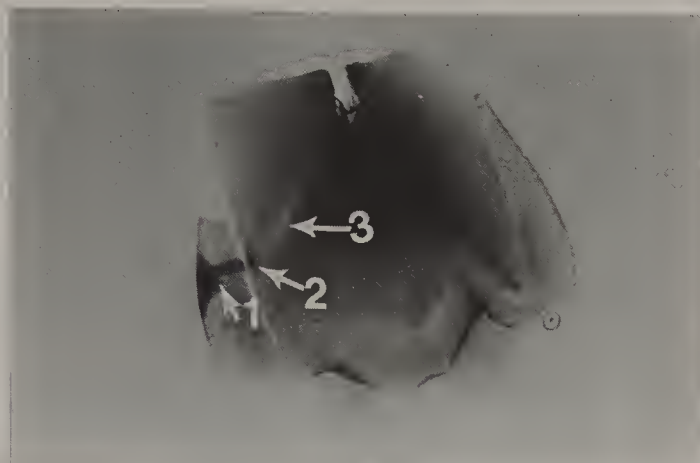
#### Histopathologic Studies

Silverstone (1982) reported that when a lesion is first detected on a radiograph and appears to be limited to the outer enamel, the lesion has already penetrated the dentin (Fig. 17-21). This finding implies that carious lesions that may appear on radiographs to involve part of the enamel only may, at the histologic level, have reached the DEJ, with a significant response from the pulpodentinal organ. However, this may also indicate that a slowly progressing enamel carious lesion may be attenuated by an effective defensive response in the dentin and pulp.



**Figure 17.20 Arrested Caries.** (A) Photograph of a patient with multiple teeth with arrested caries. (B) Arrested caries in lower first molar, which has a black-brown polished occlusal surface.





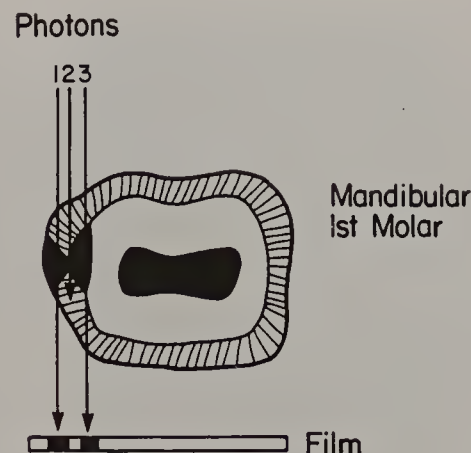
**Figure 17.21 Histopathology of Carious Lesion.** Thin ground section of carious lesion on distal surface of an upper first premolar. The radiograph of this lesion before extraction revealed penetration of the carious lesion to half the width of the enamel at 1. This thin ground section shows that the carious lesion has actually reached the dentinoenamel junction at 2. Note the “transparent” or sclerotic dentin at 3. This is considered a defensive mechanism of the pulpodentinal complex because its formation alters the permeability of the dentinal tubules, blocking access of irritants to the pulp.

## CARIES PROGRESSION STUDIES

The rapid decline in the rate of caries progression recognized since 1963 underlines the importance of reviewing the newer studies on caries progression. Pitts (1983) and Schwartz et al. (1984) reported that progression of interproximal enamel carious lesions is usually a slow process and that many lesions remain unchanged for long periods. Today, more conservative criteria are being used in selecting surfaces for operative treatment than were used in the past. Thus, it may be more appropriate to institute preventive and remineralization procedures for a carious lesion than to initiate restorative treatment.

### Caries-to-Normal Tooth Ratio

The radiograph underestimates the size of the carious lesion for another reason. It can be explained by the caries-to-normal ratio to tooth thickness. The classic shape of the enamel caries lesion is the V-shape, with the point of the V located closest to the DEJ. Therefore, the ratio of the thickness of the enamel to the size of the carious lesion becomes greater at the “V-point” of the carious lesion. At this point, the x-ray energy becomes reduced enough by the enamel to block out the registration of the radiolucent carious lesion in this region of the enamel. The carious lesion will then appear smaller on the radiograph than the actual demineralization of the enamel from dental caries. When the carious lesion reaches the DEJ, it spreads along the junction and progresses rapidly through the dentin to the pulp. In the dentin, this creates a smaller tooth structure-to-carries ratio, and the radiolucency of the dentinal carious lesion is seen again on the radiograph (Fig. 17-22). This creates a radiographic appearance of interproximal enamel caries with a small opening on the enamel periph-

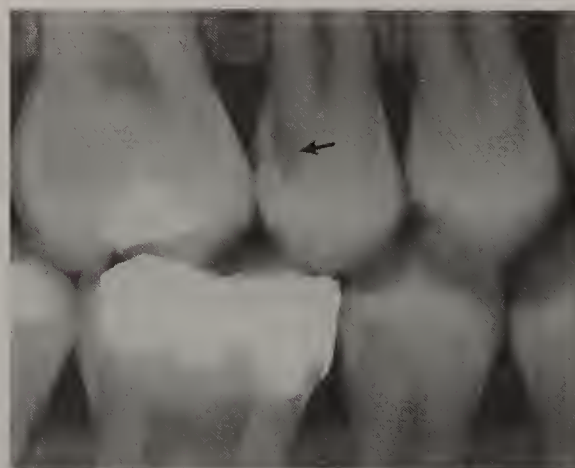


**Figure 17.22 Normal Tooth-to-Caries Ratio.** The film records a radiopaque area for photon 2, because the normal tooth-to-carious-tooth-structure ratio is greater in this area of the tooth compared with areas of the tooth that photons 1 and 3 are penetrating.

ery, a band of normal enamel, and finally carious dentin. This radiographic appearance could be misinterpreted as enamel caries only; in this case, if the dentist decided to delay restorative treatment, it could result in unnecessary carious pulpal involvement of the tooth (Fig. 17-23).

## CERVICAL BURNOUT

The constricted cervical neck of the tooth, the area between the crown and the root, absorbs less x-ray energy than the areas above and below it. This is because of the presence of enamel above the cervical neck and the alveolar bone covering the root of this tooth below the cervical neck. It results in a radiolucent band running across the cervical neck of anterior teeth (Fig. 17-24) and a triangular, wedge-shaped radiolucency at the interproximal cervical neck of the posterior teeth (Fig. 17-25). This is called cervical burnout because of the great density difference



**Figure 17.23 Normal Tooth-to-Caries Ratio Radiograph.** Note the apparent enamel carious lesion on the mesial and distal surfaces of the upper second premolar (arrow). However, with a closer look, this lesion has penetrated the dentin.

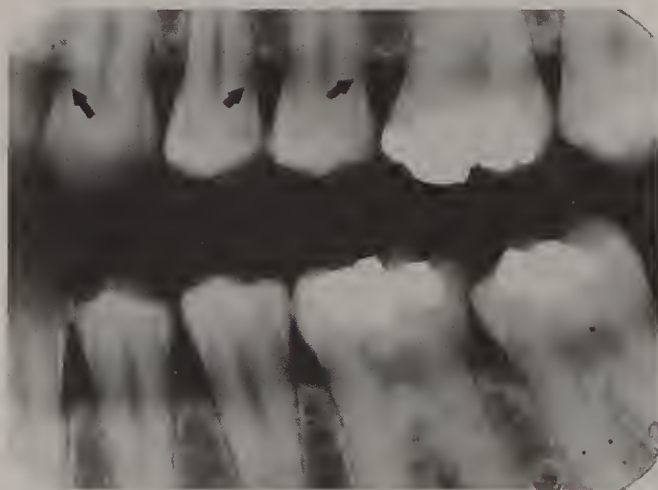


**Figure 17.24 Anterior Cervical Burnout.** Cervical burnout in upper centrals. Note the dark radiolucent collar at the cervical neck of the incisors (arrows).

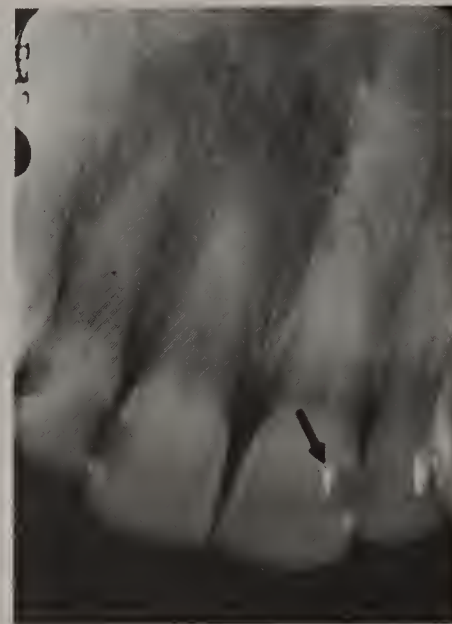
between the cervical neck of the tooth and the tissues above and below it. Other reasons for cervical burnout, in addition to density tissue differences, are anatomical differences such as the shape of the cements/enamel contour, various root configurations, and poor horizontal angulation of the beam. Thus, cervical burnout will often disappear if the radiograph is retaken with an improved horizontal angulation.

## RESTORATIVE MATERIALS

Materials of relatively high atomic weights (such as amalgams and gold) appear radiopaque on the radiograph and are not confused with caries, although older silicate and plastic/resin restorations tend to be radiolucent and simu-

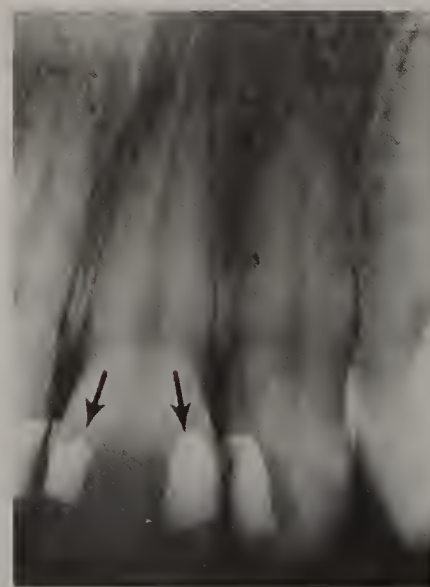


**Figure 17.25 Posterior Cervical Burnout.** Note radiolucent areas (arrows) that are cervical burnout areas and **not** caries.



**Figure 17.26 Restorative Materials that Mimic Caries.** Silicates and resins are radiolucent and could mimic caries (arrow). Cement bases (arrow) under silicates are radiopaque because they contain metallic elements such as zinc in these materials.

late dental caries (Fig. 17-26). Older silicate materials often require the use of suitable radiopaque base materials, and this procedure assists the practitioner in differentiating older silicates from caries. Anterior composite restorations are radiopaque (Fig. 17-27). Both zinc oxide-eugenol and zinc phosphate cements appear radiopaque because of the zinc used in these materials. The older calcium hydroxide materials were radiolucent; the newer ones contain additives to render them radiopaque. Calcium hydroxide is ordinarily used as a subbase between a



**Figure 17.27 Anterior Composite Restorations.** Composite restorations (arrows) are radiopaque because they contain metallic materials. Sometimes a radiolucent line can be seen under the composite restorations. These are sealing or bonding materials and not leaky margins or recurrent caries.



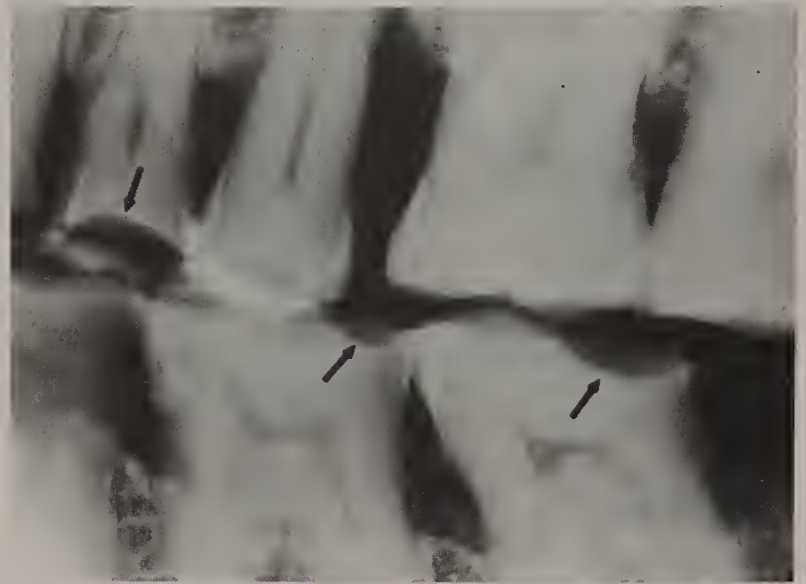
pulpal exposure or a near exposure and conventional base materials, such as zinc phosphate cements. If the restoration is very old (before 1970), the subbase area may be radiolucent on the radiograph and difficult to differentiate from caries.

### DEVELOPMENTAL/ACQUIRED DEFECTS IN ENAMEL

Developmental defects, particularly enamel hypoplasia, can simulate caries radiographically (Fig. 17-28). Pits and fissures on the facial and lingual surfaces simulate caries but are readily identified by clinical examination. Because these pits tend to stain, caries is often suspected. Caries is detected clinically if the explorer point sticks on removal from the defect. The lesion is termed an enamel developmental defect without caries involvement, if the explorer does not stick. As mentioned previously, this clinical procedure is controversial, and could spread the carious lesion.

**Attrition** is defined as the physiologic wearing away of teeth. Clinically, the earliest change occurs as a small facet on a cusp tip or a slight flattening of the incisal edge. When the enamel has been completely worn away and the dentin has been exposed, a cavity in the tooth will appear. The attrition cavity on the occlusal or incisal surfaces of teeth may appear as dental caries on the radiograph (Fig. 17-29).

**Abrasion** is the abnormal wearing away of tooth substance by a mechanical process. This usually occurs on exposed root surfaces as a result of improper tooth-brushing (Fig. 17-30). A V-shaped depression is created on the

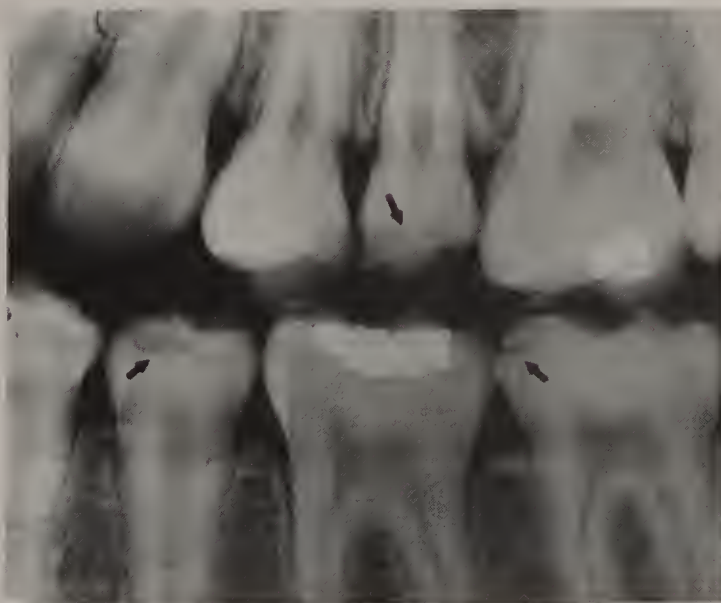


**Figure 17.29 Attrition Mimics Caries.** Note the severe attrition of occlusal surfaces (arrows) mimicking caries.

root side of the CEJ where there is some gingival recession. This V-shaped depression mimics carious lesions on the radiograph (Fig. 17-31). The improper use of dental floss and toothpicks may also contribute to abrasive wearing away of the teeth, which can mimic interproximal enamel or root caries.

### TECHNIQUE ERRORS THAT WILL AFFECT CARIES DETECTION

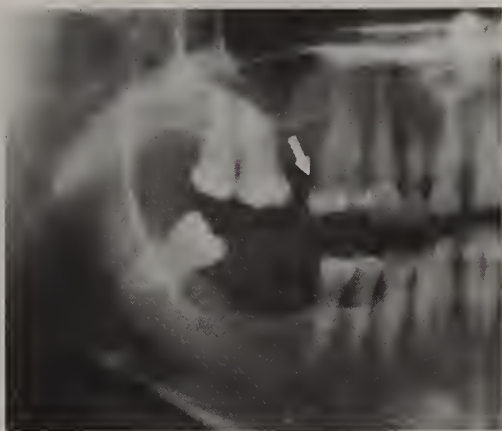
For the dentist to interpret a radiograph properly, it is essential that the radiograph has diagnostic quality. As discussed previously, diagnostic quality can only be achieved by following the principles of good radiographic tech-



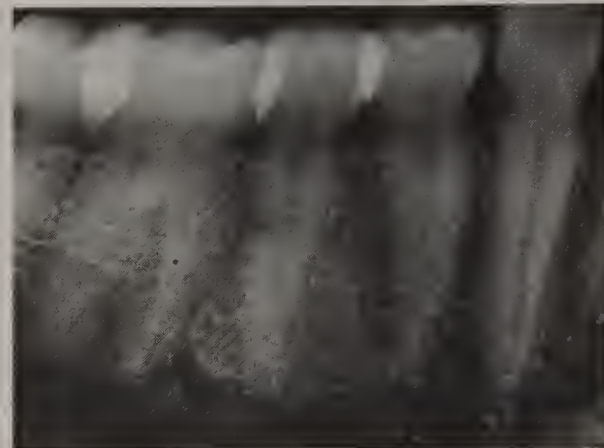
**Figure 17.28 Enamel Hypoplasia Mimics Caries.** Enamel hypoplasia of lower and upper second premolars and the mesial surface of the mandibular second molar (arrows).



**Figure 17.30 Cervical Toothbrush Abrasion Mimics Caries.** Toothbrush abrasion of lower premolars mimics caries.



**Figure 17.31 V-Shaped Toothbrush Abrasion Mimics Caries.** The V-shaped depression shown here (arrow) in a panoramic radiograph mimics a carious lesion. Note other areas of toothbrush abrasion.



**Figure 17.33 Improper Horizontal Angulation.** Periapical of lower premolars showing severe overlapping that makes it impossible to interpret interproximal caries

nique covered in previous chapters. The important common errors that affect caries interpretation are projection errors.

### COMMON ERRORS IN PROJECTION

If the film is not placed properly in the mouth and the x-ray beam directed accurately to the teeth and film, then shape distortion and overlapping of interproximal contacts of the teeth will occur.

### IMPROPER VERTICAL AND HORIZONTAL ANGULATION

**Improper vertical angulation** causes foreshortening of the tooth images and projects the enamel cap of the crown of the tooth over the interproximal enamel surfaces of the tooth. This obliterates the carious lesion from view on the radiograph (Fig. 17-32). **Improper horizontal angulation** causes overlapping of the contact areas of the crowns of the teeth, which in turn makes it impossible to interpret the interproximal enamel surfaces of the teeth for caries (Fig. 17-33).

