FUNDAMENTALS OF FIXED PROSTHODONTICS

FOURTH EDITION

Herbert T. Shillingburg, Jr, DDS
David A. Sather, DDS
Edwin L. Wilson, Jr, DDS, MEd
Joseph R. Cain, DDS, MS
Donald L. Mitchell, DDS, MS
Luis J. Blanco, DMD, MS
James C. Kessler, DDS

quintessence books

Fundamentals of Fixed Prosthodontics

Fourth Edition

Cover design based on a photograph of Monument Valley on the Navajo Reservation in northern Arizona taken at sunrise by Dr Herbert T. Shillingburg, Jr.

FUNDAMENTALS OF FIXED PROSTHODONTICS

FOURTH EDITION

Herbert T. Shillingburg, Jr, DDS

David Ross Boyd Professor Emeritus
Department of Fixed Prosthodontics
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

with

David A. Sather, DDS

Edwin L. Wilson, Jr, DDS, MEd

Joseph R. Cain, DDS, MS

Donald L. Mitchell, DDS, MS

Luis J. Blanco, DMD, MS

James C. Kessler, DDS

Illustrations by

Suzan E. Stone

Quintessence Publishing Co, Inc
Chicago, Berlin, Tokyo, London, Paris, Milan,
Barcelona, Istanbul, Moscow, New Delhi, Prague,
São Paulo, and Warsaw

Library of Congress Cataloging-in-Publication Data

Fundamentals of fixed prosthodontics / Herbert T. Shillingburg Jr. ... [et al.]. -- 4th ed.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-0-86715-475-7
I. Shillingburg, Herbert T.
[DNLM: 1. Denture, Partial, Fixed. 2. Crowns. 3. Dental Prosthesis Design. 4. Prosthodontics--methods. WU 515]

617.6'9--dc23
2011041249

5 4 3 2 1

Quintessence Publishing Co, Inc
4350 Chandler Drive
Hanover Park, IL 60133
www.quintpub.com

Editor: Leah Huffman
Design: Ted Pereda
Production: Patrick Penney

Printed in the USA

Dedication

In Memoriam
Constance Murphy Shillingburg
1938–2008

This book is dedicated to the loving memory of Constance Murphy Shillingburg. We met at the University of New Mexico at the beginning of her freshman year in 1956. We were married 4 years later, 1 week after she graduated. During my first 2 years in dental school, I made 13 trips, totaling over 22,000 miles, from Los Angeles to Albuquerque. She shared all of the triumphs and disappointments of my last 2 years in dental school. It was not my career; it was our career. She supported me in all that I did. She didn’t question my leaving practice to start a career in academics or our moving from California to Oklahoma. We had three daughters along the way. Although

she had three open-heart surgeries in her teens because of rheumatic fever and then two cancer surgeries later in life, she was the most optimistic person I ever met.

She accompanied me on 29 trips outside the United States. At first she came along because she loved to travel, and I didn't enjoy the trips nearly as much without her. However, I very quickly learned that my hosts and audiences were enchanted by her. They enjoyed her as much or more than they did me, and she used what she learned on those trips in her teaching. She died 3 weeks after we celebrated our 48th wedding anniversary. There is a song on the most recent Glen Campbell album, Ghost on the Canvas, that sums it up perfectly: "There's no me… without you."

Authors

Luis J. Blanco, DMD, MS
Professor and Chair
Department of Fixed Prosthodontics
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

Joseph R. Cain, DDS, MS
Professor Emeritus
Department of Removable Prosthodontics
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

James C. Kessler, DDS
Director of Education
L. D. Pankey Institute
Key Biscayne, Florida

Donald L. Mitchell, DDS, MS
Professor Emeritus
Department of Oral Implantology
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

David A. Sather, DDS
Associate Professor
Department of Fixed Prosthodontics
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

Herbert T. Shillingburg, Jr, DDS
David Ross Boyd Professor Emeritus
Department of Fixed Prosthodontics
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

Edwin L. Wilson, Jr, DDS, MEd
Professor Emeritus
Department of Occlusion
University of Oklahoma College of Dentistry
Oklahoma City, Oklahoma

Preface

Fixed prosthodontics is the art and science of restoring damaged teeth with cast metal, metal-ceramic, or all-ceramic restorations and of replacing missing teeth with fixed prostheses using metal-ceramic artificial teeth (pontics) or metal-ceramic crowns over implants. Successfully treating a patient by means of fixed prosthodontics requires a thoughtful combination of many aspects of dental treatment: patient education and the prevention of further dental disease, sound diagnosis, periodontal therapy, operative skills, occlusal considerations, and, sometimes, placement of removable complete or partial prostheses and endodontic treatment.

