Clinical Aspects of Dental Materials

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Lippincott Williams & Wilkins

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LIPPINCOTT WILLIAMS & WILKINS
A **Wolters Kluwer** Company
Philadelphia • Baltimore • New York • London
Buenos Aires • Hong Kong • Sydney • Tokyo

Editor: Lawrence McGrew
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530 Walnut Street
Philadelphia, Pennsylvania 19106-3621 USA

351 West Camden Street
Baltimore, Maryland 21201-2436 USA

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Printed in the United States of America

Library of Congress Cataloging-in-Publication Data
Gladwin, Marcia A.
Clinical aspects of dental materials / Marcia A. Gladwin, Michael D. Bagby.
p. cm.
Includes bibliographical references and index.
ISBN 0-683-30291-4
1. Dental materials. 2. Dental casting. I. Bagby, Michael D.
II. Title.
[DNLM: 1. Dental Materials. 2. Dental Casting Technique.
3. Dental Impression Technique. WU 190 G543d 1999]
RK652.5.G56 1999
617.6'95—dc21
DNLM/DLC 99-29257
for Library of Congress CIP

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Preface

The objective of this text is to provide a dental materials background that emphasizes the clinical aspects of dental materials as well as to introduce concepts of materials science. It is our hope that the student will become more familiar with the practice of dentistry through the use of this text.

In too many instances, the practice of dentistry and dental hygiene in an office setting becomes separated and disjointed. As a member of the dental team, the hygienist must be an advocate for dentistry. Although knowledge of caries, periodontology, and oral pathology are basic to the hygienist's daily responsibilities, knowledge of restorative dentistry will help the hygienist be a more effective member of the general dentistry team. This involves the promotion of preventive and restorative dental care for the patient. To do this, the hygienist must be aware of the composition and use of dental materials. The benefits of dentistry may be best understood and accepted by the patient when the hygienist can easily explain the recommended procedures, as well as discuss alternative procedures and materials.

The text is divided into two sections: theory and clinical applications. The rapid introduction of new products in dentistry is intimidating. Learning some of the theoretical concepts of materials science will allow you to understand the use of categories of materials so you won't have to memorize mountains of facts. Proper handling of materials is stressed throughout the text; handling is usually more important than the particular product selected. Chapter 20, "General Rules for Handling Materials," summarizes this essential information. At the end of the theory chapters, learning activities are listed to provide a greater understanding of the topic presented. In addition, procedures important to the practice of dental hygiene are presented in "Part II: Laboratory and Clinical Applications."

Some sections of the text are labeled as "optional." The instructor should feel free to designate other sections as optional as well. It is hoped the outline format will facilitate a clear organization of the topic for the student, as well as facilitate reading and laboratory assignments.

The authors recommend that the course instructor make available, as a reference, a dental materials textbook that is aimed toward dental students. Texts edited by Anusavice and Craig are excellent. Such texts are cited as "Supplemental Readings" at the end of many chapters. The authors have avoided lists of mechanical properties. An excellent resource for this information can be found at the web site maintained by Dr. William O'Brien and the University of Michigan-NIDR Materials Science Research Center at the University of Michigan School of Dentistry. The website address is http://www.lib.umich.edu/libhome/Dentistry.lib/Dental_tables/intro.html.

Several chapters contain unique subject matter for dental hygiene students. Chapter 1 introduces the student to materials as well as descriptions of common dental restorations. Many figures in the text are clinical photographs and radiographs of the same case, illustrating the use of dental materials.

Chapters 4 and 5, "Adhesive Materials" and "Direct Polymeric Restorative Materials," address the increasingly important adhesive restorative materials. Basic concepts are emphasized, as it seems new products are introduced almost daily.

Chapter 12, "Radiographic Appearance of Dental Tissues and Materials," assists the student in identifying dental tissues and materials on a radiograph and provides the rationale for differences in radiolucency and radiopacity in tooth tissues and dental materials. The chapter also includes a reference chart of typical dental materials and the radiographic characteristics they should exhibit.

Chapter 14, "Clinical Detection and Management of Dental Restorative Materials During Scaling and Polishing," provides criteria and a reference chart to identify tooth-colored restorative materials and a strategy for correctly managing all restorative procedures during scaling and polishing procedures.