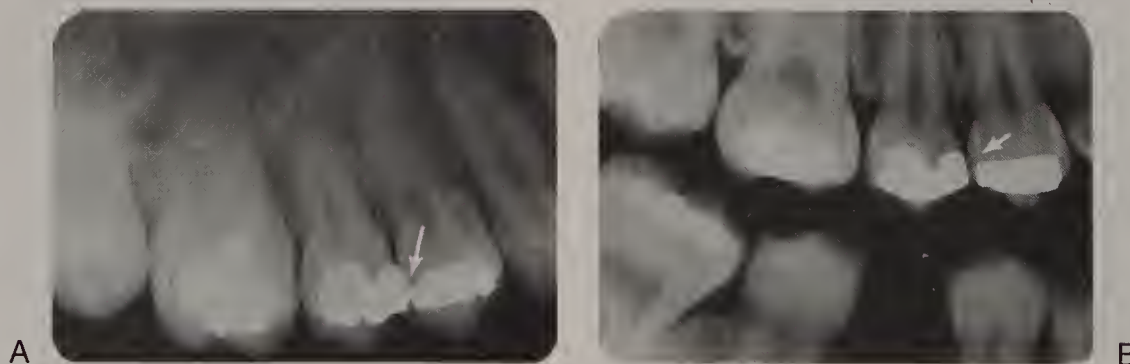
## WORKSHOP/LABORATORY EXERCISES

### EXERCISE 17.1 ASSESSMENT OF CARIES

Set up several viewboxes with radiographs. Request that students rotate at various times to answer questions or to identify carious lesions present on the radiographs.

### REVIEW QUESTIONS

1. In discussing radiologic caries interpretation, how is the phenomenon of cervical burnout explained?
  - A. Tissue density and thickness in the cervical area of the tooth is less than the adjacent tooth and bony tissues.
  - B. Tissue density in the cervical region of the tooth is greater than the adjacent tooth and bony tissues.



**Figure 17.32 Improper Vertical Angulation.** (A) Periapical radiograph taken with improper vertical angulation. Note how interproximal spaces are distorted. (B) Bitewing radiograph of same patient as in A. Note caries on distal of upper first premolar, which could not be seen on the periapical radiograph with improper vertical angulation.



- C. The cervical region of the tooth is more receptive to dental caries.
  - D. The cervical region of the tooth attenuates the x-ray beam more than the rest of the tooth.
  - E. The exposure time used is too low.
2. In most cases, which pattern of caries development describes the smooth surface caries?
    - A. Saucer-shaped with the base of the saucer toward the DEJ.
    - B. Triangular with the base toward the periphery of tooth enamel.
    - C. Triangular with the base toward the DEJ.
    - D. Hair-like line penetrating enamel toward the DEJ.
    - E. Flame-like configuration with the base at periphery of enamel of tooth.
  3. Which of the following statements are true concerning acute caries?
    1. Initial lesion is small at the surface.
    2. Large initial lesion at the surface in its incipency.
    3. More common in children.
    4. More common in adults.
    5. Progress is slow.
    6. Progress is rapid.
    - A. 2, 4, and 5.
    - B. 2, 3, and 6.
    - C. 1, 4, and 5.
    - D. 2, 3, and 5.
    - E. 1, 3, and 6.
  4. Recurrent or secondary caries in most cases occurs because of which of the following?
    - A. Inadequate extension of the cavity preparation.
    - B. Improper adaptation of the restorative material to margins of the cavity preparation.
    - C. Incomplete removal of the caries from the tooth before placing the restoration.
    - D. All of the above.
  5. How is root (cemental) caries usually revealed on the radiograph?
    - A. A radiolucent area just beneath a restoration.
    - B. An ill-defined, radiolucent, saucer-shaped area located in the interproximal region just below the CEJ.
    - C. A V-shaped radiolucent area in the enamel just below contact point.
    - D. A black circle on either of the facial/lingual surfaces.
  6. What are the primary factors in the cause of caries?
    1. Saliva and teeth.
    2. Calculus.
    3. Diet.
    4. Occlusal trauma.
    5. Plaque.
    - A. 1, 3, and 5.
    - B. 1, 2, and 4.
    - C. 2, 3, and 5.
    - D. 3 and 4.
    - E. 1, 2, 3, 4, and 5.
  7. Can carious lesions develop without plaque?
    - A. Yes.
    - B. No.
  8. Dental caries is essentially a process of which of the following?
    - A. Atrophy.
    - B. Decalcification.
    - C. Infection.
    - D. Malnutrition.
    - E. Chemical imbalance.
  9. Interproximal enamel caries is usually recognized on the radiograph as a radiolucency with which of the following shapes or configurations?
    - A. Flame-shaped.
    - B. Line-shaped.
    - C. W-shaped
    - D. Half-moon shape.
    - E. Triangular-shaped.
  10. How does lamellar caries appear on a radiograph on an interproximal enamel surface?
    - A. Thin line radiolucency.
    - B. Mushroom-shaped radiolucency.
    - C. V-shaped radiolucency.
    - D. Flame-shaped radiolucency
    - E. Small cone-shaped radiolucency.
  11. Rampant caries can be seen in which of the following?
    - A. Primary teeth of young children.
    - B. Permanent teeth of teenagers.
    - C. Adults with xerostomia.
    - D. Mandibular permanent incisors.
    - E. All of the above.
  12. Which of the following tooth surfaces is the most prevalent location for caries in the oral cavity?
    - A. Facial surfaces.
    - B. Posterior interproximal surfaces.
    - C. Occlusal surfaces.
    - D. Lingual surfaces.
    - E. Root surfaces.

13. Which of the following statements is true of chronic caries?
  - A. Commonly seen in adults 25 years of age and older.
  - B. Slow penetration of enamel.
  - C. Large initial entrance of caries.
  - D. All of the above.
14. Why does root caries frequently occur in the elderly?
  - A. More gingival recession in the elderly.
  - B. Cementum seems to be less resistant to caries than enamel.
  - C. Elderly seem to have more food packing areas.
  - D. Elderly are more prone to xerostomia (dry mouth).
  - E. All of the above.
15. The majority of replacements of amalgam restorations is due to which of the following?
  - A. Different cavity preparation.
  - B. Recurrent (secondary) caries.
  - C. Poor oral hygiene.
  - D. Root caries.
  - E. Radiopaque layer of dentin under a restoration.
16. Which of the following is not misrepresented in the radiograph as carious lesions?
  - A. Cervical "burnout" areas.
  - B. Anterior silicate restorations.
  - C. Anterior plastic or resin restorations.
  - D. Anterior composite restorations.
  - E. None of the above.
17. How does "toothbrush abrasion" appear on posterior teeth on the radiograph?
  - A. Small, circular radiolucent areas on occlusal surfaces of teeth.
  - B. Dark cavity on the occlusal or incisal surfaces.
  - C. V-shaped, radiolucent depressions on the root side of CEJ of the teeth.
  - D. Black, round holes appearance on the facial/lingual surfaces of the tooth.

## CASE-BASED QUESTIONS

### CASE 17.1

This patient is a 35-year-old man who has been experiencing sensitivity to hot, cold, and sweets.



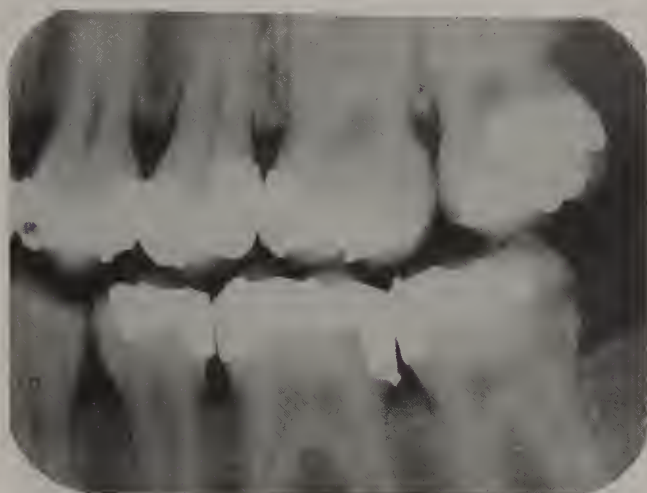
### QUESTIONS

1. What term best describes the morphology of the caries on the distal of the second premolar?
  - A. Interproximal.
  - B. Approximal.
  - C. Cone-shaped.
  - D. Flame-shaped.
  - E. Linear.
2. What do you think is (are) this patient's main problem(s)?
  - A. Multiple caries.
  - B. Periodontal disease.
  - C. Halitosis.
  - D. A and B.
3. What significant past treatment do you think he had?
  - A. Fixed restorative dentistry.
  - B. Scaling and root planing.
  - C. Orthodontic treatment.
  - D. Oral surgery.



**CASE 17.2**

This is a routine bitewing of a 43-year-old man.

**QUESTION**

1. Which of the following carious mandibular teeth may also have significant periodontal problems?
  - A. Distal of first premolar.
  - B. Mesial of second premolar.
  - C. Distal of first molar.
  - D. Distal of second molar.

**CASE 17.3**

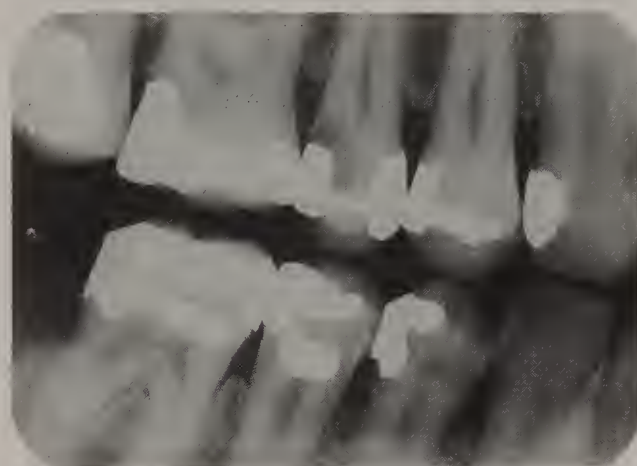
This patient is a 45-year-old woman who complains that her teeth are sensitive to hot and cold. The cervical areas are sensitive on probing.

**QUESTION**

1. This patient's problems are due to:
  - A. Exposed cementum due to vertical bone loss.
  - B. Cervical caries.
  - C. Cocaine abrasion.
  - D. Toothbrush abrasion.

**CASE 17.4**

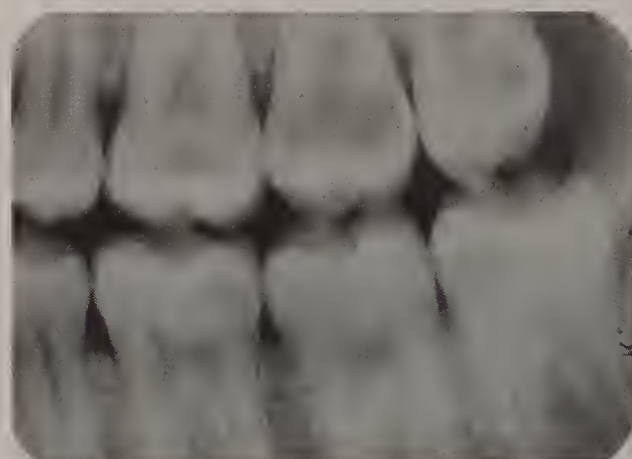
This patient has a slight toothache, and deep caries is discovered on the distal of the maxillary second premolar.

**QUESTION**

1. The term that best describes this type of caries is:
  - A. Interproximal.
  - B. Approximal.
  - C. Recurrent (secondary).
  - D. Root.

**CASE 17.5**

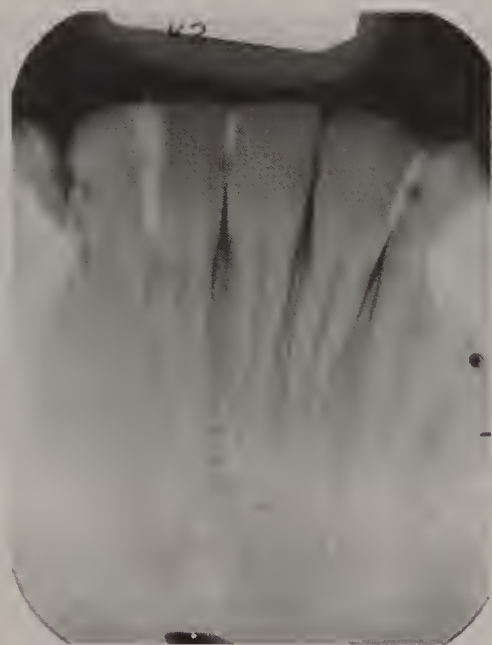
This is a 26-year-old graduate student with a toothache. You note the problem seems to be occlusal caries.

**QUESTIONS**

1. Which molars have occlusal caries?
  - A. The uppers.
  - B. The lowers.
  - C. The uppers and lowers.
  - D. Only the upper second.
2. At a young age, what procedure could have prevented his current problem?
  - A. Diet counseling.
  - B. Sealants.
  - C. Home care.
  - D. Fluoride treatments.
  - E. All of the above.

**CASE 17.6**

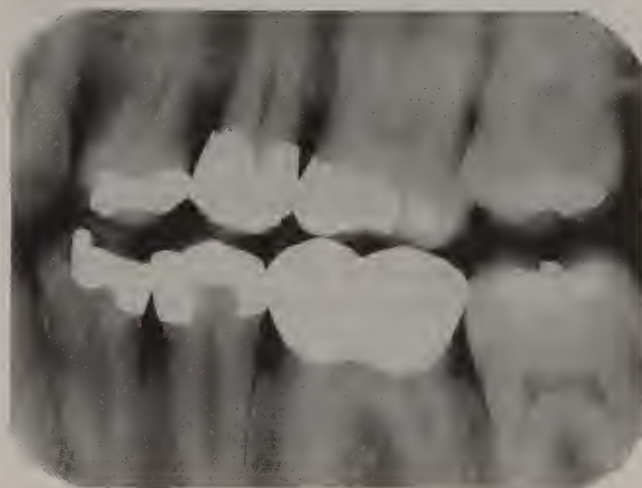
This patient is a 14-year-old girl. Almost all the lower anterior teeth are carious.

**QUESTION**

1. The most significant reason for recognizing this pattern of caries is:
  - A. A strong susceptibility to caries.
  - B. A response to pubertal hormonal change.
  - C. A lack of proper home care.
  - D. The patient did not floss properly.

**CASE 17.7**

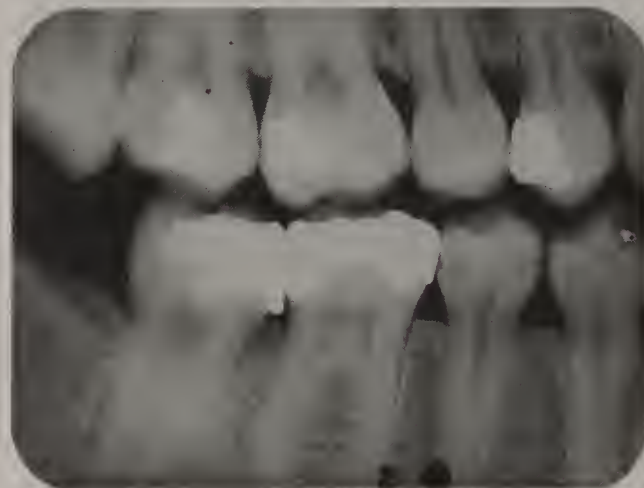
This patient is a 40-year-old man. He reports periodic discomfort in his teeth, which is hard to describe and localize and is very intermittent.

**QUESTION**

1. These radiographs indicate there is a leaky margin at:
  - A. The lower first molar.
  - B. The mesial of the upper second premolar.
  - C. The distal of the lower first premolar.
  - D. B and C.
  - E. None of the above.

**CASE 17.8**

This 35-year-old man has made an appointment for a dental examination in your office. Bitewing radiographs were taken.

**QUESTIONS**

1. Which of the surfaces named (identified) have definite radiographic evidence of caries?
  1. Distal of maxillary second premolar.
  2. Distal of mandibular first premolar.
  3. Mesial of mandibular second premolar.
  4. Distal of mandibular second premolar.
  - A. 2 and 3.
  - B. 2, 3, and 4.
  - C. 1, 2, 3, and 4.
  - D. 3 and 4.
  - E. 1 and 2.
2. Which area(s) on the radiograph reveal definite radiographic evidence of periodontal disease between which of the following teeth?
  - A. Maxillary first molar and second premolar.
  - B. Maxillary second premolar and first premolar.
  - C. Mandibular premolars.
  - D. Mandibular molars.
  - E. All areas look normal.

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# Radiologic Diagnosis of Periapical Disease

## LEARNING OBJECTIVES

Upon successful completion of this unit, the student will be able to:

1. Explain the role of the lamina dura and apical periodontal membrane space in the diagnosis of periapical disease on the radiograph.
2. Know how to interpret on the radiograph acute periapical pathology of pulpal origin.
3. Know how to interpret on the radiograph chronic apical periodontitis and its variants.
4. Test his or her knowledge by answering the Review Questions.

## KEY WORDS/PHRASES

|                                  |                                                        |                         |                               |
|----------------------------------|--------------------------------------------------------|-------------------------|-------------------------------|
| acute apical abscess (AAA)       | apical cyst                                            | dental/apical granuloma | necrosis (necrotic)           |
| acute apical periodontitis (AAP) | chronic apical abscess (CAA) with or without a fistula | fistula (parulis)       | periapical cemental dysplasia |
| antral mucositis                 |                                                        | granulomatous tissue    | suppuration/suppurative tumor |
| apical cementoma (AC)            | chronic apical periodontitis (CAP)                     | hypercementosis         |                               |
| apical condensing osteitis (ACO) |                                                        | lamina dura             |                               |

## RADIOLOGIC DIAGNOSIS OF PERIAPICAL DISEASE

### LAMINA DURA IN PERIAPICAL DISEASE

In almost every normal tooth, the lamina dura can be traced from the alveolar crest, around the root (Fig. 18-1), and into the bifurcation and trifurcation areas. In periapical disease, resorption of the lamina dura occurs at the apex of the tooth. Radiographically, it appears to have lost its continuity, its thickness, and its degree of radiopacity. This usually indicates, with few exceptions, that periapical disease is present (Fig. 18-2).

### PERIAPICAL/APICAL DISEASE OF PULPAL ORIGIN: INTRODUCTION

Because there is little correlation between clinical and histopathologic findings of periapical (apical) lesions of

pulpal origin, diagnostic differentiation of periapical disease is usually based on the patient's clinical findings rather than on histopathologic findings. Therefore, peri-

cal abscess (AAA), (3) dental/apical granuloma, (4) apical cyst, (5) chronic apical abscess (CAA), and (6) apical condensing osteitis (ACO). Lesions with significant symptoms, such as pain or swelling, are designated as acute;

## ACUTE APICAL CONDITIONS

### ACUTE APICAL PERIODONTITIS (ACUTE PERIAPICAL PERIODONTITIS) (APP)

Acute apical periodontitis (AAP) is an inflammatory response of the apical periodontal ligament to pulpal irritants via the root canal or from trauma. In most cases, the



**Figure 18.1 Lamina Dura.** Lamina dura is a thin, white line (arrows) that can be traced around the apical ends of all normal teeth.

pulp is irreversibly inflamed or **necrotic** (dead tissue); however, AAP may be associated with a vital tooth, such as in occlusal trauma, from irregular wear of teeth, a large carious lesion, a recently inserted high restoration, or a foreign object wedged between the teeth. The clinical features of AAP are slight to severe spontaneous pain and pain from percussion. Pulp testing will result in abnormal responses. If the AAP is caused by an irreversible pulpitis, the treatment will require a complete pulpectomy followed by appropriate root canal therapy. Most cases of AAP are associated with normal apical periodontal ligament spaces and intact lamina dura. A slight widening of



**Figure 18.2 Periapical Disease.** When there is an interruption in the continuity of the lamina dura (as shown here by arrows on the root of the upper lateral incisor), apical pathoses should be suspected. Note loss of lamina dura at root apex.