Restorations in this field of dentistry can be the finest service rendered for dental patients or the worst disservice perpetrated upon them. The path taken depends upon one's knowledge of sound biologic and mechanical principles, the growth of manipulative skills to implement the treatment plan, and the development of a critical eye and judgement for assessing detail.

As in all fields of the healing arts, there has been tremendous change in this area of dentistry in recent years. Improved materials, instruments, and techniques have made it possible for today's operator with average skills to provide a service whose quality is on a par with that provided only by the most gifted dentist of years gone by. This is possible, however, only if the dentist has a thorough background in the principles of restorative dentistry and an intimate knowledge of the techniques required.

This book was designed to serve as an introduction to the area of restorative dentistry dealing with fixed partial dentures and cast metal, metal-ceramic, and all-ceramic restorations. It should provide the background knowledge needed by the novice as well as serve as a refresher for the practitioner or graduate student.

To provide the needed background for formulating rational judgments in the clinical environment, there are chapters dealing with the fundamentals of treatment planning, occlusion, and tooth preparation. In addition, sections of other chapters are devoted to the fundamentals of the respective subjects. Specific techniques and instruments are discussed because dentists and dental technicians must deal with them in their daily work.

Alternative techniques are given when there are multiple techniques widely used in the profession. Frequently, however, only one technique is presented. Cognizance is given to the fact that there is usually more than one acceptable way of accomplishing a particular task. However, in the limited time available in the undergraduate dental curriculum, there is usually time for the mastery of only one basic technique for accomplishing each of the various types of treatment.

An attempt has been made to provide a sound working background in the various facets of fixed prosthodontic therapy. Current information has been added to cover the increased use of new cements, new packaging and dispensing equipment for the use of impression materials, and changes in the management of soft tissues for impression making. New articulators, facebows, and concepts of occlusion needed attention, along with precise ways of making removable dies. The usage of periodontally weakened teeth requires different designs for preparations of teeth with exposed root morphology or molars that have lost a root.

Different ways of handling edentulous ridges with defects have given the dentist better control of the functional and cosmetic outcome. No longer are metal or ceramics needed to somehow mask the loss of bone and soft tissue. The biggest change in the replacement of missing teeth, of course, is the widespread use of endosseous implants, which make it possible to replace teeth without damaging adjacent sound teeth.

The increased emphasis on cosmetic restorations has necessitated expanding the chapters on those types of restorations. The design of resin-bonded fixed partial dentures has been moved to the chapters on partial coverage restorations. There are some uses for that type of restoration, but the indications are far more limited than they were thought to be a few years ago.

Updated references document the rationale for using materials and techniques and familiarize the reader with the literature in the various aspects of fixed prosthodontics. If more background information on specific topics is desired, several books are recommended: For detailed treatment of dental materials, refer to Kenneth J. Anusavice's *Phillip's Science of Dental Materials, Eleventh Edition* (Saunders, 2003) or William J. O'Brien's *Dental Materials and Their Selection, Fourth Edition* (Quintessence, 2008). For an in-depth study of occlusion, see Jeffrey P. Okeson's *Management of Temporomandibular Disorders and Occlusion, Sixth Edition* (Mosby, 2007). The topic of tooth preparations is discussed in detail in *Fundamentals of Tooth Preparations* (Quintessence, 1987) by Herbert T. Shillingburg et al. For detailed coverage of occlusal morphology used in waxing restorations, consult the *Guide to Occlusal Waxing* (Quintessence, 1984) by Herbert T. Shillingburg et al. Books of particular interest in the area of ceramics include W. Patrick Naylor's *Introduction to Metal Ceramic Technology* (Quintessence, 2009) and Christoph Hämmerle et al's

Dental Ceramics: Essential Aspects for Clinical Practice (Quintessence, 2009).