Chapter 19, "Care and Maintenance of Instruments," addresses dental hygiene instruments as an important dental material. The composition of instruments is discussed, as well as the appropriate manner in which to care for them. The Hu-Friedy Manufacturing Company was most generous in providing text and artwork for this chapter.

Chapter 21, "Infection Control and Safety in the Dental Office," goes beyond dental materials to cover this important topic. It is hoped the information presented in this chapter will be used to prevent the transmission of disease and injuries to both clinicians and patients.

The authors have attempted to relate dental materials science to the clinical practice of dental hygiene. Brief descriptions of the above chapters emphasize this relationship. The authors will consider their efforts to be successful if this text improves the student's ability to provide quality dental care.

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Acknowledgments

The authors wish to express their heartfelt thanks to the following individuals for their contributions to this textbook. Without their help, the project would have been much more difficult:

—To the eight contributing authors for their energy, dedication to their assignment, and gracious acceptance of our editing.
—To Drs. Stephen Gladwin, Henry Miller, Eric Menke, Chris Kayafas, and John Dempsey for their comments and assistance with several chapters. Their efforts improved the manuscript.
—To Carol Spear, R.D.H., M.S., not only for her contribution of chapters but also for her photography skills for many of the figures.
—To Charles Hoffman, M.S.W., for graphics production and to Lori Hurley for both graphics and preparation of manuscripts. Their skills were very much needed and appreciated.
—To Drs. Jerry Nieusma and Louise Veselicky for helpful advice.
—To the many clinicians, dental materials scientists, and dental products manufacturers that contributed photographs, text, and artwork.
—To the staff of the Biomedical Communications at WVU Health Sciences Center for their help with photography, slide copying, and film processing.
—To the library staff of the American Dental Association for research assistance.
—To the Organization for Safety & Asepsis Procedures.
—To CorelDraw for original clipart.
—To the friends and relatives of the authors, both near and far, for their constant encouragement and support from beginning to end.
—And lastly, to the staff at Lippincott Williams & Wilkins: Sharon, Tanya, Tim, Larry, Debby, Yvonne, Angela, and Bill for their guidance and assistance in making our efforts suitable for the dental hygiene student.

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Part I

FUNDAMENTAL PERSPECTIVES

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Chapter 1

Introduction

OBJECTIVES

After studying this chapter, the student will be able to do the following:

1. Summarize the reasons a dental hygienist should be knowledgeable in the science of dental materials.
2. Discuss some of the conditions that make the oral cavity a hostile environment.
3. Identify four characteristics or properties a dental material must possess to survive in the oral environment.
4. Explain how the following organizations evaluate and/or classify dental drugs, materials, instruments, and equipment:
   - American Dental Association (ADA)
   - Food and Drug Administration (FDA)
   - International Standards Organization (ISO)
5. Name three categories into which dental materials may be classified, and discuss each of these.

KEY WORDS/PHRASES

abutment
base
biocompatibility
biomaterial
bridge
cast
cavity preparation
dental implant
dental materials
denture
esthetic materials
fixed partial denture
impression
liner
luting agent
maxillofacial prosthesis
polishing
pontic
prosthesis
removable partial denture
restoration
retainer
specification
study model

I. Rationale for Studying Dental Materials

Basic science and dental hygiene science courses must be studied and integrated with each other to provide students with the knowledge and skills necessary to ensure that quality dental hygiene care is provided to their patients. This care includes assessing and diagnosing the patient's oral needs. To fulfill these needs the dental hygienist must establish, implement, and evaluate goals specified for the patient.

"Dental materials" is one of many required courses in the dental hygiene curriculum that focuses on materials used in the prevention and treatment of oral disease and the promotion of health. The scope of practice of a dental hygienist includes the delivery of therapeutic, educational, and preventive patient services. Materials used in the practice of dental hygiene include instruments made from common industrial materials, therapeutic agents, and dental biomaterials to prevent disease. At times, therapeutic dental products and preventive materials overlap.

The preventive aspects of dental hygiene include primary prevention, which attempts to impede the development of disease, and secondary prevention, which attempts to limit the destruction caused by disease. Both aspects of preventive dentistry involve the use of instruments (made from materials) and dental materials.

