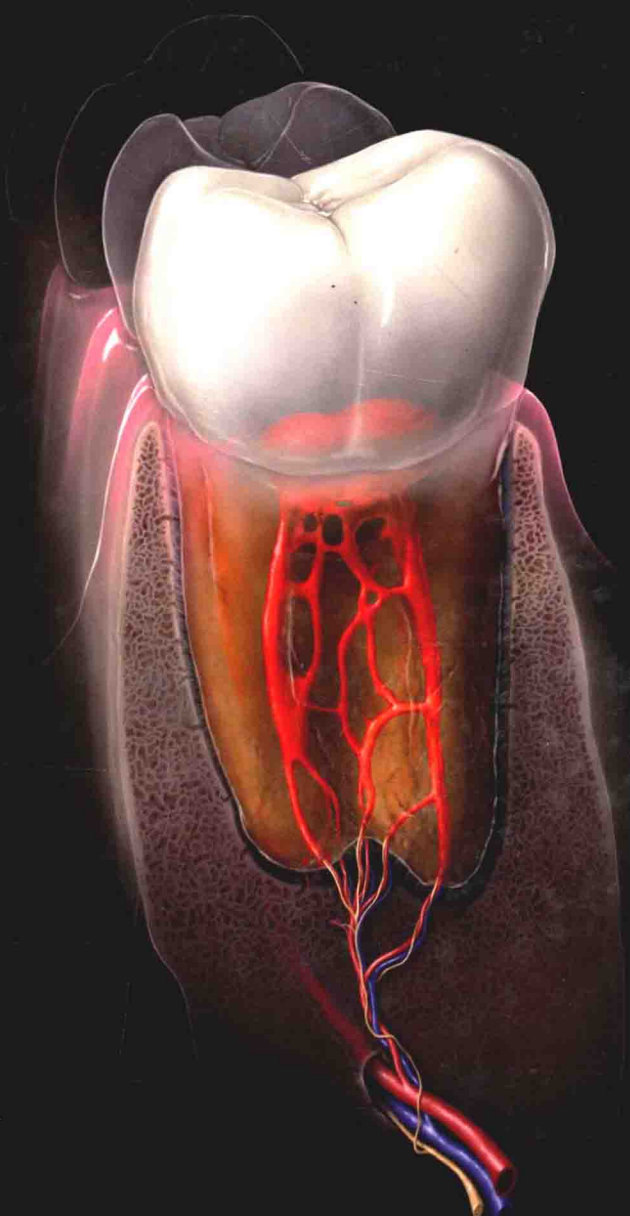
KENNETH M. HARGREAVES | LOUIS H. BERMAN

COHEN'S PATHWAYS *of the* PULP



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COHEN'S PATHWAYS *of the* PULP

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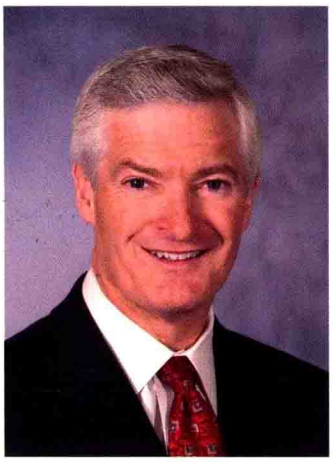

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Dr. Hargreaves is Professor and Chair of the Department of Endodontics at the University of Texas Health Science Center at San Antonio. He is a Diplomate of the American Board of Endodontics and maintains a private practice limited to endodontics. He is an active researcher, lecturer, and teacher and serves as the Editor-in-Chief of the Journal of Endodontics. He is principal investigator on several nationally funded grants that combine his interests in pain, pharmacology, and regenerative endodontics. He has received several awards, including a National Institutes of Health MERIT Award for pain research, the AAE Louis I. Grossman Award for cumulative publication of research studies, and two IADR Distinguished Scientist Awards.