—*Herbert T. Shillingburg, Jr,* DDS

Acknowledgments

No book is the work of just its authors. It is difficult to say which ideas are our own and which are an amalgam of those with whom we have associated. Two fine restorative dentists had an important influence on this book: Dr Robert Dewhirst and Dr Donald Fisher have been mentors, colleagues, and, most importantly, friends. Their philosophies have been our guide for the last 40 years. Dr Manville G. Duncanson, Jr, Professor Emeritus of Dental Materials, and Dr Dean Johnson, Professor Emeritus of Removable Prosthodontics, both of the University of Oklahoma, were forthcoming through the years with their suggestions, criticism, and shared knowledge. Thanks are also due to Mr James Robinson of Whip- Mix Corporation for his help with materials and instruments in the chapters that deal with laboratory procedures. Appreciation is expressed to Dr Mike Fling for his input regarding tooth preparations for laminate veneers. Thank you to Mr Lee Holmstead, Brasseler USA, for his assistance with the illustrations of the diamonds and carbide burs.

Illustrations have been done by several people through the years: Mr Robert Shackelford, Ms Laurel Kallenberger, Ms Jane Cripps, and Ms Judy Amico of the Graphics and Media Department of the University of Oklahoma Health Sciences Center. Artwork was also contributed by Drs Richard Jacobi and Herbert T. Shillingburg. This book would not have come to fruition without the illustrations provided by Ms Suzan Stone and the computer program, *Topaz Simplify*, suggested by Mr Alvin Flier, a friend from 40 years ago in Simi, California. A special thank you to the Rev John

W. Price of Houston, Texas, for restoring my sense of mission in June 2008.

Thanks to you all.

1
An Introduction to Fixed Prosthodontics

The scope of fixed prosthodontics treatment can range from the restoration of a single tooth to the rehabilitation of the entire occlusion. Single teeth can be restored to full function, and improvement in esthetics can be achieved. Missing teeth can be replaced with fixed prostheses that will improve patient comfort and masticatory ability, maintain the health and integrity of the dental arches, and, in many instances, elevate the patient's self-image.

It is also possible, through the use of fixed restorations, to render an optimal occlusion that improves the orthopedic stability of the temporomandibular joints (TMJs). On the other hand, with improper treatment of the occlusion, it is possible to create disharmony and damage to the stomatognathic system.

Terminology

A *crown* is a cemented or permanently affixed extracoronal restoration that covers, or veneers, the outer surface of the clinical crown. It should reproduce the morphology and contours of the damaged coronal portions of a tooth while performing its function. It should also protect the remaining tooth structure from further damage.

If it covers the entire clinical crown, the restoration is called a *full veneer*, *full coverage*, *complete*, or just a *full crown* (Fig 1-1). It may be fabricated entirely of a gold alloy

or another untarnishable metal, a ceramic veneer fused to metal, an all-ceramic material, resin and metal, or resin only. If only portions of the clinical crown are veneered, the restoration is called a *partial coverage* or *partial veneer crown* (Fig 1-2).

Intracoronal restorations are those that fit within the anatomical contours of the clinical crown of a tooth. *Inlays* may be used as single-tooth restorations for Class II proximo-occlusal or Class V gingival lesions with minimal to moderate extensions. They may be made of gold alloy (Fig 1-3a), a ceramic material (Fig 1-3b), or processed resin. When modified with occlusal coverage, the intracoronal restoration is called an *onlay* and is useful for restoring more extensively damaged posterior teeth needing wide *mesio-occlusodistal (MOD) restorations* (Fig 1-4).

Another type of cemented restoration that has gained considerable popularity in recent years is the all-ceramic *laminate veneer*, or *facial veneer* (Fig 1-5). It is used on anterior teeth that require improved esthetics but are otherwise sound. It consists of a thin layer of dental porcelain or cast ceramic that is bonded to the facial surface of the tooth with an appropriate resin.

The *fixed partial denture* is a prosthetic appliance that is permanently attached to remaining teeth or implants and replaces one or more missing teeth (Fig 1-6). In years past, this type of prosthesis was known as a *bridge*, a term that has fallen from favor[1,2] and is no longer used.