There are four reasons why a dental hygienist should be knowledgeable in the science of dental materials:

A. To Understand the Behavior of Materials

This will aid in the delivery of quality patient care. For example, the proper placement of sealants will prevent dental caries. The proper restoration of teeth and maintenance of restorations will limit the destructive effects of caries and periodontal disease. The proper care and maintenance of instruments (prevention of corrosion) are important when sterilizing and disinfecting. The proper use of all of dental materials is fundamental to the art and science of dentistry.

B. To Handle Materials Properly

Like preventive dentistry, restorative dentistry relies heavily on the proper use of biomaterials. **Biomaterials** are man-made materials used to replace tissues or function in intimate contact with living tissues. **Dental materials** are biomaterials used in or around the oral cavity. While the hygienist may or may not be involved in the placement of restorations, he or she plays a significant role in the placement of preventive materials and the maintenance of restorations. Understanding the physical, chemical, and mechanical properties of materials is very important, as it influences the handling of materials.

Handling a dental material properly is a primary factor in its success or failure. The goal of this text is to present dental materials and their manipulation from a clinical perspective. If materials are properly mixed and placed, improved patient care will result.

C. To Assess and Treat the Patient

The dental hygienist must be able to recognize all dental materials placed in the mouth. These may be visible clinically or radiographically. Proper identification is important so that they are not mistaken for caries (radiographically) or another similar-looking restoration that should be maintained in a different manner. An example would be to recognize an all-ceramic crown. Acidulated phosphate-fluoride (APF) gels can etch the surface of some ceramic materials. Using an APF gel is contraindicated for patients with ceramic restorations; a neutral fluoride gel should be utilized.

D. To Educate the Patient

In many instances patients may ask the dental hygienist to discuss the characteristics and properties of one dental material compared to another, both of which may be a reasonable option for the patient. Patients may also ask the hygienist to describe the steps involved in the fabrication of a certain type of restoration. Or they may also inquire about home care regimens, "Will I need to do anything more than brushing or flossing?" Knowledge of dental materials is critical so that the patient is given professional, complete, and correct answers.

II. Biomaterials and the Oral Environment

A. Oral Tissues as Biologic Materials

Whether a material is used for preventive or restorative purposes, the oral environment places great restrictions on which materials can be used and the manner in which they are used. When one realizes oral tissues are biologic materials, a variety of properties and functions are evident. All oral tissues must function in the hostile environment of the oral cavity.

1. Enamel

Enamel is a hard and wear-resistant surface material. While enamel is able to resist the compressive forces of biting, it is weak in its resistance to bending and other forces that occur when food is ground by molars. Enamel is well supported by dentin. Enamel will dissolve in oral fluids if the pH is too acidic. Dental caries is the result of such an acidic attack.

2. Dentin
   Dentin makes up the bulk of the tooth. It acts as a cushion for the brittle enamel and provides strength to resist the complex forces that occur when biting. Dentin is more susceptible to acidic attack than enamel.
3. Pulp
   The pulp provides nutrients to the dentin and responds to stimuli with pain.
4. Periodontium
   The periodontium supports the tooth in a stable but dynamic position and provides feedback on the force placed on the tooth. The periodontium includes the periodontal ligament, cementum, and alveolar bone.
5. Gingival Tissue
   A very important function of the gingival tissues is to seal out the many noxious agents of the oral cavity, which include chemicals and microbes, from gaining access to the periodontium and deeper tissues in the body. Gingival tissues surround and attach to teeth, forming a barrier. Although the oral cavity is considered to be inside the body, in many ways it is more like the outside. Biomaterials placed in the oral cavity have very different requirements than devices implanted inside the body.

B. Replacement Materials for Oral Tissues

1. Restriction on Materials Use
   When oral tissue is lost, dental professionals attempt to replace it with a dental material. The replacement material mimics the function of oral tissues and must withstand the same harsh environment. The biologic nature of the oral environment and the size of the oral cavity restrict the use of materials. These restrictions include:
   a) Biting forces that may fracture teeth and replacement material
   b) Degradation of
      (1) Materials, such as corrosion of metals
      (2) Teeth, such as dental caries
   c) Temperature changes that cause restorations to contract and expand differently than teeth, causing leakage around the restoration and tooth sensitivity
   d) **Biocompatibility,** the lack of harmful effects to the patient
   e) Esthetic demands of the patient
2. Effects of Dental Materials and the Oral Environment on Each Other
   The dental hygienist must have an understanding of the characteristics and properties of dental materials. This knowledge will provide insight as to how a dental material may affect the oral environment and the effects of the oral environment on the dental material. These characteristics and properties may also limit the dentist in the selection and use of a dental material.