**Figure 18.3 Acute Apical Periodontitis.** Upper second premolar has large, recurrent (secondary) caries on distal surface. Note thickened periodontal ligament space at apical end of root. The tooth gave abnormal responses to pulp testing, elicited spontaneous pain, and was painful to percussion. The pulp was severely inflamed, and anesthesia was difficult to obtain during the pulpectomy procedure.

the apical periodontal ligament space usually indicates irreversible pulpitis or pupal necrosis (Fig. 18-3).

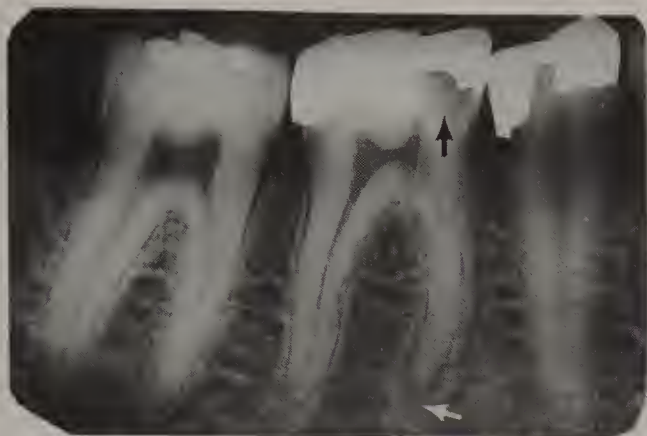
#### **ACUTE APICAL ABSCESS (ACUTE ALVEOLAR ABSCESS)**

Acute apical abscess (AAA) is a painful, localized collection of pus in the alveolar bone at the root apex of the tooth after the death of the pulp, with extension of the infection through the periapical foramen into the periapical tissue. The cause of AAA is a previously existing AAP with a necrotic pulp that has advanced to an extensive acute suppurative inflammation stage. The pulp is nonvital and associated with painful percussion tests. Palpation of the facial surface of the soft tissue of the offending tooth root reveals swelling and pain. In the later stages as the abscess (pus) develops, the pain becomes more intense and continuous; the tooth becomes loosened and protrudes from the socket. The initial treatment of AAA is the establishment of drainage that will relieve acute symptoms at once. Radiographically, the periapical tissue of AAA may appear normal, because fulminating infections may not have had sufficient time (10 days or more) to erode enough cortical bone to reveal a radiolucency. However, a slight widening of the periodontal ligament is usually present (Fig. 18-4).

#### **CHRONIC APICAL (PERIAPICAL) PERIODONTITIS**

Chronic apical periodontitis (CAP) can be subdivided into the following four subtypes: dental/apical granuloma, apical cyst, chronic apical abscess, and apical condensing osteitis (ACO) (Fig. 18-5).

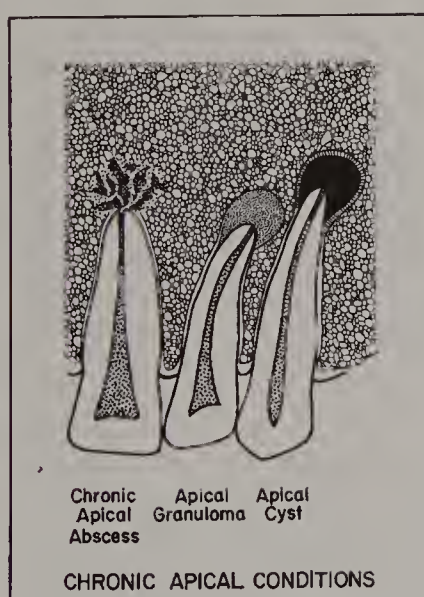




**Figure 18.4 Acute Apical Abscess.** Note thickening of periodontal ligament space of mesial root of lower first molar (white arrow). Tooth has large, recurrent (secondary) carious lesion under mesial portion of restoration of this tooth (black arrow). The tooth is mobile, nonvital, and has percussion pain, with swelling and tenderness to palpation. On removal of restoration and entry into the pulp, a purulent exudate (pus) drained from the access opening; the pain subsided almost immediately.

### APICAL GRANULOMA (PERIAPICAL GRANULOMA, DENTAL GRANULOMA)

An apical granuloma is an advanced form of chronic apical periodontitis (CAP) characterized by a growth of granulomatous tissue (chronic inflammatory tissue) continuous with the apical periodontal ligament, resulting from death of the pulp, and diffusion of mild infective material, or toxic irritants, into the periapical tissue, stimulating, in turn, a productive cellular reaction. Basically, the apical granuloma may be looked upon as a successful attempt by the periapical tissue to neutralize and confine the irritating toxic products that are escaping from the root canal. The term granuloma is a misnomer because



**Figure 18.5 Chronic Apical Lesions.** Radiographic appearance of three chronic apical lesions. (The fourth chronic periapical lesion, condensing osteitis, is not shown.)

the tissue “referred to” is composed principally of chronic inflammatory tissue (granulomatous tissue); it is not a tumor (new, uncontrolled, progressive growth of tissue), as is intimated. The apical granuloma is actually a mass of chronic inflammation tissue, usually surrounded by a fibrous (containing fibers) sac continuous with the periodontal ligament, and attached to the apex of the tooth. The term apical or dental granuloma is in common usage and, until a more appropriate term is found, we will use it in our classification.

Apical granulomas are the most common periapical radiolucency found in dental practice. They are asymptomatic; except in rare cases they break down and undergo suppuration (pus formation). The teeth will not respond to thermal or electrical pulp tests. When an apical granuloma is present, root canal therapy is usually the treatment of choice if the tooth is to be retained. Radiographically, the apical granuloma appears as a radiolucent, circular to ovoid area that encloses the root end and extends periapically from it. Trabeculations of the alveolar bone may be seen superimposed over the lesion, because the lesion has a grayish appearance and is not dark (Fig. 18-6). In a long-standing lesion, the margin of the lesion may become clearly defined, and sometimes, at the apices of maxillary molars, a condition called “localized antral mucositis” may be seen on the radiograph. Antral mucositis is an inflammation of the mucous membrane in the maxillary sinus and is seen on the radiograph as a small, radiopaque swelling in the floor of the maxillary sinus surrounding the apices of the maxillary molar. Because the apical granuloma and apical cyst may have identical radiographic appearances, the apical cyst sometimes may be differentiated from the granuloma by virtue of its size. The apical granuloma is usually smaller than 1 cm in diameter, whereas the apical cyst may become as large as 10 cm and may, in rare instances, fill an entire jaw. In



**Figure 18.6 Apical Granuloma.** Radiographic appearance of apical granuloma of nonvital mandibular second premolar. The lesion is somewhat rounded and well circumscribed, and bony trabeculations are superimposed over the lesion giving it a gray appearance.

clinical practice, it usually is not necessary to differentiate between an apical granuloma and an apical cyst radiographically, because both respond well to root canal therapy without surgical intervention.

### **APICAL CYST (RADICULAR CYST, ROOT END CYST, PERIAPICAL CYST, ALVEOLAR CYST)**

The apical cyst is a true cyst in that it is an abnormal pathologic space within bone lined by stratified squamous epithelium and filled with a fluid or semifluid. Apical cysts are the most common cysts of the jaws. They are painless unless infected. They do not respond to pulp tests.

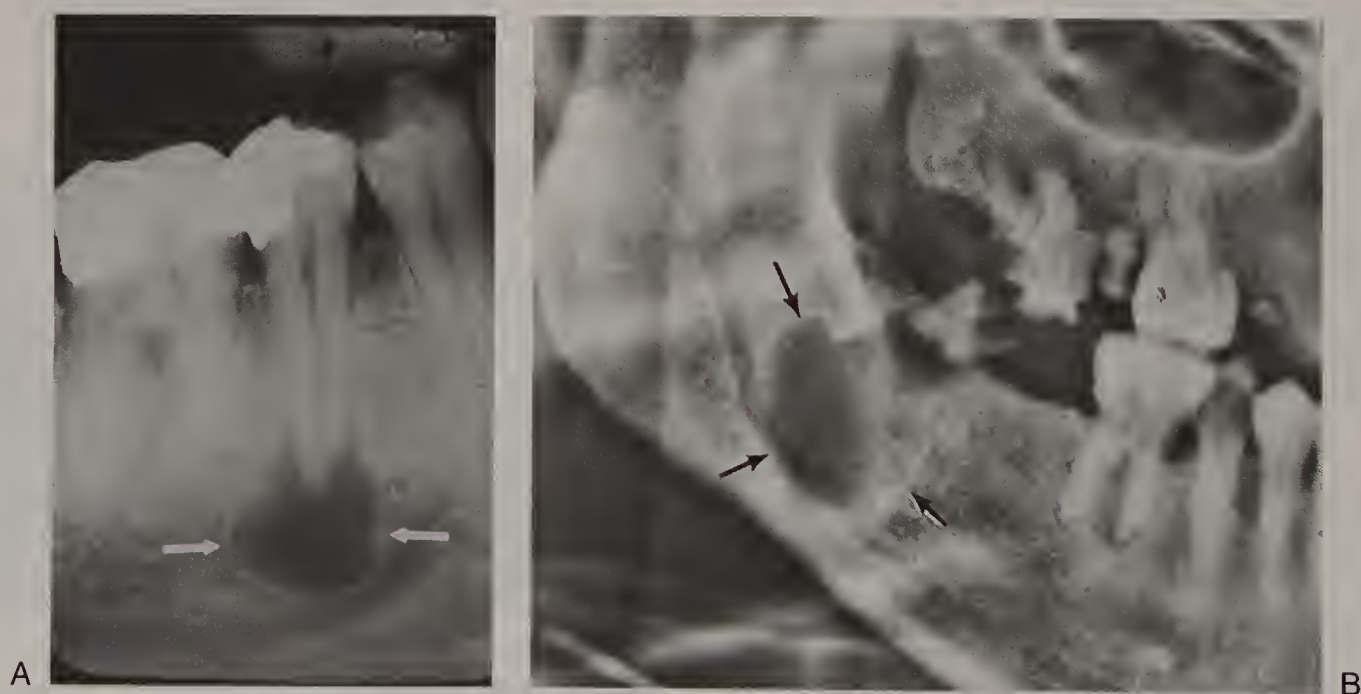
Practically all apical cysts originate from preexisting apical granulomas, and their pathogenesis depends on an inflammatory response. Histologically, the apical cyst can be described as a cyst within a granuloma (granulomatous tissue). Cysts expand slowly; the fluid that is formed within cysts raises the interstitial (interspaces of tissue) pressure abutting the bone margins, resulting in apical bone resorption. Eventually, the lesion may reach a large size. An apical cyst is usually treated by removal of necrotic pulpal irritants and complete obturation of the root canal system. The healing pattern is similar to the apical granuloma, although it may be more prolonged if the apical cyst is large. The radiologic appearance of the apical cyst is a more circumscribed area of radiolucency than apical granuloma, and it is usually bounded by a thin, unbroken line of sclerotic bone. The radiolucent area is generally round in outline except where it approximates adjacent teeth, in which case it may be flattened in

outline (oval pattern). Because the apical cyst is a cavity in bone that contains fluid, it appears as a dark radiolucent area with little signs of bone trabeculation (Fig. 18-7). They are usually larger than apical granulomas. If the radiolucency is more than 1 cm in diameter, it is more likely to be an apical cyst.

### **CHRONIC APICAL ABSCESS (SUPPURATIVE PERIAPICAL PERIODONTITIS, CHRONIC PERIAPICAL ABSCESS, CHRONIC DENTOALVEOLAR ABSCESS, SUBACUTE PERIAPICAL ABSCESS)**

The chronic apical abscess (CAA) is a long-standing, low-grade inflammatory reaction to toxic irritants from a necrotic (dead tissue) pulp. It is characterized by the formation of an abscess (pus/dead tissue) at the periapical region of a tooth. On examination, the tooth may be slightly loose or tender to percussion. On palpation, the periapical soft tissue may be slightly swollen and tender. Often a gum boil (parulis) is found. The tooth shows no reaction to electric pulp testing. The microscopic picture varies but depending on the stage of infection, it basically consists of an abscess (pus/dead tissue) in the center of granulomatous tissue (chronic inflammatory tissue). There are two types of chronic apical abscess: one **with a fistula** (abnormal passage) and one **without a fistula**. The chronic apical abscess heals spontaneously after adequate root canal treatment.

The chronic apical abscess **with a fistula** is the most common of the two chronic apical abscesses. It is charac-



**Figure 18.7 Apical Cyst (Periapical Cyst, Radicular Cyst).** (A) Classic appearance of apical cyst of lower second premolar. (B) Large apical cyst of retained roots of mandibular third molar (arrows).



terized by active pus formation draining through a **fistulous opening** (abnormal orifice) at the surface of the oral mucosa or the skin of the face (Fig. 18-8). A small proliferation of granulomatous tissue often forms on the mucosal surface and is referred to as a **gum boil**, or **parulis**, which is also frequently observed in conjunction with infection of primary teeth (Fig. 18-9). As soon as drainage is established through the mucoperiosteal tissue in an AAA, either by incision or by a fistulous tract, symptoms subside and a **chronic apical abscess with a fistulous tract** is formed.

Frequently, a radiolucency will be seen at the furcation of primary molars. This is the usual region for apical pathology to be seen in children. It is possibly due to accessory canals in the furca region of the primary molars. It is often seen in children with a chronic apical abscess with a **fistula (parulis)** in a primary molar.

The **chronic apical abscess (CAA)** without a fistula seldom develops directly from an AAA. It probably occurs as a natural developmental sequence of the death of the pulp with extension of the infective process periapically, in which the virulence and number of the bacterial organisms are low and the host resistance is high. Although mild, painful symptoms may occur, it is usually symptom free. When the production of pus commences, it begins a slow route that yields the least resistance through bone. When no **fistula** is present, the toxic products are some-

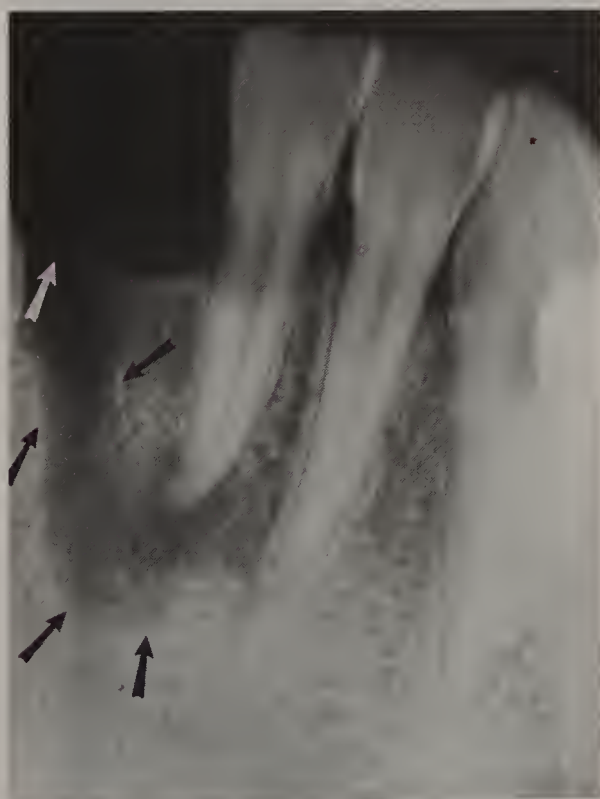


**Figure 18.9 Parulis or Gum Boil.** This is the classic sign of a chronic apical abscess. This is a young patient who had previously experienced all the acute symptoms of an acute apical abscess of upper lateral incisor. After free drainage of pus from the gum boil, the acute symptoms subsided.

condition sometimes referred to as a “blind abscess.” Radiographically, the chronic apical abscess without a fistula will demonstrate diffuse, irregular borders (Fig. 18-10). The radiolucent area fades indistinctly into normal bone and is usually represented by an area of lesser density than the granuloma or cyst.

### APICAL CONDENSING OSTEITIS (FOCAL SCLEROSING OSTEOMYELITIS)

**Apical condensing osteitis (ACO)** (focal sclerosing osteomyelitis) is a reaction of bone to a mild bacterial infection of periapical bone in persons who have a high degree of tissue resistance and tissue reactivity. Periapical bone in ACO reacts to a mild bacterial infection by a diffuse increase of trabecular bone, rather than the usual reaction of bone destruction. Therefore, a periapical infection acts



**Figure 18.8 Chronic Apical Abscess With a Fistula (Sinus Tract).** Chronic apical abscess originating from acute apical abscess of lower lateral incisor. Note radiolucent fistulous tract (black arrows) through alveolar bone to opening at surface of oral mucosa (white arrow).



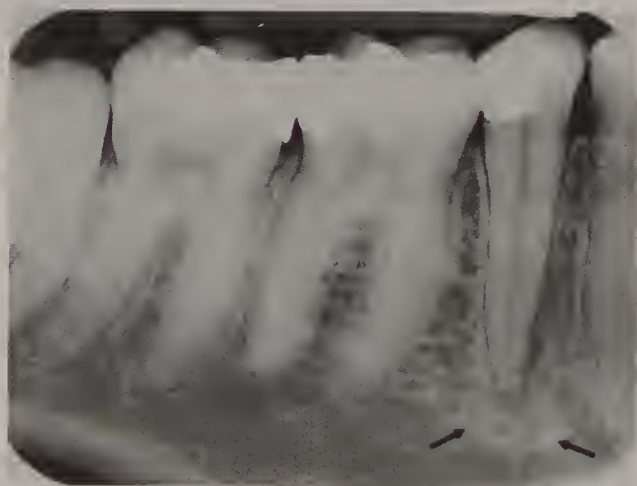
**Figure 18.10 Chronic Apical Abscess Without a Fistulous Tract.** Note the diffuse area of radiolucency of the mesial root of the lower first molar (arrow). The apical granuloma and the apical cyst have more definite circumscribed area of radiolucency than the chronic apical abscess.

as a stimulus, rather than an irritant in ACO. It is usually found around the apices of mandibular first molar teeth with large carious lesions with chronically inflamed pulps in patients younger than 20 years of age. However, ACO may occur around the apex or apices of any tooth. Usually, there are no signs or symptoms in ACO of the disease, other than mild pain associated with an infected pulp. The pulp tissue of these teeth with ACO usually does not respond to electrical or thermal stimuli. In addition, these teeth generally will not be sensitive to palpation or percussion. A return to the normal trabecular pattern may occur after root canal therapy, although the sclerotic bone may remain as bone scar. Radiographically, ACO appears as a pathognomonic, well-circumscribed radiopaque mass of sclerotic (hard, compact) bone surrounding and extending below the apex of one or both roots of teeth (Fig. 18-11). There is usually a radiolucency immediately adjacent to the periapical end of the involved tooth.