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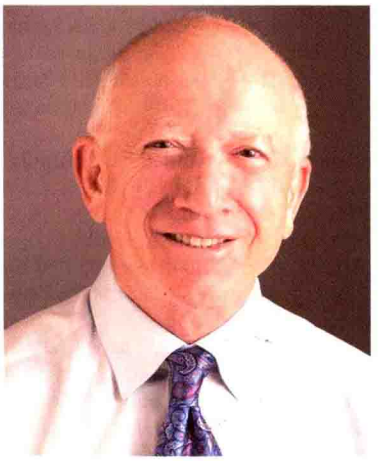
He has served in leadership roles for various dental organizations, including chair of the International Federation of Endodontic Associations' Research Committee, member on committees of the American Association of Endodontists, European Society of Endodontology, and as scientific reviewer for international endodontic and dental journals. He has also served as president of the Southern California Academy of Endodontists, Israel Endodontic Society, International Association for Dental Research—Israel Division, and chair of the Israel National Board of Diplomates in Endodontics.

Dr. Rotstein has published more than 150 scientific papers and research abstracts in the dental literature as well as chapters in international endodontic textbooks, including *Pathways of the Pulp*, *Ingle's Endodontics*, *Endodontics: Principles and Practice*, *Seltzer and Bender's Dental Pulp*, and *Harty's Endodontics in Clinical Practice*. He has lectured extensively in more than 25 countries throughout 5 continents.



Stephen Cohen
MA, DDS, FICD, FACD

The field of endodontics would be difficult to imagine without *Pathways of the Pulp*. In speaking with colleagues across North America and around the world, it becomes clear that *Pathways* has had an immense, ubiquitous, and persistent impact on endodontics. This enduring contribution to our specialty is due to the genius of Stephen Cohen, who, together with Richard Burns, developed the most distinguished and perpetually updated evidenced-based textbook in our specialty. Their insight was to form a collaboration of the most renowned experts in our field, with expansion of the authorships for each new edition, and with an unwavering emphasis on the art and science of contemporary endodontic therapy. The result was a textbook that is both comprehensive and nuanced, which has transcended 11 editions and 14 languages since 1976. As each edition of *Pathways* evolved, it changed with the times, updating from unquestionable dogma into what was later considered the novel state of the art. Each edition progressed through the decades of endodontics and was inclusive of the next generation of technologies, philosophies, materials, devices, and instruments. As a result, with Steve as the lead editor since its inception, *Pathways of the Pulp* is considered the most comprehensive and innovative endodontic textbook available, literally defining the field of endodontics.

Stephen is an active educator, having lectured for decades around the world and serving as a Clinical Professor of Endodontics at the Arthur A. Dugoni School of Dentistry of the University of the Pacific. His passion for teaching, coupled with his distinctive authoritative voice and his vast scientific and clinical expertise, generates a highly effective combination for educating students on every facet of the endodontic specialty. His steadfast commitment in his authoring and editing of *Pathways of the Pulp* has propelled this textbook into what it is today.

In short, Dr. Stephen Cohen is a renaissance man, being both a practitioner and a teacher, whose breadth of expertise is leveraged by a passionate focus on detail and clarity. Defined by his unquestionable ethics and pursuit of perfection, Stephen's philosophy of learning, teaching, and practicing endodontics can best be summed up in his own words, as he penned in the Introduction of his last edition of *Pathways*:

"As clinicians we must meet this rich convergence of discovery and invention with an equally rich commitment to continuous learning, exposing ourselves to all the science our field has to offer. This is our duty to our founders, this is our responsibility to our patients, and this is our gift to ourselves."

Steve is a pioneer who has transformed the field of endodontics. For the tenth edition of this textbook, we recognized his legacy by renaming this textbook *Cohen's Pathways of the Pulp*. We reinforce our esteem appreciation of him by dedicating this eleventh edition to our mentor and friend, Dr. Stephen Cohen.

Kenneth M. Hargreaves and
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New to This Edition

EIGHT NEW CHAPTERS

Chapter 2: Radiographic Interpretation covers imaging modalities, diagnostic tasks in endodontics, three-dimensional imaging, cone beam computed tomography, intraoperative or postoperative assessment of endodontic treatment complications, and more!

Chapter 4: Pain Control looks at two overarching topics: local anesthesia for restorative dentistry and endodontics and analgesics and therapeutic recommendations.

Chapter 11: Evaluation of Outcomes covers the reasons for evaluating treatment outcomes, outcome measurements for endodontic treatment, the outcomes of vital pulp therapy procedures, nonsurgical root canal treatment, nonsurgical retreatment, and surgical retreatment.