III. History and Selection of Dental Materials

A. History

1. Ancient Times to the 1700s
   Why are certain materials chosen instead of others to serve as dental restorative materials? Actually, much has been learned throughout history by trial and error. In ancient times, gold was used not only for its corrosion resistance but also for its "workability" or ease of processing. Long ago, artists learned to form gold into many shapes. The relationship between the art and science of dentistry dates back to the infancy of the profession. It must be remembered that for centuries humans have attempted to improve their appearance with adornments such as jewelry and makeup. The replacement of lost teeth is also an ancient practice. In ancient times, it was more likely for esthetics than function. As dentistry developed throughout the ages, more and more materials were utilized. Some of these included:
   a) Ivory, which was carved
   b) Porcelain, which was fired into tooth shapes
   c) Wax and gypsum, which were used for impressions and models
   d) Zinc oxide–eugenol and zinc phosphate, which evolved as fillings and cements to "glue" the restoration to the tooth
2. During the 1800s
   By this time, dentistry was becoming a scientifically based discipline. The pace of development of new materials quickened. Amalgam, a silver filling material, was widely accepted and frequently used. Porcelain was also used for inlays and crowns.
3. The 20th Century
   a) Dental materials science has developed into its own discipline. New materials and techniques are constantly being developed.
   b) A variety of cast metals are utilized. Alloys are made of gold, chromium and nickel, chromium and cobalt, and titanium. Cast metals are used for crowns, bridges, and partial dentures.

c) Polymers and composites are alternatives for nearly every dental materials need.
d) The pace of dental materials development is so fast, some of this text will be outdated before it is published.
e) Luckily, the basic concepts of materials science and their use do not change. Both the student and the practitioner need to understand the behavior of the materials they use. After all, they are the ones who must select a product from a rather long list of possibilities.

B. Selection of Dental Materials and Products

The knowledge gained in a dental materials course will aid in the selection of products. Manufacturers readily provide data on strength and a variety of other properties. At times they provide the results of short-term clinical trials. But how reliable is that information? More importantly, how useful is that information? It has been a goal of dental materials scientists to predict the performance of a material from its strength and other mechanical properties. Unfortunately, success has been elusive. Clinical trials are the most reliable source of information for many products. The clinician must evaluate the product information but also consider the source of the information.

IV. Standards for Dental Materials

Standards for dental materials have been developed in dentistry in the same manner as standards have been developed in other industries. Standards describe the properties of a product so a user may select the proper material for a particular use. Standards are common in everyday life. Examples include the octane rating of gas, film speed, the size of nuts and bolts, computer communications, and low-fat foods. In the United States, standards are published and administered by the American National Standards Institute (ANSI). Many industries have organizations that work under the guidance of ANSI to develop and administer the standards for products of that industry.

A. Council on Scientific Affairs of the American Dental Association

In the United States, standards and guidelines for evaluating dental products are developed and administered by the Council on Scientific Affairs of the American Dental Association (ADA). The Council evaluates dental drugs, materials, instruments, and equipment. A successful evaluation culminates in the awarding of the ADA's Seal of Acceptance. The applicant (such as a toothpaste company or any manufacturer of a dentally related product) submits data on their product following the ADA guidelines. Upon approval of the product, the applicant is permitted to use the ADA's Seal of Acceptance. This Seal is illustrated in Figure 1.1. It is commonly seen on accepted brands of toothpaste and toothbrushes. The ADA Seal is awarded for a period of 3 years, and then the applicant must resubmit the product.

Some of the guidelines have very specific requirements for physical and mechanical properties that are measured in the laboratory and are called **specifications**. Specifications have been developed for many but not all dental materials. Unfortunately, researchers have not been able to develop a series of tests that adequately predict the clinical performance of many dental materials. As a result, the Acceptance Program relies on clinical data for the evaluation of certain dental products. If a product is shown to be safe and effective, it can be given the Seal of Acceptance.