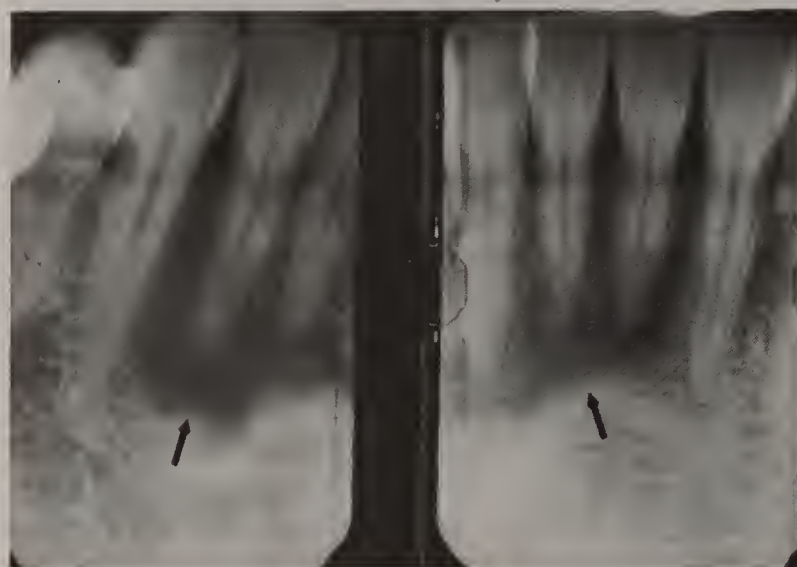
## OTHER APICAL (PERIAPICAL) CONDITIONS

### APICAL CEMENTOMA (PERIAPICAL CEMENTOMA, PERIAPICAL CEMENTAL DYSPLASIA)

The apical cementoma (AC) (periapical cemental dysplasia) is a benign, slowly growing, connective tissue proliferation thought to originate from cellular elements in periodontal ligament. Developing lesions destroy the lamina dura and spread periapically, replacing the surrounding normal trabecular bone with a fibrous tissue mass (radiolucent) within which varying amounts of radiopaque material (cementum or osseous material) may be observed, especially as the lesion matures. It has limited growth potential with a long duration. It is most often

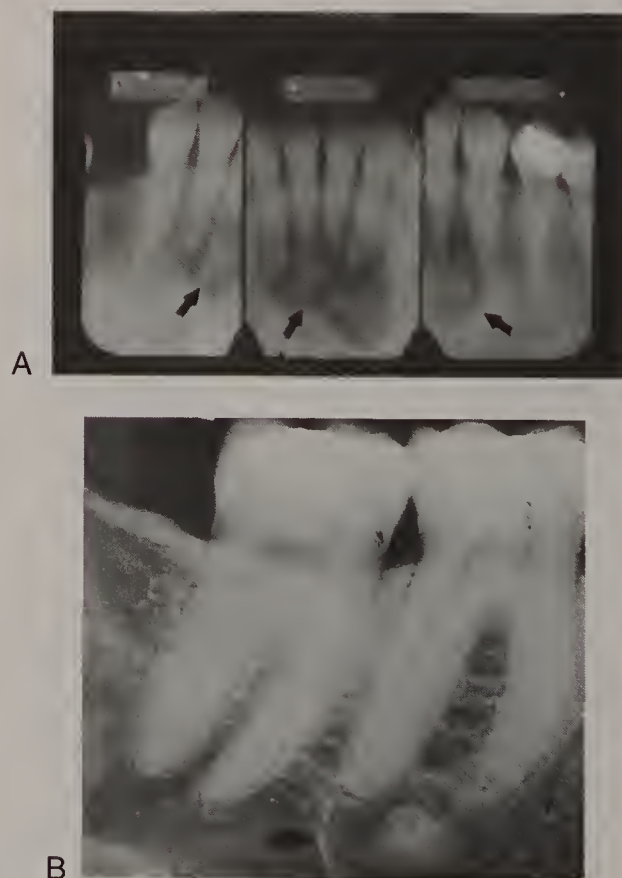


**Figure 18.11 Apical Condensing Osteitis.** Condensing osteitis of lower second premolar with large restoration (arrows).



**Figure 18.12 Immature Apical Cementoma (Periapical Cemental Dysplasia).** Immature apical cementomas are radiolucent lesions. The mandibular incisor teeth are vital. The immature apical cementomas are “filling in” with radiopaque material (arrows).

seen in middle-aged African-American and Asian women. The mandibular teeth are most frequently involved, and the teeth are vital. (No treatment is indicated.) In the early stages of the apical cementoma, the radiologic appearance varies from a thickened periapical periodontal membrane



**Figure 18.13 Mature Apical Cementoma (Periapical Cemental Dysplasia).** (A) Mature cementoblastic stage of apical cementoma of vital mandibular incisors (arrows). (B) Target lesion (opacity with lucent halo) of apical cementoma (arrow).



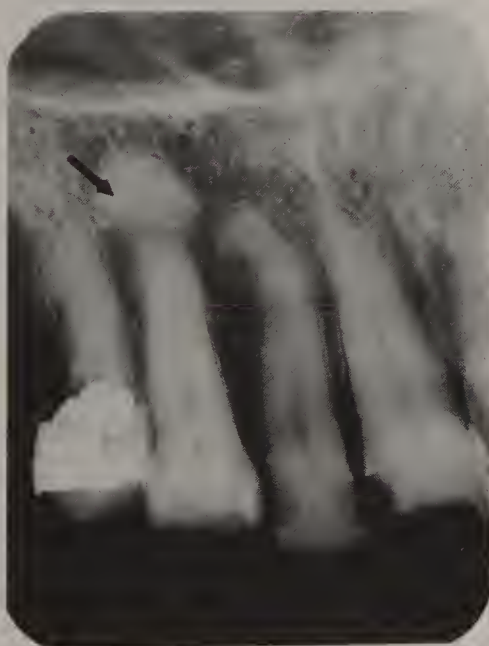


**Figure 18.14 Hypercementosis.** Increased formation of hypercementosis forming a generalized type producing symmetrical enlargement of entire roots of premolars.

space associated with destruction of the lamina dura to a well-defined radiolucent lesion similar to a chronic inflammatory periapical lesion (Fig. 18-12). However, in the case of the apical cementoma, the pulps of the teeth are vital. In later stages, increasing amounts of radiopaque material are laid down in the lesion (Fig. 18-13).

## HYPERCEMENTOSIS

Secondary cementum is formed on permanent teeth throughout the life of an individual. Hypercementosis is the excessive formation of secondary cementum on the root surfaces. It is the abnormal increase in the thickness of cementum and may affect single teeth or the entire den-



**Figure 18.15 Hypercementosis (Nodular Type).** Nodular type of hypercementosis on root tips of canine and lateral. (Also note attrition and silicate restorations.

tion. It produces no clinical signs or symptoms. The increased formation of cementum occurs mainly as a generalized type of hypercementosis producing a radiographic appearance of a symmetric enlargement of the entire root (Fig. 18-14). Two common radiographic types of generalized hypercementosis are: (1) dense cemental type, whereby the secondary cementum is of the same density as the primary cementum and dentin of the tooth, and (2) transparent type, wherein there is a demarcation between the primary cementum and dentin of the tooth and the secondary cementum. In some instances of hypercementosis, the secondary cemental formation is focal, appearing on the radiograph as a nodular or bulbous enlargement near or at the root apex (Fig. 18-15).

## REVIEW QUESTIONS

- Which of the following is most common?
  - Chronic periapical abscess.
  - Periapical cyst.
  - Dental granuloma.
  - Condensing osteitis.
  - Residual cyst.
- Which of the following usually is (are) associated with nonvital pulps of teeth?
  - Hypercementosis.
  - Cementoma (periapical cemental dysplasia).
  - Periapical cyst.
  - Periapical osteosclerosis.
  - All of the above.
- Which of the following would best differentiate condensing osteitis from a periapical cementoma (periapical cemental dysplasia)?
  - Pulp of tooth is nonvital in condensing osteitis.
  - Condensing osteitis affects mandibular incisors 80% of the time.
  - Condensing osteitis is seen mostly in women
  - Periapical cementomas (periapical cemental dysplasia) are attached to root, whereas condensing osteitis is not.
  - Periapical cementomas (periapical cemental dysplasia) are seen mostly in teenagers and are usually associated with a carious mandibular first molar.
- Which of the following would most likely cause the most pain and many times would not be seen on the radiograph?
  - Periapical granuloma.
  - Periapical cementoma.

- C. Chronic apical abscess.
  - D. Acute apical abscess.
  - E. Periapical cyst.
5. Which of the following can mimic a periapical radiolucent lesion on the dental radiograph?
- 1. Apex region of immature tooth.
  - 2. Mental foramen.
  - 3. Nasopalatine foramen.
  - 4. Greater palatine foramen.
  - A. 1, 2, 3, and 4.
  - B. 1, 2, and 4.
  - C. 1, 2, and 3.
  - D. 3 and 4.
  - E. 1 and 2.
6. Which of the following may be associated with acute apical periodontitis?
- A. Vital tooth.
  - B. Occlusal trauma.
  - C. Irreversibly inflamed or necrotic pulp.
  - D. High restoration recently placed.
  - E. All of the above.
7. Which of the following would most often not reveal a periapical lesion on the radiograph?
- A. Apical condensing osteitis.
  - B. Apical cyst.
  - C. Apical granuloma.
  - D. Chronic apical abscess.
  - E. Acute apical abscess.
8. Apical granuloma is:
- 1. A periapical tumor.
  - 2. Composed principally of granulomatous tissue.
  - 3. Composed of granulation tissue.
  - 4. An advanced form of chronic apical periodontitis.
  - 5. A painful, localized collection of pus.
  - A. 1, 2, and 3.
  - B. 3, 4, and 5.
  - C. 2 and 4.
  - D. 3 and 4.
  - E. 2 and 5.
9. Which of the following differentiate radiographically the apical cyst and apical granuloma?
- A. Apical cyst is more circumscribed.
  - B. Apical cyst is more radiolucent.
  - C. Apical cyst is most often bounded by an unbroken line of sclerotic bone than an apical granuloma.
  - D. Apical cysts are usually larger than apical granulomas.
  - E. All of the above.
10. Which of the following is most often found in patients younger than 20 years of age?
- A. Apical granuloma.
  - B. Acute apical abscess.
  - C. Apical condensing osteitis.
  - D. Chronic apical abscess.
  - E. Apical cyst.
11. Which of the following lesions are usually associated with vital teeth?
- A. Hypercementosis.
  - B. Chronic apical abscess.
  - C. Apical granuloma.
  - D. Apical cyst.
  - E. Chronic apical abscess.
12. Which of the following apical conditions causes the most pain?
- A. Acute apical periodontitis.
  - B. Apical granuloma.
  - C. Apical cyst.
  - D. Acute apical abscess.
  - E. Chronic apical abscess.
13. What tooth is usually involved with apical condensing osteitis?
- A. Upper lateral incisor.
  - B. Lower first molar.
  - C. Upper second molar.
  - D. Upper first premolar.
  - E. Lower canine.
14. Which teeth are usually involved with apical cementosis?
- A. Upper incisors.
  - B. Lower incisors.
  - C. Lower molar.
  - D. Upper molar.
  - E. Lower premolars.
15. Which of the following most accurately describes the radiographic findings of a chronic apical abscess without a fistula?
- A. Rounded, well-circumscribed, dark radiolucency bounded by a thin radiopaque border.
  - B. Slight widening of periodontal ligament space at apical region.
  - C. Rounded, well-circumscribed, gray appearing radiolucency.
  - D. Diffuse radiolucency with irregular borders.
  - E. Well-circumscribed, radiopaque mass bounded by a thin radiolucent line.



## CASE-BASED QUESTIONS

**CASE 18.1**

This patient has a toothache. All the teeth have onlays or crowns and are difficult to pulp test.

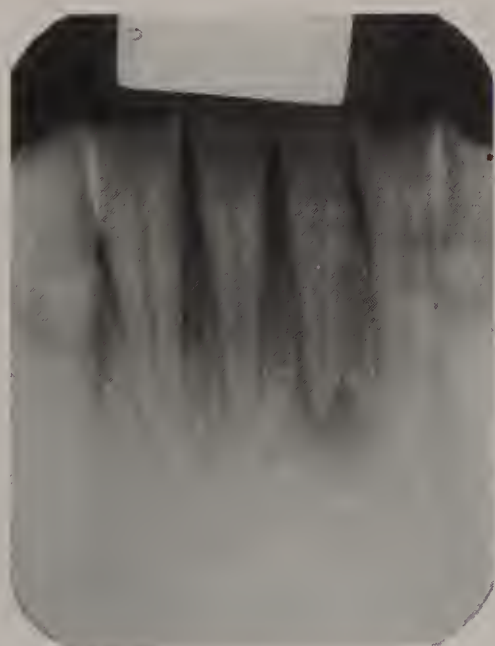
**QUESTION**

1. Which tooth do you think is the culprit?

- A. First premolar.
- B. Second premolar.
- C. First molar.
- D. Some other tooth.

**CASE 18.2**

This is a 28-year-old beach volleyball player. The left central incisor is nonvital; the cause was previous trauma.

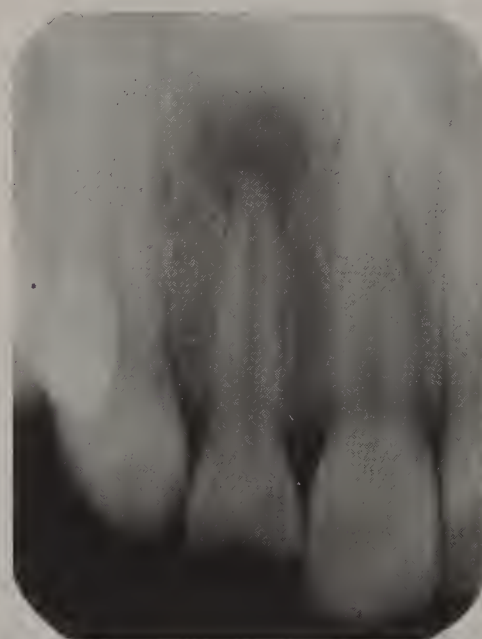
**QUESTION**

1. The resorption at the apex indicates the lesion is most likely an:

- A. Apical granuloma.
- B. Apical condensing osteitis.
- C. Apical abscess.
- D. Apical cementoma.

**CASE 18.3**

This 13-year-old boy fell off his skateboard some time ago. The tooth is nonvital.

**QUESTION**

1. By radiographic appearance, only the periapical lesion of the upper right lateral is most likely an:

- A. Apical condensing osteitis.
- B. Apical cyst.
- C. Apical abscess.
- D. Apical cementoma.

**CASE 18.4**

This patient is a 6-year-old boy with a gum boil adjacent to the left second primary molar.

**QUESTIONS**

1. The furcal radiolucency is:

- A. Of periodontal origin.
- B. Of pulpal origin.
- C. Resorption due to the erupting second premolar.
- D. Normal for this age.

2. The erupting second premolar:
  - A. Will probably be normal.
  - B. May develop preeruption caries.
  - C. May develop Turner's hypoplasia.
  - D. May become cystic.
  - E. C and D.

**CASE 18.5**

This 12-year-old girl has a large carious lesion in the first premolar.

**QUESTION**

1. A sign of pulpal involvement is:
  - A. Caries.
  - B. Strange-looking apex.
  - C. Localized antral mucositis.
  - D. Not seen on this radiograph.

**CASE 18.6**

This 21-year-old college student has a toothache. There is caries in all three of these teeth.

**QUESTIONS**

1. Which tooth do you think is the culprit?
  - A. Second premolar.
  - B. First molar.
  - C. Second molar.
  - D. All of the above.

2. What periapical changes suggesting irreversible pulpitis are present?
  - A. Loss of the lamina dura.
  - B. Thickened apical periodontal ligament space.
  - C. Resorption of apical bone.
  - D. Condensing osteitis.
  - E. All of the above.

**CASE 18.7**

This 11-year-old boy has a tooth that is sensitive to hot, cold, and sweets. You note deep occlusal caries and periapical radiolucencies in the first molar.

**QUESTION**

1. What is the best conclusion regarding the tooth in this case?
  - A. The tooth is vital and the apices are not yet closed.
  - B. The tooth is nonvital with apical involvement.
  - C. Neither A nor B.
  - D. It is too early to decide; place a sedative dressing.

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# Glossary

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## A

**Abrasion:** Abnormal wearing away of tooth substance by a mechanical process.

**Accelerators:** This chemical serves to swell the film emulsion and provides an alkaline medium during processing.

**Activator:** This gives the solution the proper pH and neutralizes any remaining developer on the film. It also acts to aid the other processing chemicals in their activity.

**Acute:** Having a rapid onset, short severe course, and pronounced symptoms; opposite of chronic.

**Acute effects:** Effects that are usually the result of high doses of radiation (usually over the whole body). The symptoms of these acute effects may include nausea, vomiting, hemorrhage, diarrhea, fever, loss of hair, and death.

**Ala:** The wing of the nose. In dental radiography, the depression at which the nostril connects with the cheek.

**Ala-tragus line:** An imaginary line that intersects the ala of the nose and the tragus of the ear; used in positioning a patient for a panoramic film (ala is the tissue that surrounds the nostril; tragus is a cartilaginous projection anterior to the external opening of the ear).

**ALARA concept:** This principle emphasizes that the dose to the patient should be kept as low as reasonably achievable under a given set of circumstances.

**Alpha particle (symbol  $\alpha$ ):** The nucleus of a helium atom ejected from a radioactive nucleus when it disintegrates.

**Alternating current:** A flow of electrons in one direction followed by a flow of electrons in the opposite direction.

**Alveolar bone:** That portion of the maxillary or mandibular bone that surrounds and supports the roots of the dentition.

**Alveolar crest:** The most coronal portion of alveolar bone found between the teeth; it is composed of dense cortical bone and appears radiopaque.

**Ampere (A):** The unit of intensity of an electric current produced by 1 volt (V) acting through a resistance of 1 ohm.

**Anode:** The positive terminal of an x-ray tube; a tungsten block embedded in a copper stem and set at an angle to the cathode. The anode emits x-rays from the point of impact of the electron stream from the cathode.

**Anomaly:** A significant deviation from the normal or a departure from the regular order of things.

**Anterior nasal spine:** This structure appears as a radiopaque area at the base of the nasal septum. It represents a bony protuberance to which the nasal cartilage is attached.

**Atom:** The smallest particle of an element that has the characteristic properties of that element.

**Atomic number (Z):** The number of protons in the nucleus of an atom.

**Attenuation:** In radiography, the process by which a beam of radiation is reduced in energy when passing through matter.

**Attrition:** Physiologic wearing away of teeth as a result of tooth-to-tooth contact as in mastication, clenching, and bruxism.

## B

**Background radiation:** Radiation that occurs naturally in the environment.

**Backscatter:** Radiation that is scattered backward into the path of the original beam.

**Beta particle (symbol  $\beta^-$ ):** Electrons, positive or negative, emitted by the nucleus of a radioactive atom when it disintegrates.

**Benign:** Harmless or nonmalignant.

**Binding energy:** The energy needed to eject an electron from the atom.

**Bremsstrahlung radiation (white radiation):** A spectral distribution of x-rays ranging from very-low-energy photons to those produced by the peak kilovoltage applied across an x-ray tube. Bremsstrahlung or braking radiation refers to the sudden deceleration of electrons (cathode rays) as they interact with highly positively charged (high atomic number) nuclei such as tungsten.

## C

**Calculus:** In dentistry, a deposition of mineral salts to form a concretion or ring around the root of a tooth or to cover parts of the crown.

**Cancellous (spongy) bone:** This bone surrounds the lamina dura and tooth socket. It is composed of thin strands of bone called trabeculae that cross one another in an irregular manner. Separating the trabeculae are spaces containing bone marrow.