A tooth or implant serving as an attachment for a fixed partial denture is called an *abutment*. The artificial tooth suspended from the abutments is a *pontic*. The pontic is connected to the fixed partial denture retainers, which are extracoronal restorations that are cemented to or otherwise attached to the abutment teeth or implants. Intracoronal restorations lack the necessary retention and resistance to be used as fixed partial denture retainers. The *connectors* between the pontic and the retainer may be rigid (ie, solder

joints or cast connectors) or nonrigid (ie, precision attachments or stress breakers) if the abutments are teeth. As a rule, only rigid connectors are used with implant abutments.

Diagnosis

A thorough diagnosis of the patient's dental condition must first be made, considering both hard and soft tissues. This must be correlated with the individual's overall physical health and psychologic needs. Using the diagnostic information that has been gathered, it is then possible to formulate a treatment plan based on the patient's dental needs, mitigated to a variable degree by his or her medical, psychologic, and personal circumstances.

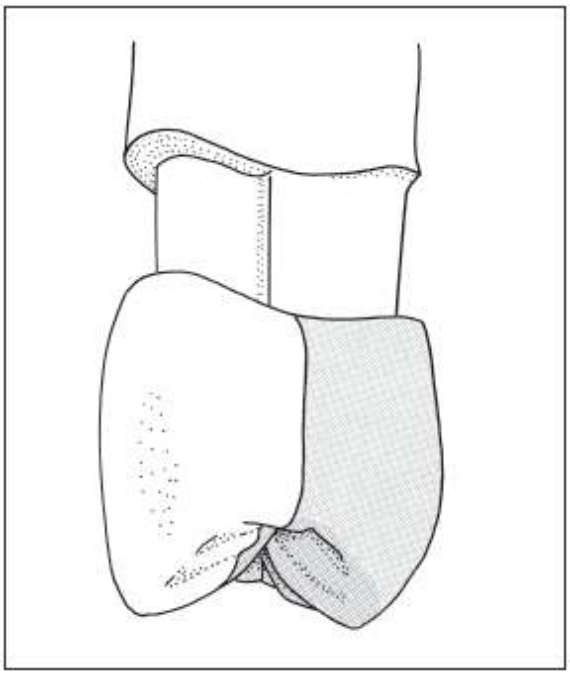

Fig 1-1 *A full veneer, full coverage, or complete crown covers the entire clinical crown of a tooth. The example shown is a metal-ceramic crown.*

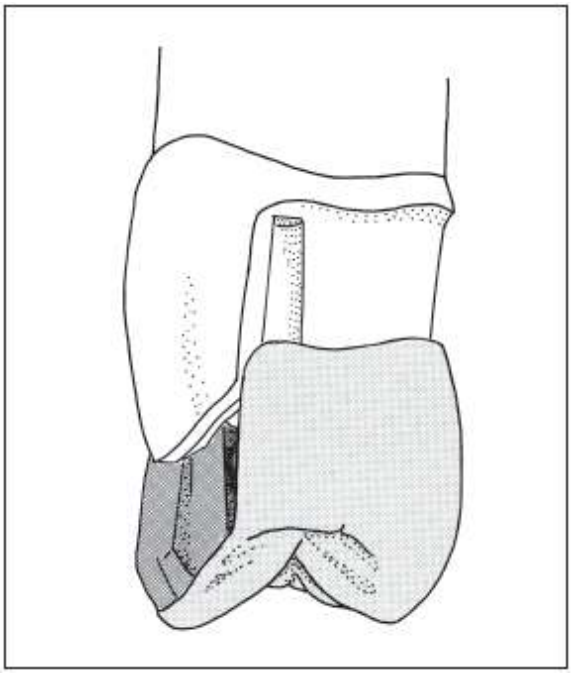

Fig 1-2 *A partial veneer or partial coverage crown covers only portions of the clinical crown. The facial surface is usually left unveneered.*