Chapter 16: Root Resorption looks at the histological features of root resorption, external inflammatory resorption, external cervical resorption, and internal resorption.

Chapter 19: Managing Iatrogenic Endodontic Events looks at treatment scenarios for eight different iatrogenic events: cervicofacial subcutaneous emphysema, sodium hypochlorite accidents, perforations (nonsurgical), inferior alveolar nerve injury (surgical), sinus perforation, instrument separation, apical extrusion of obturation materials, and ledge formation.

Chapter 21: Cracks and Fractures looks at three categories of cracks and fractures: cracked and fractured cusps, cracked and split teeth, and vertical root fractures, emphasizing the early diagnosis of these conditions.

Chapter 23: Vital Pulp Therapy addresses the living pulp, pulpal response to caries, procedures for generating reparative dentin, indications and materials for vital pulp therapy, MTA applications, treatment recommendations, and more!

Chapter 27: Bleaching Procedures provides a review of internal and external bleaching procedures, their impact on pulpal health/endodontic treatment, with presentations of cases and clinical protocols.

NEW CHAPTER ORGANIZATION

Chapters have been reorganized and grouped into three parts: Part I: *The Core Science of Endodontics*, Part II: *The Advanced Science of Endodontics*, and Part III: *Expanded Clinical Topics*. The seven chapters in Part 1 focus on the core clinical concepts for dental students; the chapters in Parts II and III provide the information that advanced students and endodontic residents and clinicians need to know. In addition, seven additional chapters are included in the online version.

The new organization better reflects the chronology of endodontic treatment.

EXPERT CONSULT

New features included on the Expert Consult site include:

- Seven chapters exclusively online:
  - *Chapter 24: Pediatric Endodontics: Endodontic Treatment for the Primary and Young Dentition*
  - *Chapter 25: Endodontic and Periodontic Interrelationships*
  - *Chapter 26: Effects of Age and Systemic Health on Endodontics*
  - *Chapter 27: Bleaching Procedures*
  - *Chapter 28: Understanding and Managing the Fearful Dental Patient*
  - *Chapter 29: Endodontic Records and Legal Responsibilities*
  - *Chapter 30: Key Principles of Endodontic Practice Management*

- Twelve lecture modules consisting of assigned readings, PowerPoint slides, written objectives for each lecture, and suggested examination questions. Topics covered include:
  - Diagnosis
  - Treatment planning
  - Pain control
  - Isolation
  - Cleaning and shaping
  - Obturation
  - Surgery
  - Assessment of outcomes
  - Pulp biology
  - Pathobiology
  - Emergencies
  - Restoration

- New videos and animations

Introduction

ENDODONTICS: A VIEW OF THE FUTURE

The Editors have had the privilege of "standing on the shoulders" of our generous contributors, enabling us to "look over the horizon" to gain a glimpse at our endodontic future. As we advance into the years ahead, we will incorporate even more refined and accurate improvements in pulpal diagnosis, canal cleaning and disinfection, canal obturation, and surgical enhancements.

In looking more clearly toward our impending endeavors, it becomes important to scrutinize the deficiencies of our past and present. Over the past several decades we have gone from arsenic to sodium hypochlorite, from bird droppings to gutta percha, from hand files to motor-driven files, from culturing to one-visit appointments, from two-dimensional to three-dimensional radiography, and from pulp removal to pulpal regeneration. And still, the clinical and academic controversies are pervasive. So, where will the future of our specialty take us?

With patients living longer and with the inescapable comparison of endodontics to endosseous implants, the demand for endodontic excellence has greatly increased. To that end, we suspect that future evidence-based approaches will continue to question the longevity of successful implant retention, intensifying the need for more predictable endodontic outcomes.