**Canthus:** The angle at either end of the slit that separates the eyelids. In radiography, the inner canthus is

- the part of the slit nearest to the nose; the outer canthus is the part farthest from the nose.
- Cassette:** A light-tight case, usually made of thin, low-x-ray absorption plastic for holding x-ray film. One or two intensifying screens for the conversion of x-rays to visible light photons are mounted inside the cassette in close contact with the film.
- Cathode:** The negatively charged component of an x-ray tube that repels electrons toward the anode.
- Cathode rays:** A stream of electrons passing from the hot filament of the cathode to the anode in an x-ray tube.
- Central ray:** The theoretical center of the x-ray beam. This term is used to designate the direction of the x-rays in a given projection; may be considered to extend from the focal spot of the x-ray film.
- Cervical:** Pertaining to the neck or cervical vertebrae. Pertaining to the cemento-enamel junction area of a tooth.
- Cervical burnout:** A radiolucent artifact seen on a dental radiograph resulting from the differences in densities of adjacent tissues.
- Characteristic curve:** A type of input-output response curve. In radiography, this curve expresses the change in optical density (output) with the change in exposure of x-ray film; also called H & D curve or sensitometric curve.
- Characteristic radiation:** A form of radiation originating from an atom following removal of an electron or excitation of the atom. The wavelength of the emitted radiation is specific for the element concerned and the particular energy levels that are involved.
- Chronic effects (because of radiation exposure):** These effects, which are usually shown as a decrease in the ability of the tissue to resist trauma and infection, are usually produced over a long period.
- Clearing agent:** The agent in the fixer solution that dissolves the unexposed, undeveloped silver halide crystals, leaving the black metallic silver in the exposed and developed areas of the film more readily discernible; also called hypo.
- Collimator:** A common term for a variable-aperture, beam-limiting device for restricting the field of x-ray photons in a beam to a desired shape and size.
- Compton scatter radiation (scatter radiation):** The incident radiation has sufficient energy to dislodge a bound electron but attacks a loosely bound electron. The remaining radiation energy proceeds in a different direction as scatter radiation.
- Contrast:** The difference in image density appearing on a radiograph, representing various degrees of beam attenuation.
- \*Film contrast:** A characteristic inherent in the type of film used.
- \*Long-scale contrast:** An increased range of grays between the blacks and whites on a radiograph. Higher kilovoltages increase this range.
- \*Short-scale contrast:** A reduced range of grays between the blacks and whites on a radiograph. Lower kilovoltages decrease this range.
- \*Subject contrast:** The relative differences in density and thickness of the components of the radiographed subject, as evidenced by the varied radiographic densities caused by the differences in absorbing power of the different kinds of material traversed by an x-ray beam.
- Contrast, radiographic:** The difference in optical density (film blackening) between areas of interest in a radiograph. The combination of subject contrast and film contrast determines radiographic contrast.
- Corpuscular radiation:** Minute subatomic particles such as protons, electrons, and neutrons; also alpha and beta particles. These particles occupy space, have mass and weight, and with the exception of neutrons have an electrical charge.
- Cortical bone:** Compact bone that forms the outer and inner plates of the alveolar process.
- Crestal bone:** That portion of the alveolar bone that extends from tooth to tooth. It appears radiopaque.
- Current:** The flow of charged particles, for example, electrons.

## D

- Definition:** In radiography, the sharpness and clarity of the outline of the structures on the image shown on the film. Poor definition is generally caused by movement of the patient, film, or the tubehead during exposure.
- Densitometer:** A device consisting of a light source, an aperture, and a light sensor used to measure optical density.
- Density:** The degree of darkening of exposed and processed photographic or x-ray film.
- Density, optical:** The degree of blackening of film after exposure and processing.
- Density, physical:** The mass of a substance per unit volume. For example, g/cm<sup>3</sup>.
- Detail:** The point-by-point delineation of the minute structures visible in the shadow images on the radiograph. Detail may be good or poor.
- Developer:** A chemical solution that converts the latent image on film to a visible image.
- Developer agent:** Elon and hydroquinone; substances that reduce the halides in the film emulsion to metallic silver. Elon brings out the details, and hydroquinone brings out the contrast in the film.
- Direct current:** Electric current that flows continuously in one direction. Unidirectional current is produced in batteries but cannot be used in x-ray machines unless they are modified.
- Distal:** Remote; farther from any point of reference; e.g., midline.



**Disto-oblique radiograph:** An image useful for viewing the most posterior areas of the mouth, such as impacted third molars.

**Distortion:** An inaccuracy in the shape of an object as it is displayed in the radiograph. Distortion is brought about by misalignment of the cone relative to the object.

**Dose (dosage of radiation):** The amount of energy absorbed per unit mass of tissue at a site of interest.

\***Absorbed dose:** The amount of energy imparted by ionizing radiation to a unit mass of irradiated material at a place of interest. The unit of absorbed dose in the traditional system is the rad (100 erg/g). The currently accepted unit of absorbed dose is the gray (Gy) (1 Gy = 1 J/kg).

\***Cumulative dose:** The total dose resulting from repeated exposures to radiation of the same region or of the whole body.

\***Doubling dose:** The amount of ionizing radiation absorbed by the gonads of the average person in a population over several generations that will result in a doubling of the current rate of spontaneous mutations.

\***Erythema dose:** Antiquated approach to radiation measurement based on the amount of radiation to cause erythema (redness) of the skin.

\***Exit dose:** Dose of radiation at the surface of body opposite to that on which the beam is incident.

\***Threshold dose:** The minimum dose that will produce a detectable degree of any given effect.

**Dose equivalent:** The product of absorbed dose and modifying factors, namely the quality factor, distribution factor, and any other necessary factors. The traditional unit of dose equivalence is the rem (rads  $\times$  qualifying factors). The International System (SI) (mks) unit of dose equivalence is the sievert (grays  $\times$  qualifying factors).

**Dosimeter (radiation meter):** An instrument used to detect and measure an accumulated dosage of radiation.

## E

**Effective dose equivalent:** The purpose of the effective dose equivalent is to relate exposure to risk. In an attempt to make some comparison in the risk assessment for all types of exposures, the concept of effective dose equivalent was developed. The unit of effective dose equivalent is the sievert.

**Electromagnetic radiation:** Forms of energy propelled by wave motion as photons of energy. This is a combination of electric and magnetic energy.

**Electromagnetic spectrum:** The range of all electromagnetic radiations according to their energy.

**Electron:** A minute, negatively charged particle that revolves around the positively charged nucleus in assigned orbits or shells.

**Electron volt (eV):** The kinetic energy gained by an electron falling through a potential difference of 1 volt.

**Element:** A substance that is composed exclusively of atoms having the same atomic number, which cannot be separated into simpler substances by ordinary chemical means.

**Emulsion, film:** A mixture of gelatin and silver halide crystals (in suspension) in which latent image formation takes place.

**Energy:** The ability to do work.

**Excited state:** The addition of energy to a system, thereby transforming it from its ground state to an excited state.

**Exposure:** A measure of the amount of ionization produced in air by an x-ray beam; measured in milliroentgens (mR) or Roentgens (R).

**External oblique ridge:** A ridge originating from the anterior border of the ramus of the mandible extending to the lateral body of the mandible in the molar region.

## F

**Filament:** A coiled tungsten wire that, when heated to incandescence, emits electrons.

**Film speed:** The sensitivity of film emulsion to x-ray or light exposure. The amount of exposure the light or x-rays require to produce a given image density.

**Filter:** Material (usually aluminum) placed in the path of the useful beam to preferentially absorb the less-energetic (less-penetrating) x-rays.

**Filtration, added:** A material or device inserted between the x-ray tube and the patient to preferentially absorb lower-energy photons from an x-ray beam.

**Filtration, total:** The equivalent amount of filtering material (usually stated in millimeters of aluminum [mm Al]) between the focal spot and the object being radiographed; also the sum of the added and inherent filtration that is usually from glass of x-ray tube (0.5 mm Al equivalent).

**Fixer:** A chemical solution that both removes the unexposed and undeveloped silver halide crystals from the coated film emulsion and hardens the gelatin.

**Fluorescence:** The property of a phosphor to emit light in the visible region of the electromagnetic spectrum as a result of absorbing higher-energy radiation, such as x-rays.

**Focal spot:** That part of the target of an x-ray tube that is bombarded by the focused electron stream when the tube is energized.

**Focal trough:** In panoramic radiography, a three-dimensional curved zone or image layer in which structures are reasonably well defined; a patient must be positioned so that the dental arches are located within the focal trough area.

**Focusing cup:** Along with the filament, the focusing cup determines the size and shape of the target (focal spot). The cup is constructed of molybdenum.

**Fog (fogging):** A darkening of the whole or part of a radiograph by sources other than the radiation of the primary beam to which the film was exposed.

**Foramen:** A naturally formed hole or passage through a bone or tooth. Often the opening for a canal through which blood vessels and nerves pass. Appears radiolucent on radiograph.

**Fossa:** A broad, shallow, scooped-out or depressed area of bone; appears radiolucent.

**Frankfort plane:** A term used in cephalometric radiography. The horizontal plane between the porion and the orbitale. Clinically, the ALA-Tragus line.

**Frequency:** The number of crests of a wavelength passing a given point per second. This provides an indication of the energy of the radiation. The higher the frequency, the shorter the wavelength. The shortest wavelengths have the most energy and penetrating ability.

## G

**Gamma radiation:** Short wavelength electromagnetic radiation of nuclear origin.

**Generator:** A machine that converts alternating current electrical power into a waveform suitable for the production of x-rays.

**Genetic effect:** Changes produced in the genes and chromosomes of all nucleated body cells. In customary usage, the term relates to the effect produced in the reproductive cells.

**Genial tubercles:** Tiny bumps of bone in the anterior region of the mandible that serve as attachment sites for the genioglossus and geniohyoid muscles; appear radiopaque.

**Gray (Gy):** A unit of absorbed dose or energy deposited in tissue; 1 Gy = 100 rad.

## H

**H & D curve:** A characteristic curve of a photographic emulsion obtained by plotting film density against the logarithm of the exposure; named after the British scientists and founders, Hurter and Driffield.

**Half-value layer (HVL):** The thickness of a given material required to reduce the ionizing effect of the primary beam of radiation to one-half its original (unattenuated) value.

**Hamulus:** This bony projection appears radiopaque and extends downward from the medial pterygoid plate. It is located behind the maxillary tuberosity region.

**Hardener:** Hardeners help to toughen and shrink the gelatin in the film emulsion. This also helps to reduce the drying time needed at the completion of the processing.

**Hertz (Hz):** Unit of measurement of frequency of electromagnetic radiation; 1 Hz = 1 cycle/sec.

**Heterogeneous radiation:** Radiation consisting of various wavelengths and energies.

**Homogeneous radiation:** Radiation that consists of only one wavelength and energy.

**Horizontal angulation:** The position of the cone/beam indicating device, with movement occurring in a right-to-left direction (horizontal).

**Hydroquinone:** This is responsible for blackening the exposed silver halide crystal and for bringing out the contrast.

## I

**Impulse:** In dental radiography, a measure of exposure time. Many of the newer x-ray machines are calibrated to make the exposure in impulses instead of fractions of a second. There are 60 impulses per second.

**Incisive foramen (nasopalatine foramen):** This structure is an opening through which the nasopalatine nerves and artery pass. This area appears as a radiolucent, oval-shaped structure between the central incisors.

**Intensifying screen:** A device used to convert x-ray energy to light energy. It consists of a card or plastic sheet coated with fluorescent material, positioned singly or in pairs in a cassette to contact the film. When the cassette is exposed to x-radiation, the light emitted from the fluorescent intensifying screen exposes the film and produces the latent image.

**Interproximal:** The mesial and distal surfaces of the tooth crown where the adjacent tooth touches.

**Inverse Square Law:** The relationship between distance and radiation intensity in which the exposure varies inversely as the square of the distance from the source.

**Ion:** An atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

**Ionization:** The process or the result of a process by which a neutral atom or molecule acquires either a positive or a negative charge.

**Ionization chamber:** A cylinder or enclosure in a monitoring device that contains electrodes. An electric field is maintained between them for the purpose of collecting the charge when the gas or air in the chamber is ionized during exposure to radiation.

**Ion pair:** A pair of ions, one positive and one negative, that results when an electron is removed from an atom in the ionization process.

## J

**Joule (J):** Unit of work and energy equal to 1 Newton (N) expended along a distance of 1 meter (m).

## K

**Kilo:** A prefix used with a unit of measure indicating that the unit should be multiplied by 1000. For example, 1 kilovolt (kV) is equivalent to 1000 volts (V).



- Kiloelectron volts (keV):** One thousand electron volts.
- Kilovoltage peak (kVp):** The maximum potential difference between anode and cathode in an x-ray tube.
- Kinetic energy:** The energy possessed by a mass such as an electron because of its motion.

## L

- Latitude, exposure:** A measure of the tolerance allowed in the choice of exposure values required to produce the desired density range.
- Latitude, film:** The capability of a film emulsion to record a wide range of exposures, resulting in the film having long-scale contrast.
- Latent image:** The invisible change produced in an x-ray or photographic film emulsion by the action of x-radiation or light, from which a visible image is produced on the film by chemical processing.
- Latent period:** The period between the time of exposure of tissue to an injurious agent (e.g., radiation) and the clinical manifestation of a particular response.
- Lateral fossa:** A smooth, depressed area of the maxilla located between the canine and lateral incisor; appears radiolucent.
- Linear energy transfer (LET):** The linear rate of loss of energy by an ionizing particle traversing a medium.
- Lingual foramen:** A very small opening through which a branch of the incisive artery emerges. It is located in the center of the genial tubercles on the lingual side of the mandible.

## M

- Mach band effect:** A simulated, false appearance of caries due to the optical illusion presented from light and dark objects (e.g., enamel and dentin) placed next to one another.
- Magnification, radiographic:** The equal enlargement of a radiographic image recorded on film emulsion, minimized by reducing the object-to-film distance and increasing the focus-film distance.
- Mass number (symbol A):** The number of nucleons (protons and neutrons) in the nucleus of an atom.
- Maxillary sinus:** Paired air-filled cavities or compartments of bone located within the maxilla; above the premolars and molars. Appears radiolucent.
- Maxillary tuberosity:** This bony structure appears as a bulge distal to the maxillary molars and at the posterior end of the maxillary alveolar ridges.
- Mental foramen:** This structure provides a means for the blood vessels and nerves to supply the lower lip. It appears as a radiolucent, round, or oval-shaped area located near the apices of the mandibular premolars.
- Mental ridge:** The mental ridge is a bony prominence on the external portion of the mandible, which extends in

a sloping fashion from the premolar area to the central incisors. It appears as a radiopaque, curved ridge below the mandibular anterior teeth.

- Mesial:** The interproximal surface of the tooth toward the center of the dental arch.
- MeV:** Million electron volts.
- Midsagittal plane (midsagittal line):** An imaginary vertical line or plane passing through the center of the body that divides it into a right and left half.
- Milli:** A prefix used with a unit of measure indicating that the unit should be multiplied by one one-thousandth. For example, 1 millisecond (ms) equals one one-thousandth of a second.
- Milliamperage (mA):** A measure of the number of electrons flowing per second; also called milliamperes.
- Milliampere-seconds (mAs):** The product of the factors milliamperes and time, used to calculate changes in exposure;  $mAs = mA \times \text{time (sec)}$ .
- Molecule:** The smallest quantity of matter that can exist by itself and retain its chemical properties. It is composed of one or more atoms.
- Mutation:** A departure from the parent type, as when an organism differs from its parents in one or more heritable characteristics, as a result of genetic change.

## N

- Nanometer (nm):** Approximately one-billionth of an inch or one millionth of a millimeter.
- Negatron:** Term used for an electron to emphasize its negative charge in contradistinction to the positive charge carried by the otherwise similar positron.
- Neoplasm:** A tumor or any new or abnormal growth in which cell multiplication is uncontrolled.
- Neutrons:** An atomic particle with no charge that is similar in mass to the proton; neutrons are constituents of all atomic nuclei except that of hydrogen.
- Newton:** Unit of force that when applied to a mass of 1 kilogram will accelerate 1 meter/second/second.
- Nonstochastic effects:** These have threshold doses. It is believed that below these threshold doses, the effects do not occur. In addition, the severity of the effect is increased as the dose is increased. An example of this is erythema of the skin.
- Nutrient canals:** These canals provide a means for the blood vessels and nerves to reach the teeth. Nutrient canals are especially visible as radiolucent lines extending downward from the mandibular anterior teeth.

## O

- Occlusal radiographs:** A radiograph made with a film designed for placement between the occlusal surfaces of the teeth, with the x-ray beam directed vertically superiorly or inferiorly.

**P**

**Palate:** The roof of the mouth.

**Panoramic film:** A radiograph that shows a large area of the mandible and maxilla on a single film.

**Parulis:** A raised swollen area indicating an abscess of the gum. Often called a gum boil. A fistula (narrow canal) often connects the parulis with the core of the abscess at the apex of the root in the alveolus (tooth socket).

**Penumbra:** A penumbra, produced by light, is the secondary shadow that is the periphery of the primary shadow. In radiography, the penumbra is the blurred or ill-defined margin of an image detail; also called geometric unsharpness.

**Periapical projection:** A radiograph made by intraoral placement of film for recording shadow images of the outline and the position and mesiodistal extent of the teeth and surrounding tissue. It is the best intraoral view available for revealing the apices of the teeth and their contiguous tissues.

tissues surrounding the teeth.

**Periodontal ligament space:** A radiolucent space that exists between the root of the tooth and bone.

**Periodontitis:** Inflammation of the tissues that support the teeth; results in the destruction of the periodontium.

**Photoelectric effect:** The ejection of bound electrons by an incident x-ray photon such that the whole energy of the x-ray photon is absorbed and characteristic x-radiation is produced.

**Photon:** A quantum (bundle of energy) of electromagnetic radiation.

**Polychromatic:** Having many colors. This term is used in dental radiography to describe the x-ray beam that is composed of many wavelengths of different intensity.

**Positron (symbol  $\beta^+$ ):** A particle equal in mass to the electron but having an equal but opposite (positive) charge.

**Preservatives:** Chemicals that inhibit oxidation of the reducing agents (developing agents) by air. Sodium sulfite is the chemical usually used.

**Proton:** An elementary particle in the atomic nucleus that has a positive charge equal to that of the electron but with much greater mass.

**Q**

**Quality factor (QF):** A term that expresses the differences in biologic effectiveness of various types of radiation compared with ordinary x-rays.

**Quantum:** A packet or bundle of electromagnetic energy.

**Quantum theory:** The theory that electromagnetic energy is transferred in discrete quanta or photons.

**R**

**Radiation absorbed dose (rad):** A unit of measurement for the absorbed dose of any type of ionizing radiation in any medium; 1 rad is the energy absorption of 100 erg/g.

**Radiolucent:** A black or dark area seen on a radiograph; structures that appear radiolucent lack density and permit the passage of the x-ray beam.

**Radiopaque:** A white or light area on a radiograph; structures that appear radiopaque are dense and resist the passage of the x-ray beam.

**Rarefaction:** The state of being or becoming less dense, usually as a result of some disease process, indicated by radiolucent areas in the bone structures shown on radiographs.

**Rectification:** Conversion of alternating current to direct current.

**Reducing agents:** Chemicals that “reduce” (or change) the exposed silver halide crystal to black metallic silver.

**Rem (Roentgen equivalent man):** A unit of dose of any radiation to body tissue in terms of its estimated biologic effects relative to an exposure of 1 Roentgen of x- or gamma-radiation.