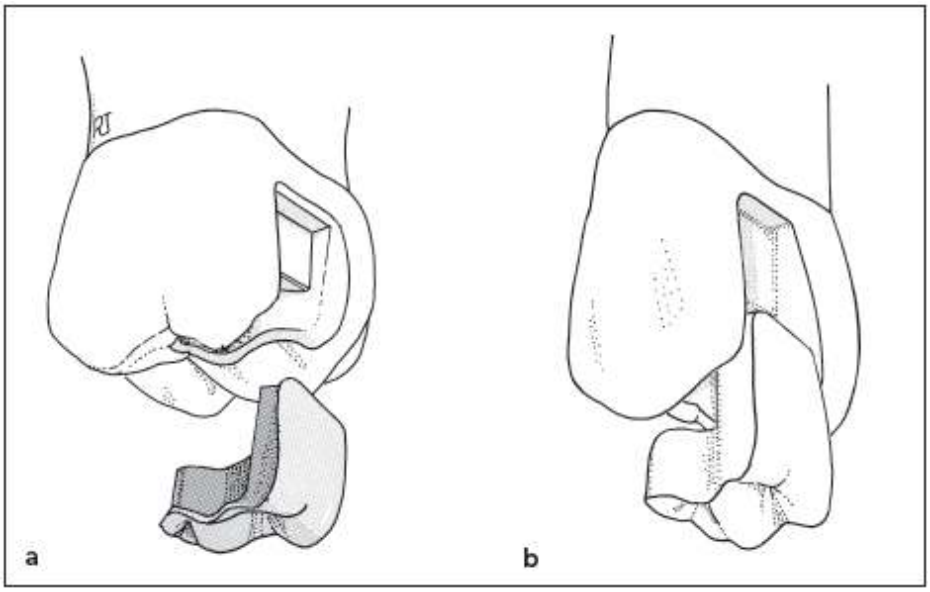

Fig 1-3 *Inlays are intracoronal restorations with minimal to moderate extensions made of gold alloy (a) or a ceramic*

material (b).

There are five elements to a good diagnostic work-up in preparation for fixed prosthodontic treatment:

1. Health history
2. TMJ and occlusal evaluation
3. Intraoral examination
4. Diagnostic casts
5. Full-mouth radiographs

Health history

It is important that a good history be taken before the initiation of treatment to determine if any special precautions are necessary. Some elective treatments might be canceled or postponed because of the patient's physical or emotional health. It may be necessary to premedicate patients with certain conditions or to avoid medication for others.

It is not within the scope of this book to describe all the conditions that might influence patient treatment. However, there are some whose frequency or threat to the patient's or office staff's well-being is significant enough to merit discussion. A history of infectious diseases, such as serum hepatitis, tuberculosis, and human immunodeficiency virus (HIV)/AIDS, must be known so that protection can be provided for other patients as well as office personnel. There are numerous conditions of a noninfectious nature that also can be important to the patient's well-being.