Surprisingly, we still base our diagnosis on a presumed and almost subjective pulpal status. Imagine a future in which endodontic diagnosis could be more objective by non-invasively scanning the pulp tissue. Imagine algorithms built into all digital radiography for interpreting and extrapolating disease processes. CBCT has made a huge impact on endodontic diagnosis, but can we enhance these digital captures with a resolution that would approach micro-computed tomography, and with less radiation? Will non-radiation imaging methods such as MRI (magnetic resonance imaging) leave the dental research clinic to provide a novel solution to address these issues? Will it be CT technology or some other form of detection for dramatically enhancing our guidance during surgical and nonsurgical treatment in order to both maximize our precision and minimize tooth structure and associated tissue removal? Considering the differences in color and consistency of the tissues within the pulp chamber, future technology may permit us to better discriminate these differences and enhance our ability for more precision when negotiating the openings to these canals. And as for clinical visualization: will there be digital or electronic enhancements of conventional loupes? Will 3-D visualization and monitor-based observation change the way we visualize and implement our procedures? During our canal cleaning and shaping, we are lucky if we can debride half of the pulpal tissues within all of the canal ramifications; however, we still use an irrigant that is so toxic by a non-selective mechanism, such that when inadvertently extruded beyond the canal system it can cause severe tissue damage. Our future technology should guide us to obtain the complete removal of organic debris within the pulpal spaces while obtaining complete canal disinfection—and without the potential morbidity from toxic non-selective chemicals. We still use files that can inadvertently separate. The resolution may be in a complete transformation in metallurgy or even the implementation of other non-metal cutting materials. Our obturation material is one of the worst filling materials in dentistry. Hopefully, the future evolution of obturation will lead us to a totally leakage-free, non-neurotoxic, and biocompatible substance that will three-dimensionally expand into *all* microscopic canal ramifications and stop when there is no more space to expand to, being limited to when it reaches the periodontal ligament. Will this obturating material be newly regenerated vital pulp?

Clearly, it is evident that our endodontic future lies in out-of-the-box thinking with the next generation of transformations coming with collaborations not just from within the biological sciences, but rather in conjunction with physicists, chemists, engineers, and a multitude of other great innovative minds. The predictability of endodontics must be incontestable, not just with better technology to guide us toward greater success, but also to better elucidate exactly when endodontics *cannot* be successful. Our future needs to focus on predictability, which will only be achieved by reinventing the wheel with disruptive technologies, rather than persisting with variations and modifications of our current convictions.

As a specialty, we have advanced by leaps and bounds since our inception, but we are still in our infancy with a brilliant future ahead of us. Since 1976 and with 11 editions, *Pathways of the Pulp* has always been about the art and science of endodontics. The dedicated contributing authors have generously given their time to meticulously describe what is considered the state of the art of our specialty. We are hopeful that future editions will guide us toward enhanced endodontic outcomes, with the never-ending pursuit of endodontic excellence.

Contents

PART I

The Core Science of Endodontics

CHAPTER 1

Diagnosis

LOUIS H. BERMAN | ILAN ROTSTEIN

CHAPTER OUTLINE

ART AND SCIENCE OF DIAGNOSIS

Diagnosis is the art and science of detecting and distinguishing deviations from health and the cause and nature thereof.[6] The purpose of a diagnosis is to determine what problem the patient is having and why the patient is having that problem. Ultimately, this will directly relate to what treatment, if any, will be necessary. No appropriate treatment recommendation can be made until all of the *whys* are answered. Therefore, careful data gathering as well as a planned, methodical, and systematic approach to this investigatory process is crucial.

Gathering objective data and obtaining subjective findings are not enough to formulate an accurate clinical diagnosis. The data must be interpreted and processed to determine what information is significant, and what information might be questionable. The facts need to be collected with an active dialogue between the clinician and the patient, with the clinician asking the right questions and carefully interpreting the answers. In essence, the process of determining the existence of an oral pathosis is the culmination of the art and science of making an accurate diagnosis.

The process of making a diagnosis can be divided into five stages:

1. The patient tells the clinician the reasons for seeking advice.
2. The clinician questions the patient about the symptoms and history that led to the visit.
3. The clinician performs objective clinical tests.
4. The clinician correlates the objective findings with the subjective details and creates a tentative list of differential diagnoses.
5. The clinician formulates a definitive diagnosis.

This information is accumulated by means of an organized and systematic approach that requires considerable clinical judgment. The clinician must be able to approach the problem by crafting what questions to ask the patient and how to ask these pertinent questions. Careful listening is paramount to begin painting the picture that details the patient's complaint. These subjective findings combined with results of diagnostic tests provide the critical information needed to establish the diagnosis.

Neither the art nor the science is effective alone. Establishing a differential diagnosis in endodontics requires a unique blend of knowledge, skills, and ability to interpret and interact with a patient in real time. Questioning, listening, testing, interpreting, and finally answering the ultimate question of *why* will lead to an accurate diagnosis and in turn result in a more successful treatment plan.