The Acceptance Program of the ADA is voluntary. Manufacturers are not required to have the Seal to market dental products in the United States. Although products might be approved for sale by the Food and Drug Administration (FDA), some products fail ADA specifications, when tested. In addition, advertising for products that have been awarded the seal is reviewed by the ADA.

B. Medical Device Amendment of 1976

The federal government, under the auspices of the FDA, has the authority under the Medical Device Amendments of 1976 to ensure the safety of all medical devices. The FDA considers dental materials to be devices. Medical devices are grouped into three categories:

1. Class I

   These are the least regulated. Only good manufacturing practices are required.

FIGURE 1.1 Seal of Acceptance of the American Dental Association. (Courtesy of the American Dental Association, Chicago, IL.)

2. Class II
   These must meet certain performance standards, such as the ADA's Seal Program. Many dental products have been "grandfathered in," as they were marketed before 1976. Other Class II devices gain approval after being shown to be equivalent to products currently in use.
3. Class III
   These are the most regulated; they require premarket approval. Clinical data must be submitted to the FDA for evaluation before Class III devices are sold. If supported by the data, the FDA then gives approval to market the product.

C. International Standards Organization

Many other countries have dental specifications or standards and governmental regulations. To simplify the mass of regulations, the International Standards Organization (ISO) attempts to unify standards throughout its member countries. ISO standards for many dental materials have been developed and continue to be developed under the guidance of the Fédération Dentaire Internationale.

D. Selecting Products

Dentists are fortunate that there are usually several products that will meet the needs of a particular clinical situation. It is important to select and use materials that result in quality service to the patient. The same product may not do so for all practitioners. It is acceptable to select products based on handling characteristics, a company's reputation and service, or packaging. If a product has been shown to be excellent, the ill-defined characteristics of "feel" or "looks" may be the final criteria that result in its selection. It is important to realize most products require some time to learn to use them properly. If one is always changing products to have the latest and greatest "widget bonder," one may be spending so much time learning to use new products that patient care may be affected. Of less consequence, that person will have drawers, closets, and refrigerators filled with expensive, partially used dental products.

V. Classifications of Dental Materials

Like oral tissues, dental materials serve a variety of functions. Some materials replace lost tooth structure and restore the function of the teeth. These materials must withstand biting forces and therefore be strong and wear resistant. Other materials are used to make impressions of oral tissues from which replicas are made. Many impression materials are soft and can be distorted and stretched when removed from the mouth. In dentistry as with other disciplines, the use of a material must be matched to the properties of that material. Dental materials can be classified in a variety of ways. They are typically classified by their use or function. Restorative materials are also classified by the location of fabrication or the longevity of use.

A. Classification by Use

1. Restorative Materials
   Materials used to replace lost oral tissues are called restorative materials. As mentioned earlier, those that replace lost tooth structure and restore the function of the teeth must be strong and hard. Some restorative materials simulate the appearance of the tissues that are being replaced. Tissues simulated by restorative materials include the enamel of teeth (fillings and crowns), the mucosa of the periodontium (dentures), and even the skin of the face (maxillofacial prostheses). Materials that are tooth-colored are often called **esthetic materials**.
2. Restorations and Crowns
   Depending on the degree of destruction of a tooth, different restorations or fillings are used to replace lost tooth structure. Some **restorations** replace a small to moderate amount of tooth structure and are supported by the remaining tooth structure. Such restorations are held in the tooth by undercuts (mechanical locks), adhesion, or both. An inlay is a restoration made outside the mouth, usually in a dental laboratory. Inlays do not have undercuts and are cemented or "luted" into the tooth (Fig. 1.2). Crowns are used to restore teeth when a substantial amount of tooth structure is missing. Crowns encircle as well as support the remaining tooth structure (Fig. 1.3). Crowns are cemented into place similar to that of an inlay.
3. Bridges
   A dental **bridge** replaces a lost tooth or teeth, as shown in Figure 1.4. A typical dental bridge is much like a bridge over a river. At each end, the dental bridge is supported by a tooth called an **abutment**. Each abutment is prepared and then restored with a crown called a **retainer**. The missing tooth is replaced with a false tooth called a **pontic**. A pontic is a replacement tooth, but only the crown portion of the tooth is replaced. The pontic and abutments are strongly joined together so that the chewing forces will not break the bridge. The dental bridge is cemented on the prepared teeth in the same manner as a crown or inlay. Like all restorations, the physical size of a bridge is limited