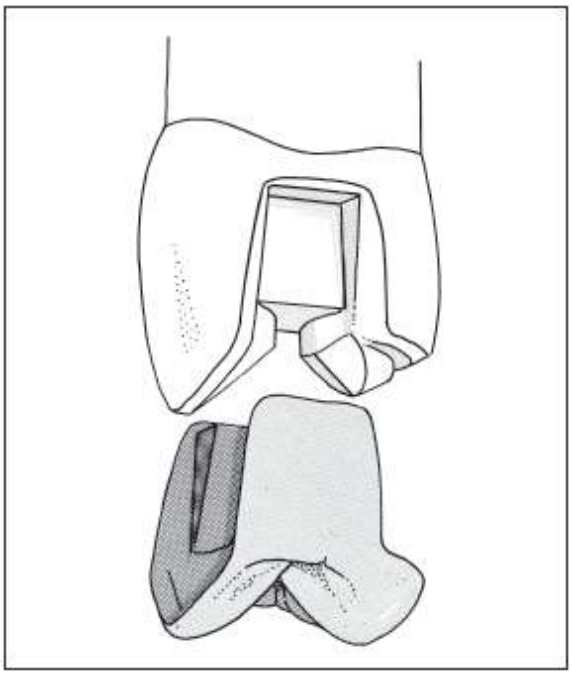

Fig 1-4 *An onlay is an intracoronal restoration with an occlusal veneer.*

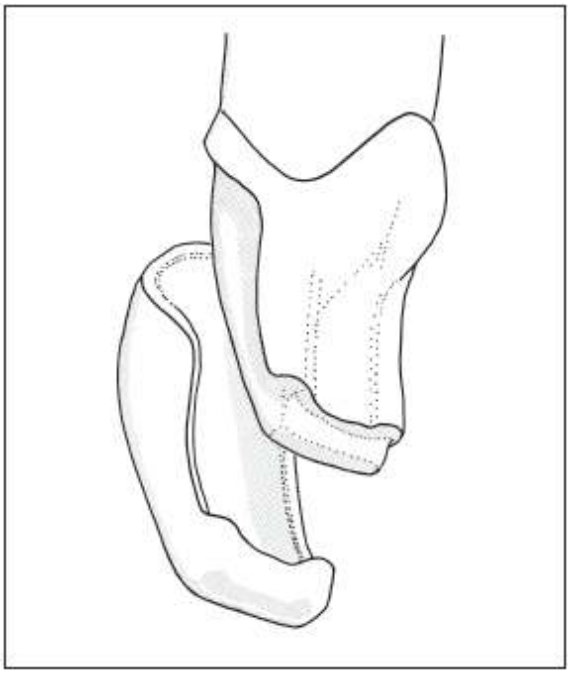

Fig 1-5 *A laminate veneer is a thin layer of porcelain or cast ceramic that is bonded to the facial surface of a tooth with*

resin.

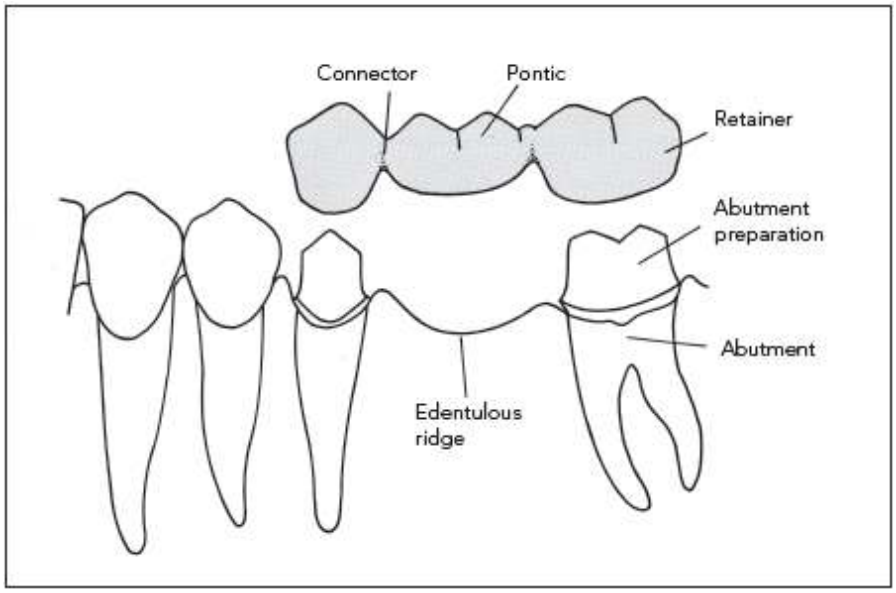

Fig 1-6 *The components of a fixed partial denture.*

Medications

The patient should be asked what medications, prescribed or over-the-counter, are currently being taken and for what purpose.[3] It is important to be aware that an estimated 25% of the population is taking some type of herbal product.[4] All medications should be identified and their contraindications noted before proceeding with treatment. The patient should be questioned about current medications at each subsequent appointment to ensure that information on the patient's medication regimen is kept up to date.

Allergies

If a patient reports a previous reaction to a drug, it should be determined whether it was an allergic reaction or syncope resulting from anxiety in the dental chair. If there is any possibility of a true allergic reaction, a notation should be made on a sticker prominently displayed in the patient's record so that the medication is not administered or prescribed. Local anesthetics and antibiotics are the most common allergenic drugs.

The patient might also report a reaction to a dental material. Impression materials and nickel-containing alloys are leading candidates in this area. It is imperative that the dentist not engage in any type of improvised allergy testing to corroborate the patient's recollection of previous problems. It is possible to initiate a life-threatening anaphylactic reaction by challenging the patient's immune system with an allergen to which he or she has been previously sensitized.