**Replenisher:** A superconcentrated solution of developer or fixer that is added daily or as indicated to the developer or fixer in the processing tank to compensate for loss of volume and loss of strength from oxidation.

**Resolution:** The ability of a film to record a true image. The ability of the radiographic image to discern the boundaries between two objects that are close together. Measured in line pairs per millimeter (lp/mm).

**Restrainers (antifogging agents):** The restrainers act to block the action of the reducing agent on unexposed crystals. Without this chemical, the processed radiographic film would be totally black.

**Roentgen (R):** A unit of radiation exposure measured in air that was named after Wilhelm Conrad Roentgen, who discovered x-rays in 1895.

**Rule of isometry:** A geometric theorem which states that two triangles with two equal angles and a common side are equal triangles.

**S**

**Sagittal plane:** An imaginary vertical line or plane that bisects the body into a right and left portion. If the plane is exactly at the midline, it is referred to as the midsagittal plane.



**Scatter radiation:** Radiation that has been deflected from its path by impact during its passage through matter. This form of secondary radiation is emitted or deflected in all directions by the tissues of the patient's head during exposure to x-radiation.

**Secondary radiation:** This is a form of radiation that is created at the instant the primary x-ray beam interacts with matter and gives off some of its energy, forming new and less-powerful wavelengths.

**Self-rectification:** Suppression of half the sine wave of the alternating current across an x-ray tube. This results from the absence of electrons at the anode side when the polarity is reversed.

**Sensitometer:** A device that exposes film to a controlled set of light exposures. It is used to evaluate a film's response to exposure.

**Sievert (Sv):** The SI unit associated with a rem; 1 rem = 100 Sv. It is a dose equivalent unit defined as the absorbed dose Gray (Gy), times the quality factor (QF). For dental x-rays, 1 Sv = 1 Gy.

**Silver halide:** A salt compound used in photographic emulsions because of its sensitivity to light and other forms of radiation. Halides are compounds of metals with halogen elements of bromine, chlorine, and iodine.

**Solvent:** A liquid that dissolves another solution. Water is the solvent used as the vehicle for mixing chemicals in the developer and the fixer.

**Somatic cells:** All body cells except the reproductive cells.

**Somatic effects:** In radiography, the effect of radiation on all body cells except the reproductive cells, especially the effect on the blood, the soft muscular tissues, and the bone.

**Source:** In radiography, the place where the x-ray photons originate. This is the focal spot on the target of the anode inside the x-ray tube.

**Speed:** A measure of the exposure needed to produce a given density on film.

**Step-wedge:** A device with graduated thicknesses (usually of aluminum) that is used to demonstrate or test various degrees of x-ray penetration.

**Stochastic effects:** Those effects in which the risk of getting the effects is dependent on the dose of radiation received. There is no known threshold below which the effects do not occur. An example of stochastic effect is cancer.

## T

**Target (x-ray tube):** The part of the anode in an x-ray tube toward which electrons from the cathode are focused and attracted and where they interact to produce x-radiation.

**Target theory:** A theory that explains some biologic effects of radiation on the basis of ionization in a very small, sensitive region within the cell.

**Thermionic emission:** The escape of electrons from the heated filament in the cathode of an x-ray tube.

**Threshold dose:** The minimum exposure that will produce a detectable degree of any given effect.

**Tomography:** A special radiographic technique used to show in detail images of structures located within a predetermined plane of tissue while eliminating or blurring those structures in the planes not selected.

**Topographic occlusal:** A radiograph that demonstrates the anterior area of the maxillary arch.

**Trabecular bone (cancellous bone):** The softer spongy bone that makes up the bulk of the inside portion of most bones.

**Tragus:** The small cartilaginous prominence of tissue located near the center and in front of the acoustic meatus (outer ear opening).

**Transformer:** One of several types of electrical devices capable of increasing or decreasing the voltage of an alternating current by mutual induction between primary and secondary coils or windings on cores of metal.

## U

**Umbra:** A complete shadow produced by light, with sharply demarcated margins. In radiography, a sharply delineated image detail.

## V

**Valence electrons:** Number of electrons in the outer shell of the atom that determines the combining power of one atom of an element (or a radical).

## W

**Wave propagation:** Energy manifested by movements in an advancing series of alternating elevations and depressions traveling through space or a medium.

**Wavelength:** The distance between the peaks of waves in any waveform. The distance between the crest of one wave to the crest of the next wave determines the energy and penetrating power of the radiation, such as light or x-rays.

## X

**X-ray (Roentgen rays):** A type of electromagnetic radiation characterized by wavelengths of 100 Angstroms (Å) or less.

**X-ray tube:** An electronic tube in which x-rays are generated.

**Y**

**Yoke:** The curved portion of the x-ray machine that can revolve 360° horizontally where it is connected to the extension arm. The tubehead is suspended within the yoke and can be rotated vertically within it.

**Z**

**Zygomatic (malar) bone:** Cheek bone (sometimes called the zygoma) that appears as a U-shaped radiopacity above the maxillary molar teeth.

**Z number:** Symbolic number referring to the number of protons in an atomic nucleus.



# State Board/Certification Examination Multiple Choice and Case-Based Questions

## MULTIPLE CHOICE QUESTIONS

1. Which of the following is not a characteristic of an x-ray photon?
  - A. It travels with a wave-like motion.
  - B. It travels at 186,000 miles/second in a vacuum.
  - C. It causes ionization in matter.
  - D. It has a mass equal to its density.
2. If a machine could produce 10,000 x-ray photons in 1 second, but you wanted it to produce more than that in 1 second, what would you change?
  - A. The milliamperage.
  - B. The exposure time.
  - C. The kilovoltage.
  - D. The thickness of filtration.
3. A car at high speed brakes or loses some of its speed (energy) turning a sharp corner. Similarly, a high-speed electron is said to lose energy. Yet, we know that in reality the energy is not really lost, but transferred to another form called an x-ray photon. This phenomenon is called:
  - A. Characteristic radiation.
  - B. Radioactive decay.
  - C. Particulate gamma radiation.
  - D. Bremsstrahlung radiation.
4. The beam of radiation emitted from the constant potential x-ray tubehead consists of:
  - A. X-ray photons of many different energies and wavelengths.
  - B. X-ray photons of uniform energies and wavelengths.
  - C. X-ray photons of the same energy but different wavelengths.
  - D. Cathode rays of varying intensities.
  - E. A larger percentage of characteristic radiation than any other type of radiation.
5. Which of the following series shows the correct progression of energy transformation in the production of x-ray photons?
  - A. Kinetic energy, electrical energy, and radiation.
  - B. Kinetic energy, radiation, and electrical energy.
  - C. Electrical energy, kinetic energy, and radiation.
  - D. Electrical energy, radiation, and kinetic energy.
6. X-radiation:
  1. Is absorbed by the tissues.
  2. Scatters.
  3. Passes through the patient.
  4. Imparts some or all of its energy to any material through which it passes.

- A. 1 and 2.  
B. 2 and 3.  
C. 2 and 4.  
D. 1, 3, and 4.  
E. All of the above.
7. A dentist has been using film speed E at 65 kVp, 10 mA, and 0.5-second exposure for a maxillary molar region. His or her assistant decides to use 15 mA. What will the new exposure time be?
- A. 0.25 second.  
B. 0.33 second.  
C. 0.7 second.  
D. 1.0 second.
8. The number of electrons in a dental x-ray tube is determined by the:
- A. Kilovoltage used.  
B. Distance between the filament and the target.  
C. Step-up transformer.  
D. Size of the focusing cup.  
E. Low-voltage circuit.
9. X-rays are known as ionizing radiation. Ionization is:
- A. The separation of the nucleus into positive and negative ions.  
B. Produced by photoelectric absorption only.  
C. Produced by the Compton effect and Bremsstrahlung only.  
D. Produced by photoelectric absorption and Compton scatter.
10. Which of the following statements describes Compton scatter?
- A. The photon uses some of its energy to remove an electron from its orbit and then transfers the remaining energy to the electron in the form of kinetic energy, which is capable of ionizing molecules.  
B. The photon gives up some of its energy in ejecting an orbiting electron and is then deflected with a longer wavelength.  
C. A high-energy photon passes close to a nucleus, releasing an electron and a positron. Some of the energy is used to give kinetic energy to the two particles.  
D. None of the above.
11. Radiopaque tissues:
- A. Absorb little of the x-rays.  
B. Absorb x-rays more fully.  
C. Are hollow regions.  
D. Are cysts, granulomas, or abscesses.  
E. None of the above.
12. Which property of x-radiation must be utilized to control magnification of the radiographic image?
- A. X-rays travel in divergent paths from their source.  
B. X-rays penetrate opaque objects.  
C. X-rays cannot be focused.  
D. X-rays cause secondary radiation when they strike the patient's face.
13. Which of the following would you do to increase film density?
1. Increase the mA.  
2. Increase the kVp.  
3. Increase the time.  
4. Decrease the distance.  
5. Increase the distance.
- A. 1, 2, and 4.  
B. 1, 2, and 5.  
C. 1, 3, and 4.  
D. 1, 3, and 5.  
E. 1, 2, 3, and 4.
14. Increasing the kVp results in:
- A. Low contrast (long-scale contrast).  
B. High contrast (short-scale contrast).  
C. Lighter film density (medium-scale contrast).  
D. None of the above.
15. Disease is transmitted in oral and maxillofacial procedures by which of the following?
- A. Direct contact with saliva.  
B. Contamination from an infected intraoral film packet.  
C. Contamination from infected processing solutions.  
D. A and B only.  
E. A, B, and C.
16. According to OSHA, the hands **must** be washed:
- A. Before donning gloves.  
B. After removing gloves.  
C. When gloves are perforated.  
D. A and C.  
E. B and C.
17. One way to avoid placing a barrier on the exposure switch is to:
- A. Spray it with an EPA-registered solution.  
B. Have the patient hold the switch.  
C. Install a remote, "switchless" control.  
D. Use a foot switch.
18. During mouth-rinsing before taking the radiographs, there is destruction of microorganisms on living tissues as long as there is contact between



the tissues and the antimicrobial agent; this denotes:

- A. Sanitization.
- B. Antisepsis.
- C. Sterilization.
- D. Disinfection.
- E. Pasteurization.

19. Which statement is most correct?

- A. The long BID can be used with either the paralleling or the bisecting-angle technique.
- B. The long BID is used with the paralleling technique only.
- C. The short BID is used satisfactorily with either the paralleling or the bisecting-angle technique.
- D. Film-holders are not necessary with the paralleling technique.

20. As used in intraoral radiography, the bisecting-angle technique is one in which the central ray x-ray beam is directed:

- A. Perpendicular to the long axis of the object.
- B. Parallel to the long axis of the object.
- C. Perpendicular to the "bisecting line."
- D. Perpendicular to the long axis of the film packet.

21. The premolar bitewing radiograph should be placed to include which of the following anatomical structures?

- A. All of the maxillary first premolar crown.
- B. All of the mandibular canine crown.
- C. The distal half of the maxillary canine crown.
- D. The mesial half of the maxillary first molar crown.

22. X-ray intensity (I), like light, is related to its distance (D) from the source. This is expressed as the inverse square law and is formulated as:

$$\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2}$$

If the distance from the source to the object is tripled, the intensity of the x-ray beam at the new distance ( $D_2$ ) would be:

- A. One ninth the original distance ( $D_1$ ).
- B. One sixth the original distance ( $D_1$ ).
- C. One third the original distance ( $D_1$ ).
- D. One half the original distance ( $D_1$ ).

23. The radiation output of a machine at a 16-inch source-film distance is 250 mR per second. Under identical exposure conditions, if the source-film

distance is changed to 8 inches, what will be the new output per second?

- A. 500 mR.
- B. 125 mR.
- C. 1000 mR.
- D. 2000 mR.

24. The embossed, raised dot on the intraoral periapical film is important because it:

- A. Identifies the side of the film toward the tongue.
- B. Identifies the facial and lingual surfaces of teeth.
- C. Identifies the apices of roots of teeth.
- D. Identifies the left and right sides of the patient.
- E. Identifies the side of film to place into the processor first.

25. Which of the following is important concerning the safelight in the darkroom?

- A. Wattage of bulb.
- B. Distance of safelight from working area.
- C. Color of filter.
- D. Length of time film is exposed to safelight.
- E. All of the above.

26. The most efficient source of light in a film duplicator is which of the following?

- A. 15-watt bulb.
- B. Fluorescent light.
- C. Flood lamp.
- D. Ultraviolet fluorescent light.

27. The latent image consists of the accumulation of:

- A. Electrons in exposed silver bromide crystals.
- B. Atomic silver at the sensitization specks.
- C. Atomic silver in gelatin molecules.
- D. Electrons in photoconductance bands.

28. Which of the following factors contribute to fog with a resultant degradation of film quality?

- 1. Unsafe safelight.
- 2. Unsafe storage following exposure.
- 3. Overdevelopment.
- 4. High temperature development with no change in processing time.
- 5. Outdated emulsion.
- 6. White light leaks in the darkroom.
- A. 1, 2, 3, and 4.
- B. 1, 3, 5, and 6.
- C. 1, 2, 3, 5, and 6.
- D. 1, 3, 4, 5, and 6.
- E. All of the above.

29. In your office, the radiographs turn brown with age almost all of the time. What corrective action will you take?
- Develop the films adequately.
  - Change the solutions more regularly.
  - Wash the films properly after fixing.
  - Fix the films adequately.
  - None of the above.
30. You turn on the water in the manual tanks at the beginning of the day, stir the solution, check the temperature, and set a developing time to go with the temperature. You take a set of films at about 9:00 a.m. that appear fine. At about 2:00 p.m., you process another set of films, which are so dark you can hardly read them. What most likely happened with the second set of films?
- Your exposure time was too long.
  - Your darkroom has a light leak.
  - Your water temperature is too hot.
  - Your chemicals are contaminated.
31. The use of outdated films may result in images that are:
- Gray.
  - Low in contrast.
  - Brownish.
  - A and B.
  - A, B, and C.
32. When a piece of rare earth screen is used to ensure that the beam is restricted to the diameter of the BID tip, you are checking the:
- Filter.
  - Benson line focus.
  - Focal spot integrity.
  - Collimator.
33. Resolution in line pairs per millimeter is the basis for a test device that checks the:
- Focal spot integrity.
  - Alignment of the collimator.
  - Ideal BID length.
  - Benson line focus alignment.
34. The sensitometer is a device to check processing in a Class III facility. It is used to detect:
- Fog.
  - Density changes.
  - Contrast changes.
  - All of the above.
35. The half-value layer (HVL) can be defined as:
- The amount of tissue that reduces beam intensity by half.
  - The added aluminum filtration in the unit.
  - The thickness of a material that cuts the exposure time by half.
  - The thickness of a standardized material that absorbs half the output.
36. A patient has a supernumerary mandibular premolar that has erupted lingual to the normal premolars and is not seen in the panoramic image. The reason for this is:
- Mechanical malfunction.
  - Processing error.
  - Premolar not in layer.
  - Supernumerary obscured by the normal premolars.
37. In panoramic radiology, spreading out of the turbinate is:
- Undesirable and caused by positioning errors.
  - Desirable and part of the normal panoramic projection.
  - Inevitable, especially in allergic patients.
  - Not seen in panoramic radiology.
38. In panoramic radiology, double images are real images of objects falling within the diamond-shaped area and:
- In front of it.
  - In back of it.
  - In front and back of it.
  - In the midline region.
39. Which of the following statements is/are true, with regard to the panoramic image?
1. Air obscures hard tissue.
  2. Soft tissue obscures air.
  3. Hard tissue obscures soft tissue.
  4. Ghost images obscure everything.
- 1 and 2.
  - 2 and 3.
  - 4 only.
  - All of the above.
40. When one condyle is higher and bigger than the other in the panoramic image, the patient is:
- Twisted.
  - Tilted.
  - Positioned with the chin too low.
  - Slumped.
41. In the panoramic image, widening of the anterior teeth along with ghosting of the contralateral rami occurs when the patient is positioned:
- Too far forward.
  - Too far back.



- C. With the chin raised too high.  
D. With the chin depressed too low.
42. In panoramic radiology, streaking out and ghosting of the hyoid bone occurs when the patient is positioned:
- A. Too far forward.  
B. Too far back.  
C. With the chin raised too high.  
D. With the chin depressed too low.
43. In the panoramic image, when the "smile" line of the teeth is exaggerated and the condyles go off the top of the film, the patient is:
- A. Twisted.  
B. Tilted.  
C. Positioned with the chin too low.  
D. Positioned with the chin too high.
44. Extraoral films are:
1. Used when large areas of the skull need to be radiographed.
  2. Loaded in cassettes.
  3. Often used when fractures of the skull are suspected.
  4. Used in conjunction with intensifying screens.
- A. 2 and 4.  
B. 3 and 4.  
C. 1, 2, and 3.  
D. 2, 3, and 4.  
E. All of the above.
45. A radiographic technique for evaluation of the maxillary sinuses is the:
- A. Submentovertex view.  
B. Caldwell view.  
C. Transorbital view.  
D. Waters view.
46. When compared with a fast-speed intensifying screen, a slow-speed screen has:
- A. Thick phosphor layers and produces an unsharp image.  
B. Thick phosphor layers and produces a sharp image.  
C. Thin phosphor layers and produces an unsharp image.  
D. Thin phosphor layers and produces a sharp image.
47. Intensifying screens:
1. Aid in reducing radiation exposure times.
  2. Contain phosphor crystals.
  3. Contain silver bromide crystals.
  4. Consist of x-ray-penetrable base material.
- A. 2 and 3.  
B. 3 and 4.  
C. 1, 2, and 3.  
D. 1, 2, and 4.  
E. All of the above.
48. Following an exposure to radiation, the residual biologic damage that remains is what type of effect?
- A. Direct.  
B. Indirect.  
C. Tolerance.  
D. Cumulative.  
E. Fractionation.
49. It is well documented that x-rays react at the cellular level and can cause biologic damage. When a photon interacts with one molecule of water, it results in:
- A. Excitation.  
B. Electrolyte formation.  
C. Attenuation.  
D. Free radical formation.
50. The latent period related to radiation biology is that period between:
- A. Exposure of the film and development of the images.  
B. Exposure to x-radiation and the appearance of clinical symptoms.  
C. The states of cell rest and cell mitosis.  
D. Subsequent doses of x-radiation.
51. The annual whole-body effective radiation dose emitted for the general population (infrequent exposure) is:
- A. 5 mSv.  
B. 10 mSv.  
C. 1 mSv.  
D. Not specified.
52. The majority of biologic damage produced by ionizing radiation is generally believed to result from:
- A. Direct interactions of ionizing radiation with DNA.  
B. Multi-hit direct inactivation of ribosomes.  
C. Damage inflicted by free radicals.  
D. Leakage of ATP from irradiated cells.
53. Mutations from radiation exposure may occur:
- A. Only in reproductive organs as genetic abnormalities.  
B. In both somatic and reproductive tissue.  
C. Only in the critical organs.  
D. Only in the cytoplasm.