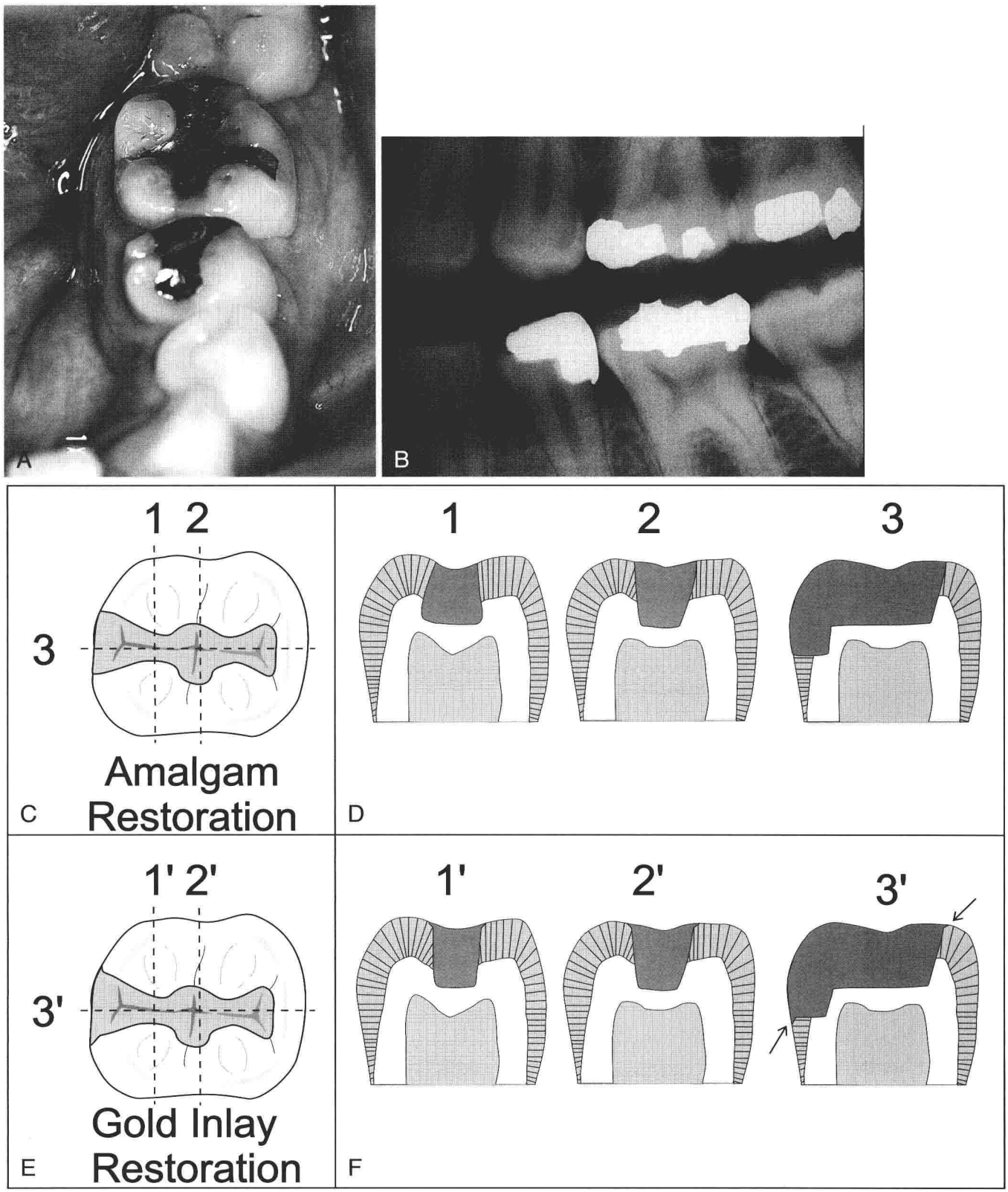

FIGURE 1.2 Photograph (**A**) and radiograph (**B**) of inlay (#20) and amalgam (#19) restorations and drawings (**C–F**) showing the convergence and divergence of preparations for the two materials. *Arrows* indicate bevels for the inlay.

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