Cardiovascular disorders

Patients who present with a history of cardiovascular problems require special attention. Hypertension affects nearly 50 million Americans.[5] Thirty percent of those with high blood pressure (HBP) are not aware of having the condition; only 59% of them are being treated for it; and only 34% have their blood pressure controlled to recommended levels.[6] Based on these statistics, it is probable that dentists see numerous patients with undetected or uncontrolled HBP, who are prime candidates for disastrous cardiovascular events. Therefore, dentists should check blood pressure of all patients at the first appointment and at subsequent visits. No patient with uncontrolled hypertension should be treated until the blood pressure has been lowered.

The 7th Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High

Blood Pressure (JNC-7) has revised guidelines that simplify blood pressure classification.[6] There are two categories of hypertension:

- Stage 1: systolic blood pressure (SBP) ≥ 140–159 mm Hg or diastolic blood pressure (DBP) ≥ 90–99 mm Hg
- Stage 2: SBP ≥ 160 or DBP ≥ 100

In this simplified classification, *prehypertension* describes SBP = 120–139 mm Hg or DBP = 80–89 mm Hg. This replaces the category called *high normal* (SBP = 130–139, DBP = 85–89 mm Hg).[6] Risk of a stroke or heart attack doubles for each 20/10 mm Hg incremental blood pressure increase above 115/75 mm Hg.[7] For most patients, treatment should be performed only if blood pressure is below 140/90 mm Hg,[6,8] but in patients with diabetes or kidney disease, blood pressure should be lower than 130/80 mm Hg.[9,10]

Epinephrine in local anesthetic is contraindicated for patients with severe cardiovascular disease but not for patients with mild-to-moderate forms of the disease if the number of carpules used is limited to two or three.[6] The rationale is that lessening of pain will decrease the endogenous release of epinephrine, which could be 20 to 40 times greater if the patient becomes stressed by pain.[11] Retraction cord, however, does not provide any such potential benefit; therefore, cord containing epinephrine is contraindicated. Because of the availability of numerous alternatives for hemostasis and sulcus enlargement, the use of epinephrine-impregnated cords is not warranted.[6]

Patients on oral anticoagulant therapy are the most likely to experience hemorrhagic problems during dental treatment. [12] They may be taking anticoagulants for a variety of reasons: prosthetic heart valves, myocardial infarction (MI), stroke (cerebrovascular accident [CVA]), atrial fibrillation (AF), deep venous thrombosis (DVT), or unstable

angina.[13] The two most widely used coumarin derivatives are warfarin sodium (Coumadin [Bristol-Myers Squibb]) and bishydroxycoumarin (dicumarol), both of which are vitamin K antagonists. [12]

Anticoagulation level is measured by the international normalized ratio (INR). A patient whose blood coagulates normally would have an INR of 1.0.[13] Increasing the anticoagulant effect increases the INR.[12] The INR range recommended by the American College of Chest Physicians[14] and endorsed by the American Heart Association (AHA)[15] is 2.0 to 3.0 in every situation mentioned previously, except for prosthetic heart valves, for which the INR range should be 2.5 to 3.5. The INR for artificial heart valves should not exceed 4.0.[16]

The patient's physician should be consulted to learn why the patient is on anticoagulants,[12] the most recent INR value,[13,17] and when it was taken. Anticoagulant therapy is the responsibility of the physician, not the dentist. However, the physician may recommend stopping anticoagulant therapy 2 to 3 days prior to treatment, which is the traditional management of patients on anticoagulants, although the dental literature indicates that this may not be the optimal approach.[18]

An update of the recommendations by the AHA for prevention of infective endocarditis (IE) was issued in 2007.[19] Guidelines were first published in 1955, and the most recent update before the present one was published in 1997. The current guideline greatly reduces the number of patients who should be premedicated, stating, "Only an extremely small number of cases of infective endocarditis (IE) might be prevented by antibiotic prophylaxis even if it were 100% effective." [19]

Antibiotic prophylaxis for dental procedures now is recommended only for patients with cardiac conditions with the greatest risk of adverse outcome from IE[19]:

- Prosthetic heart valve
- Previous IE
- Congenital heart disease (CHD)
- Unrepaired cyanotic CHD
- CHD repaired with a prosthetic material for 6 months after repair
- Repaired CHD with residual defect at or near the prosthetic patch that would interfere with endothelialization
- Cardiac transplants that develop valvulopathy

For patients with these conditions, prophylaxis is recommended for all dental procedures that involve the gingiva, the periapical region of the teeth, or perforation of oral mucosa.