54. Collars are attached to leaded aprons or separate collars are used in conjunction with leaded aprons in dental radiography to protect what specific area of the body?
- Spinal cord.
  - Thyroid gland.
  - Neck region.
  - Gonads.
55. Which one of the following factors will reduce the patient's somatic exposure by the greatest amount?
- Leaded apron.
  - Short, pointed, plastic cone.
  - Short, lead-lined, open-ended cylinder.
  - Long, lead-lined, open-ended cylinder.
  - Long, lead-lined, rectangular beam indicating device.
56. Which of the following is least effective in reducing patient radiation dose?
- Fast films.
  - Higher kilovoltage.
  - Proper collimation.
  - Increased filtration.
57. The hazards to the operator in radiographic work are:
- Exposure to the radiation coming directly from the x-ray BID.
  - Exposure to tubehead leakage.
  - Exposure to secondary radiation emitted from the patient during an exposure.
  - Radiation coming from an adjacent room.
- 1, 2, and 3.
  - 1, 3, and 4.
  - 2, 3, and 4.
  - All of the above.
58. The benefits of x-ray beam collimation include:
- Increasing the mean energy of the beam.
  - Restriction of the beam size.
  - Decreased patient dose.
  - Increased quality of the resultant image.
- 1 and 2.
  - 3 and 4.
  - 1, 2, and 3.
  - 2, 3, and 4.
59. If you receive more than 1 mSv in a week as a radiation worker, you should:
- Evaluate the radiation protection measures used in your dental office.
  - Not work with radiation until you dissipate the 1 mSv.
  - Go on a vacation.
  - Find another job.
60. Which of the following normal anatomical structures is radiolucent and usually found on a periapical radiograph of the maxillary central region?
- Anterior nasal spine.
  - Incisive foramen.
  - Lingual foramen.
  - Nasal fossa.
61. The coronoid process of the mandible is frequently visible on a periapical radiograph of the:
- Maxillary second premolar region.
  - Maxillary second molar region.
  - Mandibular second molar region.
  - Maxillary central incisor region.
62. Which of the following statements are true concerning the use of the dental radiograph in periodontal disease diagnosis?
- Does reveal soft-to-hard tissue relationships.
  - Does not record morphology of bone deformities.
  - Does not reveal facial or lingual aspects of the tooth.
  - Does detect overhanging restorations.
  - Does not detect crown-root ratio.
- 1 and 2.
  - 2 and 4.
  - 1, 3, and 5.
  - 2, 3, and 5.
  - 2, 3, and 4.
63. Which of the following anomalies are called ghost teeth because of defective calcified tooth structures?
- Regional odontodysplasia.
  - Dental dysplasia.
  - Shell teeth.
  - Amelogenesis imperfecta.
  - Dentinogenesis imperfecta.
64. Which of the following statements are true?
- Germination is associated with the correct number of teeth in the dental arch.
  - Fusion leads to a reduced number of teeth in the dental arch.
  - Concrescence denotes dentinal union of two fully formed teeth.
  - Teeth with taurodontism usually have obliterated pulps.
  - Dens invaginatus is usually found in premolars.

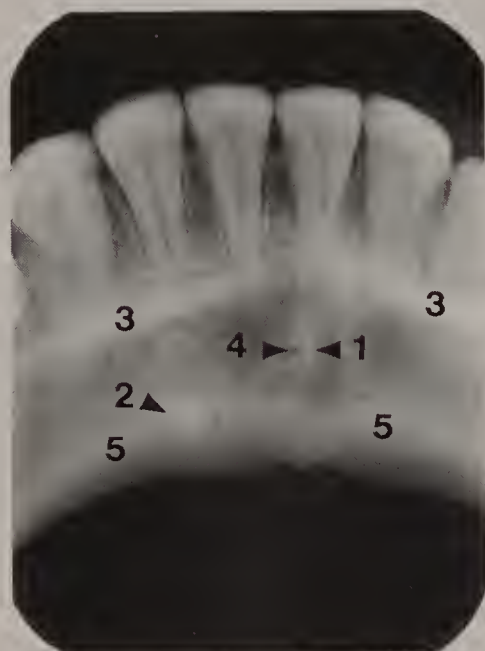


- A. 1 and 2.  
 B. 1 and 3.  
 C. 2 and 3.  
 D. 3, 4, and 5.  
 E. 2, 3, and 5.
65. Which of the following conditions have pulpal enlargement?
- A. Regional odontodysplasia.  
 B. Taurodontism.  
 C. Shell teeth.  
 D. Hypophosphatemia.  
 E. All of the above.
66. Which of the following usually are associated with nonvital pulps of teeth?
- A. Hypercementosis.  
 B. Apical cementoma (apical cemental dysplasia).  
 C. Apical cyst.  
 D. Apical osteosclerosis.  
 E. All of the above.
67. Which of the following explains why the size of the interproximal carious lesion, as seen radiographically, is usually smaller than seen microscopically or after clinical excavation of the caries?
1. Radiographic evidence will not be observed until there is sufficient decalcification of the tooth.
  2. The ratio of sound tooth structure to the carious lesion varies in different areas of the tooth.
  3. The difference in root configuration and shape of cemento-enamel contour.
  4. The differences in density (mass/volume) of enamel and dentin.
- A. 1 and 2.  
 B. 2 and 4.  
 C. 1, 2, and 4.  
 D. 2, 3, and 4.  
 E. 2 only.
68. What causes cervical burnout?
- A. A "burning out" of the peripheral surface of the tooth by increased kilovoltages.  
 B. Differences in the ratio of sound tooth structure to the carious lesion.  
 C. Depends on shape of interproximal enamel surfaces of teeth.  
 D. Density differences at cemento-enamel junction.  
 E. None of the above.
69. Which of the following apical lesions have the potential for the most destruction to the alveolar bone?
- A. Chronic apical abscess.  
 B. Apical cementoma.  
 C. Apical cyst.  
 D. Apical granuloma.  
 E. Condensing osteitis.
70. Which of the following statements are true concerning periapical disease?
1. It is possible to differentiate the chronic abscess, apical granuloma, or apical cyst by use of the radiograph.
  2. The apical granuloma is a tumor of granulomatous tissue.
  3. The apical cyst is the most common cyst of the jaws.
  4. Chronic periapical lesions are usually involved with nonvital teeth and are asymptomatic.
  5. The apical cementoma (periapical cemental dysplasia) is most often seen in males younger than 25 years of age.
- A. 1, 2, 3, and 5.  
 B. 1, 3, and 4.  
 C. 3 and 4.  
 D. 2 and 4.  
 E. 2 and 5.
71. The radiolucency occurring in the bone from an infected primary molar, as studied radiographically, most frequently appears:
- A. Around the apices.  
 B. Between two teeth.  
 C. In the bifurcation.  
 D. Around the developing permanent tooth.  
 E. As a uniform widening of the periodontal ligament space.

## CASE-BASED QUESTIONS

### CASE NO. 1

This patient complained of intermittent pain and swelling in the right submandibular gland, especially at meal times. A sialolith (stone) was found in the right Wharton's duct.



#### Questions

- To obtain this image:
  - The film was not placed parallel to the teeth.
  - The patient bit down more firmly on the bite-block.
  - The film was tilted on a downward angle, and the central ray was perpendicular to the teeth.
  - The negative vertical angulation of the BID was increased too much.
  - A and D.

- Matching the columns, identify the following:

#### Column A

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

#### Column B

- Lingual foramen.
- Mental ridge.
- Sialolith.
- Genial tubercles.
- Inferior cortex.

### CASE NO. 2

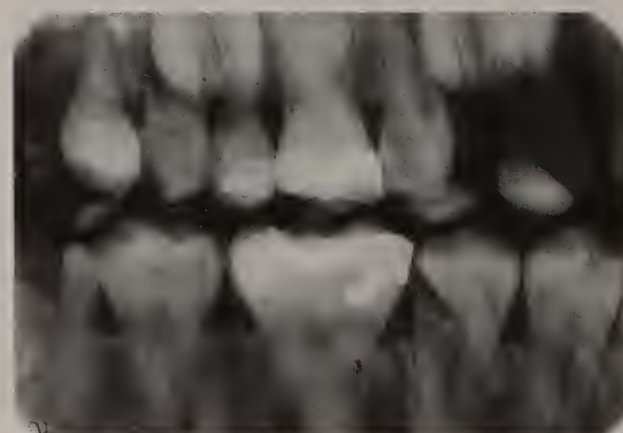
This 22-year-old, male college student developed a spontaneous, persistent toothache while watching a football game. A molar radiograph was taken by a dental hygienist at his dentist's office.



#### Questions

- The errors that occurred while taking this molar radiograph consisted of:
  - Cone-cut (partial image).
  - Improper film placement.
  - Insufficient vertical angulation.
  - A and B.
  - A, B, and C.
- Despite the errors, the problematic tooth was likely the:
  - Second premolar because it is carious.
  - The first molar because the overhangs cause periodontal problems.
  - The first molar because of periapical pathology.
  - The second molar because it is carious.

### CASE NO. 3





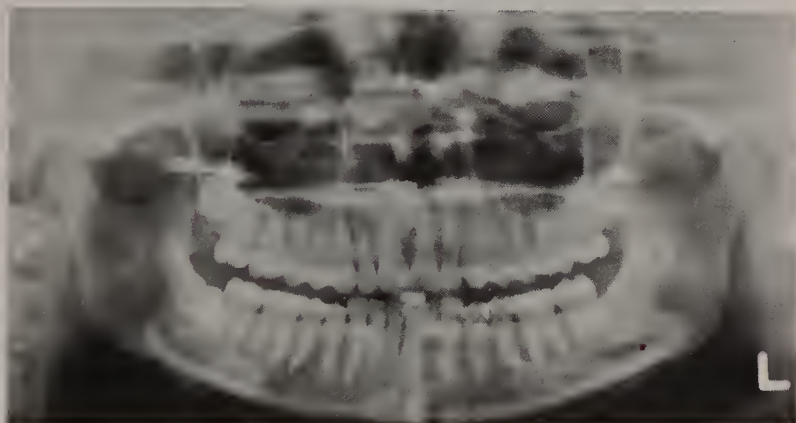
**Question**

1. The hygienist was asked to take a set of two bitewings on the patient's right side. These two images were the result of:

- Two films overlapped in the processor, and the blank film was exposed to light.
- One film was double exposed, and the other was exposed to light.
- One film was double exposed, and the other was not exposed.
- Two films overlapped in the processor, and the emulsion from the blank film stuck on top of the other.

**CASE NO. 4**

One concept of panoramic radiology is that whenever a structure is positioned **behind** the rotation center, it produces a real image on one side of the film and a ghost image on the other side of the film. Ghost image formation by anatomical structures is often associated with errors in patient positioning in the machine.

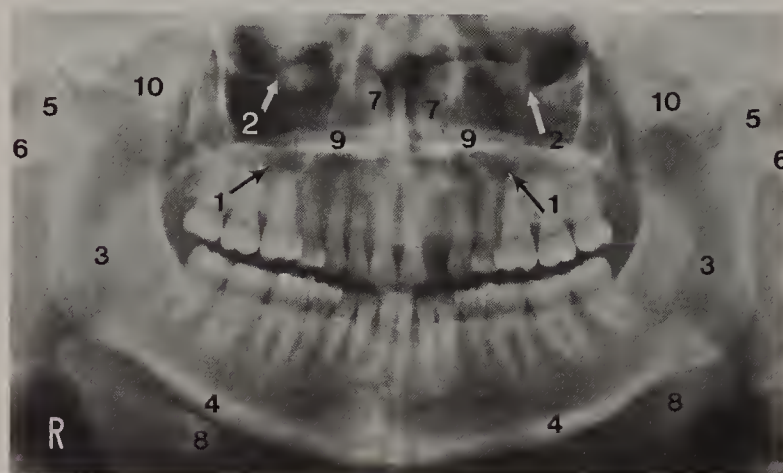
**Question**

1. Objects such as earrings and necklaces or napkin chains can produce ghost images, and this is why they should be removed before exposure. Note the ghost images produced by the two earrings left on this patient. With respect to the features of ghost images, indicate which statements are true or false.

- The ghost image is on the same side as the real image.
- The ghost image is usually smaller than the real image.
- In the ghost image only, horizontal elements are more prominent than vertical elements.
- The ghost image is usually sharper than the real image.
- The ghost image is usually above the real image.

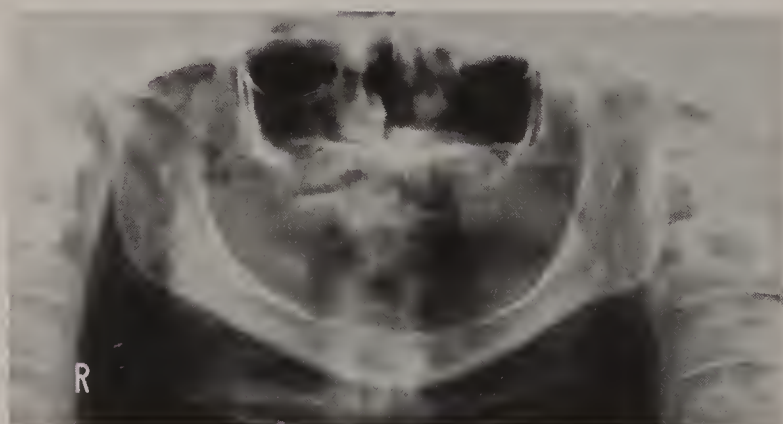
**CASE NO. 5**

This is a good panoramic image. There are some key anatomical structures we need to learn to identify.

**Question**

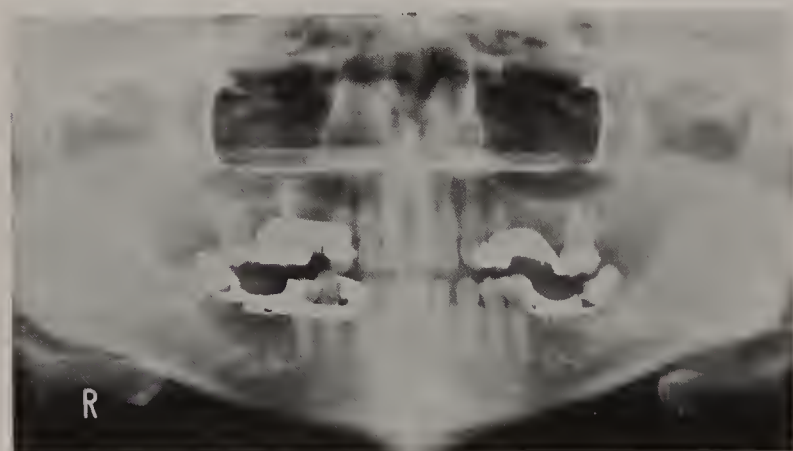
1. Identify the anatomical structures by matching the numbered structures in Column A with Column B.

| Column A  | Column B                        |
|-----------|---------------------------------|
| 1. _____  | A. Maxillary sinus              |
| 2. _____  | B. Ramus                        |
| 3. _____  | C. Condyles                     |
| 4. _____  | D. Inferior cortex mandible     |
| 5. _____  | E. Turbinates                   |
| 6. _____  | F. Spine                        |
| 7. _____  | G. Hard palate images           |
| 8. _____  | H. Floor of orbit/roof of sinus |
| 9. _____  | I. Hyoid bone                   |
| 10. _____ | J. Zygomatic arch               |

**CASE NO. 6****Question**

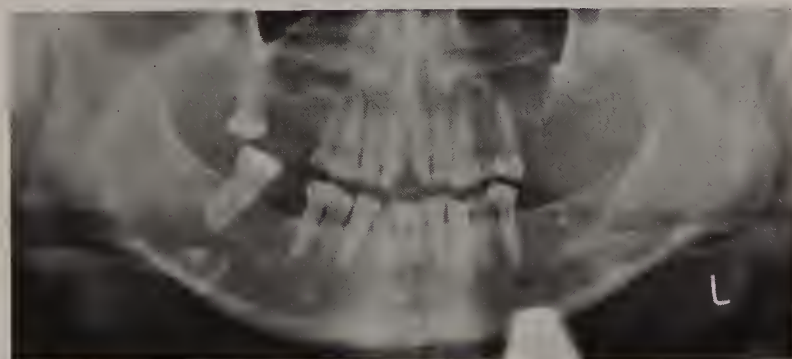
1. The positioning error in this case is:

- Movement.
- Too far back.
- Chin too high.
- Twisted.
- A and D.

**CASE NO. 7****Question**

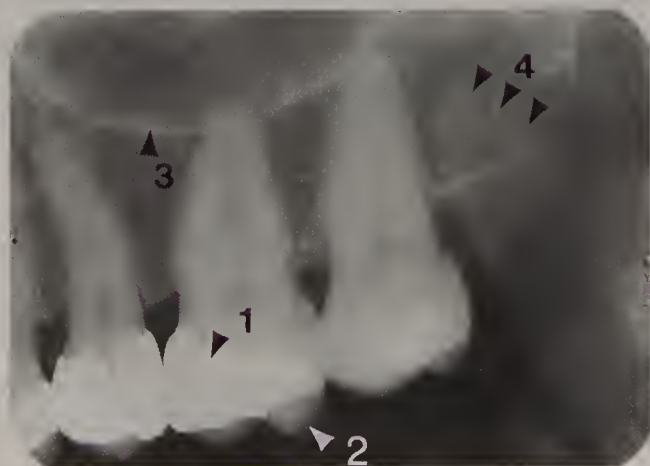
1. The error(s) in this case is (are):

- A. Partials left in.
- B. Partials left in, too far back.
- C. Partials left in, too far back, chin too high.
- D. Partials left in, too far back, chin too high, slumped.

**CASE NO. 8****Question**

1. The error(s) in this case is (are):

- A. Real image of neck jewelry.
- B. Apron artifact.
- C. Cassette leak.
- D. Fixer artifact.
- E. Chin alignment rod.

**CASE NO. 9****Question**

1. Identify the anatomical structures and materials by matching the columns.

**Column A**

- 1. \_\_\_\_\_
- 2. \_\_\_\_\_
- 3. \_\_\_\_\_
- 4. \_\_\_\_\_

**Column B**

- A. Coronoid process.
- B. Floor of sinus.
- C. Buccal cusp.
- D. Lingual cusp.
- E. Zygomatic bone.
- F. Maxillary tuberosity.
- G. Amalgam restoration.
- H. Composite restoration.

**CASE NO. 10****Question**

1. Identify the materials/structures by matching the columns.

**Column A**

- 1. \_\_\_\_\_
- 2. \_\_\_\_\_
- 3. \_\_\_\_\_

**Column B**

- A. Porcelain crown.
- B. Acrylic crown.
- C. Soft tissue of nose.
- D. Alveolar bone level.
- E. Cement.

**CASE NO. 11**



**Question**

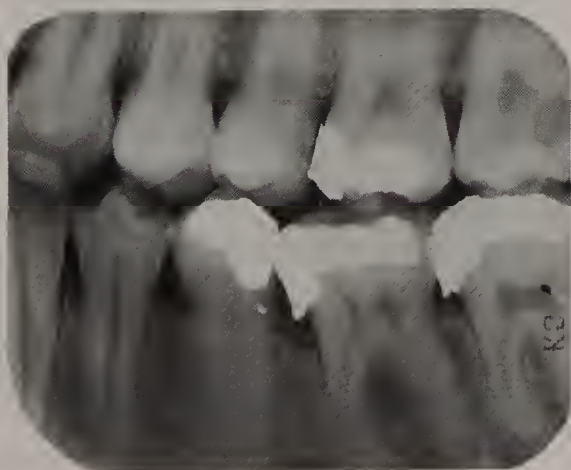
1. What is the radiopaque U-shaped structure identified by the arrow? The teeth are vital.
  - A. Floor of the maxillary sinus.
  - B. Sclerotic border of apical cyst.
  - C. Zygomatic process of temporal bone.
  - D. Inferior border of zygomatic bone.
  - E. Septum in maxillary sinus.

**CASE NO. 12**

This patient is a 38-year-old woman. She has a collagen disease with a positive rheumatoid factor.

**Question**

1. Although she is asymptomatic, the periodontal membrane spaces are significantly widened because:
  - A. Her teeth are mobile.
  - B. She has scleroderma.
  - C. She has periodontitis.
  - D. She has had orthodontic treatment.
  - E. The widening is at the outer range of normal.

**CASE NO. 13****Question**

1. This radiograph reveals definite radiographic evidence of periodontal disease between which of the following teeth?

1. Maxillary first and second premolar.
  2. Maxillary second premolar and first molar.
  3. Mandibular first and second premolar.
  4. Mandibular second premolar and first molar.
  5. Mandibular first and second molar.
- A. 1, 2, and 4.
  - B. 2 and 3.
  - C. None of the areas identified above.
  - D. 4 only.
  - E. All of the areas identified above.

**CASE NO. 14**

A 60-year-old, female, retired school teacher visits your clinic for a routine check-up; her dentist of 30 years has died. In completing the periodontal examination, a radiograph was taken of the maxillary premolar region.

**Questions**

1. Radiographically, what is the most appropriate classification of this person's periodontal condition?
  - A. Moderate generalized horizontal bone loss.
  - B. Advanced generalized horizontal bone loss.
  - C. Moderate localized horizontal bone loss.
  - D. Advanced generalized vertical bone loss.
  - E. Moderate localized vertical bone loss.
2. What is (are) the contributory factor(s) to this person's periodontal condition, as seen radiographically?
  1. Deficient contact between canine and first premolar.
  2. Recurrent root caries, a sign of poor flossing.
  3. Multiple areas of interproximal calculus.
  4. Overhanging restorations.
  5. Occlusal trauma.
  - A. 2, 3, and 4.
  - B. 1, 4, and 5.
  - C. 2, 3, and 5.
  - D. 1, 2, 3, and 4.
  - E. 1 and 5 only.

**CASE NO. 15****Question**

1. What are the developmental abnormalities of the teeth that are seen in this radiograph?

1. Shovel-shaped incisors.
  2. Dens invaginatus.
  3. Dental dysplasia.
  4. Talon cusp.
  5. Abnormally enlarged pulp.
- A. 3, 4, and 5.
  - B. 1, 2, and 4.
  - C. 2, 3, and 5.
  - D. 1, 2, 3, and 5.
  - E. 2, 3, and 4.

**CASE NO. 16****Question**

1. Which of the following anomalies are represented by this radiograph?

- A. Concrescence.
- B. Supernumerary tooth.
- C. Fusion.
- D. Gemination.
- E. Supernumerary cusps.

**CASE NO. 17****Questions**

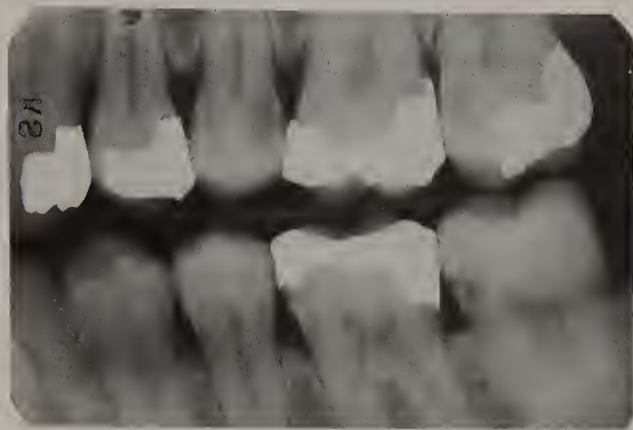
1. What is the significance of the anomaly of the upper premolar in this radiograph?

1. Difficulty in endodontic procedure.
  2. Difficulty in crown preparation.
  3. Difficulty in extraction.
  4. Tooth is more subject to periodontal disease.
  5. Tooth is more subject to caries.
- A. 1, 2, and 3.
  - B. 4 and 5.
  - C. 1, 2, 3, 4, and 5.
  - D. 1 and 3.
  - E. 2, 4, and 5.

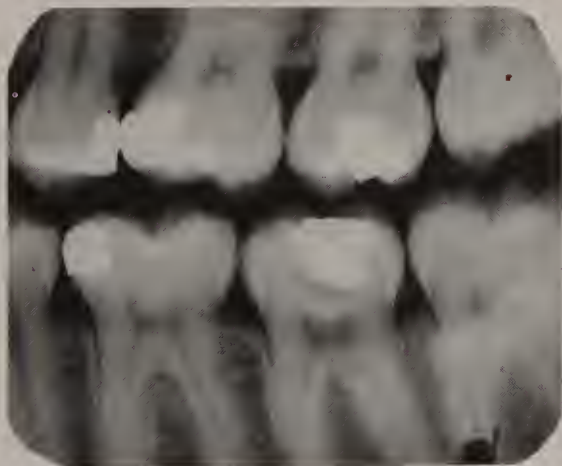
2. The anomaly is known as:

- A. Diastema.
- B. Concrescence.
- C. Dilaceration.
- D. Transposition.

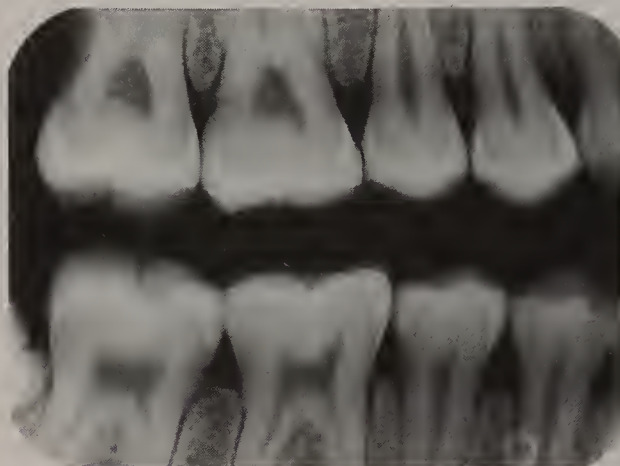


**CASE NO. 18****Question**

1. Which of the following teeth have definite radiographic evidence of dentinal caries?
  1. Upper second premolar.
  2. Upper second molar.
  3. Lower second premolar.
  4. Lower first molar.
  5. Lower second molar.
  - A. 2, 3, and 5.
  - B. 1, 2, 4, and 5.
  - C. 3, 4, and 5.
  - D. 1, 2, and 3.
  - E. 1, 2, 3, and 4.

**CASE NO. 19****Question**

1. This 35-year-old man has a dull toothache on the left side of his jaws. He cannot localize the pain. Which one of the following teeth, from the radiograph alone, is most likely the cause of the toothache?
  - A. Upper left second premolar.
  - B. Upper left first molar.
  - C. Upper left second molar.
  - D. Lower left second molar.
  - E. Lower left first molar.

**CASE NO. 20****Question**

1. There is radiographic evidence of how many carious lesions on this radiograph?
 

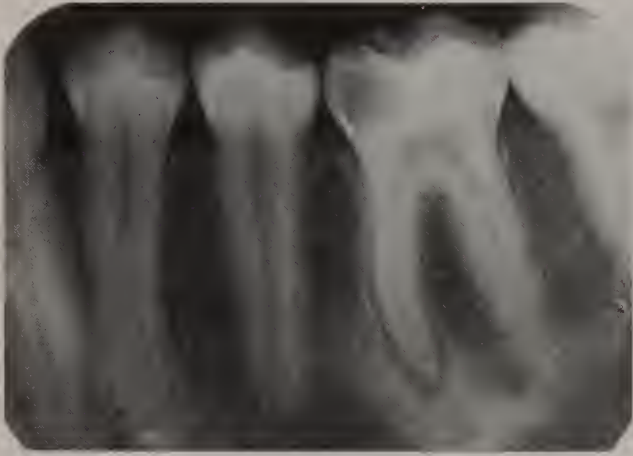
|           |          |
|-----------|----------|
| A. One.   | D. Four. |
| B. Two.   | E. None. |
| C. Three. |          |

**CASE NO. 21**

This patient is a 35-year-old, African-American woman. Although she once fell on her jaw during a track meet at an early age, the teeth are vital.

**Questions**

1. The condition affecting the incisors is:
  - A. Traumatic cysts.
  - B. Apical granulomas.
  - C. Apical cementomas.
  - D. Chemical stains (developer).
2. What is the black spot identified by the arrow?
  - A. Developer artifact.
  - B. Fixer artifact.
  - C. Water mark.
  - D. Film clip mark.
  - E. Embossed dot.

**CASE NO. 22****Question**

1. This patient is a teen-ager with a large carious lesion in the mandibular first molar. The tooth is nonvital. Most likely, what is the lesion at the apical end of the mesial root?
  - A. Condensing osteitis.
  - B. Idiopathic osteosclerosis.
  - C. Apical cementoma.
  - D. Osteoma.
  - E. Benign cementoblastoma.

**CASE NO. 23****Question**

1. A 17-year-old girl has a toothache in this quadrant. Based on what you can see in this radiograph alone, which one of the teeth is most likely the cause of the toothache?
  - A. Second premolar.
  - B. First molar.
  - C. Second molar.
  - D. Third molar.
  - E. All of them.



# Answers to Review and Case-Based Questions at the Ends of the Chapters

## CHAPTER 1:

### Answers to Review Questions

1. C
2. C
3. E
4. B
5. C
6. B
7. A
8. A
9. B
10. C
11. B
12. B
13. A
14. B
15. A
16. E

## CHAPTER 3:

### Answers to Review Questions

1. A
2. A
3. B
4. A
5. C
6. C
7. D
8. D
9. C
10. D
11. B
12. A
13. B
14. D
15. C

## CHAPTER 5:

### Answers to Review Questions

1. B
2. D
3. C
4. B
5. B
6. B
7. B
8. B
9. C
10. B
11. A
12. D
13. A
14. B
15. C

## CHAPTER 6:

### Answers to Review Questions

1. B
2. A
3. C
4. B
5. B
6. B
7. D
8. D
9. A
10. D
11. E
12. E
13. C
14. B
15. C

## CHAPTER 2:

### Answers to Review Questions

1. D
2. B
3. C
4. C
5. C
6. C
7. C
8. A
9. B
10. C
11. E
12. C
13. B
14. E
15. E

## CHAPTER 4:

### Answers to Review Questions

1. D
2. E
3. C
4. E
5. A
6. B
7. C
8. E
9. E
10. B
11. D
12. D
13. C
14. A
15. A

## CHAPTER 5:

### Answers to Case-Based Questions

#### Case 5-1

1. D
2. D
3. Arrow 1—B  
Arrow 2—C  
Arrow 3—A  
Arrow 4—D

#### Case 5-2

1. B
2. Arrow 1—B  
Arrow 2—D  
Arrow 3—A  
Arrow 4—C  
Arrow 5—E

## CHAPTER 7:

### Answers to Review Questions

1. E
2. B
3. B
4. D
5. D
6. D
7. C
8. C
9. A
10. D
11. E
12. A
13. B
14. C
15. E

**CHAPTER 7:***Answers to Case-Based Questions*Case 7-1

1. B

Case 7-2

1. B

Case 7-3

1. D

Case 7-4

1. D

Case 7-5

1. C

Case 7-6

1. C

Case 7-7

1. C

Case 7-8

1. D
2. A

Case 7-9

1. B
2. A

**CHAPTER 8:***Answers to Review Questions*

1. B
2. E
3. D
4. D
5. C
6. B
7. E
8. D
9. B
10. A
11. A
12. E
13. B
14. A
15. A

**CHAPTER 9:***Answers to Review Questions*

1. C
2. A
3. D
4. A
5. C
6. B
7. B
8. C
9. B
10. E
11. E
12. D
13. C
14. D
15. A

**CHAPTER 9:***Answers to Case-Based Questions*Case 9-1

1. B
2. C

Case 9-2

1. True
2. True
3. False
4. True
5. False
6. True
7. True
8. False
9. True
10. True

Case 9-3

1. True
2. True
3. True
4. False
5. True
6. False
7. False
8. True
9. True
10. False

Matching

- Arrow 1—C  
Arrow 2—H

Arrow 3—D

Arrow 4—A

Arrow 5—F

Arrow 6—B

Arrow 7—G

Arrow 8—E

Arrow 9—I

Case 9-4

1. B

Case 9-5Matching

1. F
2. L
3. B
4. I
5. D
6. H
7. J
8. A
9. K
10. G
11. E
12. C

**CHAPTER 10:***Answers to Review Questions*

1. D
2. E
3. D
4. C
5. D
6. B
7. C
8. D
9. B
10. C
11. B
12. D
13. C
14. E
15. B

**CHAPTER 10:***Answers to Case-Based Questions*Case 10-1

1. A
2. A

Case 10-2

1. C

Case 10-3

1. D

Case 10-4

1. D

Case 10-5

1. E

Case 10-6

1. C

**CHAPTER 11:***Answers to Review Questions*

1. C
2. D
3. B
4. D
5. C
6. D
7. B
8. D
9. C
10. B
11. A
12. D
13. A
14. C
15. E
16. D
17. C
18. B
19. C

**CHAPTER 12:***Answers to Review Questions*

1. A
2. D
3. B
4. D
5. B
6. B
7. D
8. A
9. B
10. C
11. A
12. D
13. C



14. D
15. B
16. A

**CHAPTER 13:***Answers to Review Questions*

1. D
2. B
3. D
4. C
5. C
6. B
7. D
8. D
9. D
10. D
11. D
12. A
13. C
14. B
15. C

**CHAPTER 14:***Answers to Review Questions*

1. A
2. B
3. A
4. D
5. Matching
  1. B
  2. D
  3. A
  4. C
  5. F
  6. G
  7. H
  8. E
6. D

**CHAPTER 14:***Answers to Case-Based Questions*Case 14-1

Column A—Column B  
 Arrow 1—D  
 Arrow 2—C  
 Arrow 3—E  
 Arrow 4—B  
 Arrow 5—A

Case 14-2

1. B

Case 14-3

1. D

Case 14-4

1. A

Case 14-5

1. C

Case 14-6

1. D

Case 14-7

1. C

Case 14-8

1. C

**CHAPTER 15:***Answers to Review Questions*

1. B
2. B
3. E
4. C
5. A
6. D
7. A
8. E
9. B
10. B
11. C
12. D
13. E
14. D
15. E

**CHAPTER 15:***Answers to Case-Based Questions*Case 15-1

1. E

Case 15-2

1. D

Case 15-3

1. A

Case 15-4

1. E

Case 15-5

1. A

Case 15-6

1. E

**CHAPTER 16:***Answers to Review Questions*

1. C
2. D
3. D
4. C
5. A
6. C
7. B
8. C
9. B

**CHAPTER 16:***Answers to Case-Based Questions*Case 16-1

1. E
2. C

Case 16-2

1. B

Case 16-3

1. A
2. A

Case 16-4

1. D

Case 16-5

1. B
2. D

Case 16-6

1. C

**CHAPTER 17:***Answers to Review Questions*

1. A
2. B
3. E

4. D
5. B
6. A
7. B
8. B
9. E
10. A
11. E
12. C
13. D
14. E
15. B
16. D
17. C

**CHAPTER 17:***Answers to Case-Based Questions*Case 17-1

1. E
2. D
3. C

Case 17-2

1. C

Case 17-3

1. D

Case 17-4

1. C

Case 17-5

1. C
2. E

Case 17-6

1. A

Case 17-7

1. D

Case 17-8

1. D
2. D

**CHAPTER 18:***Answers to Review Questions*

1. C
2. C
3. A

- 4. D
- 5. A
- 6. E
- 7. E
- 8. C
- 9. E
- 10. C
- 11. A
- 12. D
- 13. B

- 14. B
- 15. D

**CHAPTER 18:**  
*Answers to Case-Based Questions*

- Case 18-1  
1. C

- Case 18-2  
1. A

- Case 18-3  
1. B

- Case 18-4  
1. B  
2. C

- Case 18-5  
1. C

- Case 18-6  
1. B  
2. E

- Case 18-7  
1. A



# Board/Certification Examination Multiple Choice and Case-Based Questions

## National Board/State Board/Certification Examination Multiple Choice Questions

- |       |       |       |       |
|-------|-------|-------|-------|
| 1. D  | 15. E | 34. D | 53. A |
| 2. A  | 16. E | 35. D | 54. B |
| 3. D  | 17. D | 36. C | 55. E |
| 4. B  | 18. B | 37. A | 56. B |
| 5. C  | 19. A | 38. D | 57. D |
| 6. E  | 20. C | 39. D | 58. D |
| 7. B  | 21. C | 40. B | 59. A |
| 8. E  | 22. A | 41. B | 60. B |
| 9. D  | 23. C | 42. D | 61. B |
| 10. B | 24. D | 43. C | 62. E |
| 11. B | 25. E | 44. E | 63. A |
| 12. A | 26. D | 45. D | 64. A |
| 13. E | 27. B | 46. D | 65. E |
| 14. A | 28. E | 47. D | 66. C |
|       | 29. C | 48. D | 67. A |
|       | 30. A | 49. D | 68. D |
|       | 31. D | 50. B | 69. C |
|       | 32. D | 51. A | 70. C |
|       | 33. A | 52. C | 71. C |

## National Board/State Board/Certification Examination: Case-Based Questions

### Case No. 1

1. E
2. Matching
  1. D
  2. C
  3. B
  4. A
  5. E

### Case No. 2

1. D
2. C

### Case No. 3

1. C

### Case No. 4

- A. False.
- B. False.
- C. True.
- D. False.
- E. True.

### Case No. 5

1. A
2. H
3. B
4. D
5. C
6. F
7. E
8. I
9. G
10. J

### Case No. 6

1. E

### Case No. 7

1. D

### Case No. 8

1. B

### Case No. 9

1. G
2. C
3. B
4. A

### Case No. 10

1. C

- 2. B
- 3. E

Case No. 11

- 1. D

Case No. 12

- 1. B

Case No. 13

- 1. D

Case No. 14

- 1. B
- 2. D

Case No. 15

- 1. B

Case No. 16

- 1. C

Case No. 17

- 1. D
- 2. C

Case No. 18

- 1. B

Case No. 19

- 1. D

Case No. 20

- 1. E

Case No. 21

- 1. C
- 2. E

Case No. 22

- 1. A

Case No. 23

- 1. A



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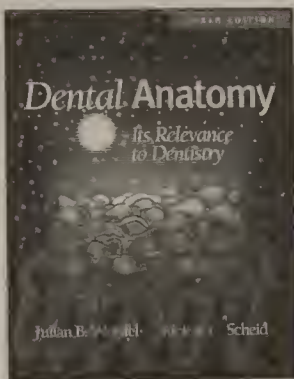
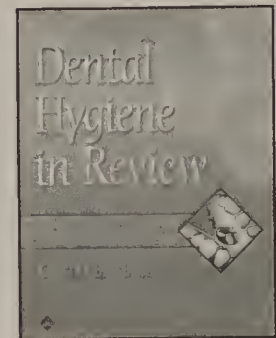


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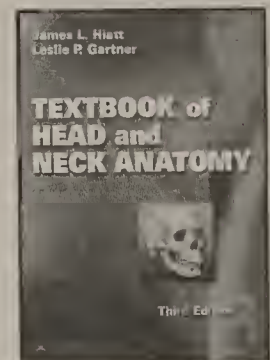
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