The antibiotic regimen now recommended is a single 2-g oral dose of amoxicillin for adults who are not allergic to penicillin, 30 to 60 minutes before the procedure.[19] There is no need to prescribe a follow-up dose after the procedure. If the patient is allergic to penicillin, 600 mg clindamycin or 500 mg azithromycin or clarithromycin may be substituted. If none of these is acceptable, consult the patient's physician or the guidelines article in the June 2007 issue of the *Journal of the American Dental Association.*[19]

Patients with valvular dysfunction from rheumatic heart disease (RHD),[20] mitral valve prolapse (MVP) with valvular regurgitation,[21] systemic lupus erythematosus,[22] and valvulopathy resulting from the diet medication fenfluraminephentermine ("fen-phen")[23] were once indicated for antibiotic prophylaxis, but following the 2007 guidelines set by the AHA, they no longer require premedication.[19] Most unrepaired congenital heart malformations still do require antibiotic prophylaxis.[19] Patients with cardiac pacemakers do not require prophylaxis.[19]

With regard to artificial joints, the American Dental Association (ADA) states, “Antibiotic prophylaxis is not indicated for dental patients with pins, plates or screws, nor is it routinely indicated for most dental patients with total joint replacements. However, it is advisable to consider premedication in a small number of patients who may be at risk of experiencing hematogenous total joint infection.”[24] For those patients not allergic to penicillin who do require premedication, 2 g amoxicillin taken orally 1 hour prior to the dental procedure is the antibiotic of choice. For variations of this regimen, the reader is referred to the advisory statement in the July 2003 issue of the *Journal of the American Dental Association.*[24]

Patients who are on an antibiotic regimen prescribed to prevent the recurrence of rheumatic fever are not adequately premedicated to prevent IE.[19] It is very possible that these patients will have developed strains of microorganisms that have some resistance to amoxicillin. If they require prophylactic antibiotic coverage, it would be wise to prescribe a different type than the one they are taking. Tetracyclines and sulfonamides are not recommended.

Epilepsy

Epilepsy is another patient condition of which the dentist should be aware. It does not contraindicate dentistry, but the dentist should know of its history in a patient so that appropriate measures can be taken without delay in the event of a seizure. Steps should also be taken to control anxiety in these patients. Long, fatiguing appointments should be avoided to minimize the possibility of precipitating a seizure.

Diabetes

More than 18 million Americans have diabetes, and another 41 million are “prediabetic.”[25] Diabetic patients are predisposed to periodontal breakdown or abscess formation.[26,27] Well-controlled diabetic patients should be able to report their self-monitoring blood glucose (SMBG) from that morning. This value, which they obtain by placing a drop of their blood in a glucometer, is a measure of their capillary plasma glucose. Their *preprandial* (fasting) reading should be in the 90 to 130 mg/dL range. Their peak *postprandial* (after meals) reading should be 180 mg/dL.[28] A long-term measure of diabetic patients’ glycemic control is their *glycosylated hemoglobin* (HbA_{1c}), a lab test that measures how much glucose is tied to red blood cells (Table 1-1). Its correlation with daily blood glucose numbers is 0.84.[29] It can be considered the average blood glucose level over the previous few months.[30]

Table 1-1 Correlation between HbA_{1c} and mean plasma glucose[29]

Those whose diabetes is poorly controlled will have elevated blood sugar, or *hyperglycemia*, and could be adversely affected by the stress of a dental appointment. *Hypoglycemia* (low blood sugar) can also cause problems. A controlled diabetic (on medication) who has missed a meal or has not eaten for several hours may become sweaty, lightheaded, and disoriented. These patients usually carry some quick source of glucose, such as candy, which should be administered. Four ounces of a regular soft drink or fruit juice or several pieces of hard candy should help them recover quickly. Treatment should be halted for that appointment, and the patient should be monitored at the office until complete recovery can be confirmed. It would be wise to have a family member drive the patient home. Dental treatment for the diabetic patient should interfere as