Chief Complaint

On arrival for a dental consultation, the patient should complete a thorough registration that includes information pertaining to medical and dental history (Figs. 1-1 and 1-2). This should be signed and dated by the patient, as well as initialed by the clinician as verification that all of the submitted information has been reviewed (see Chapter 29 for more information).

The reasons patients give for consulting with a clinician are often as important as the diagnostic tests performed. Their remarks serve as initial important clues that will help the clinician to formulate a correct diagnosis. Without these direct and unbiased comments, objective findings may lead to an incorrect diagnosis. The clinician may find a dental pathosis, but it may not contribute to the pathologic condition that mediates the patient's chief complaint. Investigating these complaints may indicate that the patient's concerns are related to a medical condition or to recent dental treatment. Certain patients may

TELL US ABOUT YOUR SYMPTOMS

LAST NAME _____ **FIRST NAME** _____

1. Are you experiencing any pain at this time? If not, please go to question 6. Yes _____ No _____

2. If yes, can you locate the tooth that is causing the pain? Yes _____ No _____

3. When did you first notice the symptoms? _____

4. Did your symptoms occur suddenly or gradually? _____

5. Please check the frequency and quality of the discomfort, and the number that most closely reflects the intensity of your pain:

LEVEL OF INTENSITY (On a scale of 1 to 10) 1 = Mild 10 = Severe	FREQUENCY	QUALITY
1___2___3___4___5___6___7___8___9___10___	_____ Constant	_____ Sharp
	_____ Intermittent	_____ Dull
	_____ Momentary	_____ Throbbing
	_____ Occasional	

Is there anything you can do to relieve the pain? Yes _____ No _____

If yes, what? _____

Is there anything you can do to cause the pain to increase? Yes _____ No _____

If yes, what? _____

When eating or drinking, is your tooth sensitive to: Heat _____ Cold _____ Sweets _____

Does your tooth hurt when you bite down or chew? Yes _____ No _____

Does it hurt if you press the gum tissue around this tooth? Yes _____ No _____

Does a change in posture (lying down or bending over) cause your tooth to hurt? Yes _____ No _____

6. Do you grind or clench your teeth? Yes _____ No _____

7. If yes, do you wear a night guard? Yes _____ No _____

8. Has a restoration (filling or crown) been placed on this tooth recently? Yes _____ No _____

9. Prior to this appointment, has root canal therapy been initiated on this tooth? Yes _____ No _____

10. Is there anything else we should know about your teeth, gums, or sinuses that would assist us in our diagnosis? _____

Signed: Patient or Parent _____ **Date** _____

FIG. 1-1 Dental history form that also allows the patient to record pain experience in an organized and descriptive manner.

TELL US ABOUT YOUR HEALTH

LAST NAME _____ **FIRST NAME** _____

How would you rate your health? Please circle one. Excellent Good Fair Poor

When did you have your last physical exam? _____

If you are under the care of a physician, please give reason(s) for treatment.

_____

Physician's Name, Address, and Telephone Number:

Name _____ Address _____

City _____ State _____ Zip _____ Telephone _____

Have you ever had any kind of surgery? Yes _____ No _____

If yes, what kind? _____ Date _____

_____ Date _____

Have you ever had any trouble with prolonged bleeding after surgery? Yes _____ No _____

Do you wear a pacemaker or any other kind of prosthetic device? Yes _____ No _____

Are you taking any kind of medication or drugs at this time? Yes _____ No _____

If yes, please give name(s) of the medicine(s) and reason(s) for taking them:

Name _____ Reason _____

_____ _____

Have you ever had an unusual reaction to an anesthetic or drug (like penicillin)? Yes _____ No _____

If yes, please explain: _____

Please circle any past or present illness you have had:

Alcoholism	Blood pressure	Epilepsy	Hepatitis	Kidney or liver	Rheumatic fever
Allergies	Cancer	Glaucoma	Herpes	Mental	Sinusitis
Anemia	Diabetes	Head/Neck injuries	Immunodeficiency	Migraine	Ulcers
Asthma	Drug dependency	Heart disease	Infectious diseases	Respiratory	Venereal disease

Are you allergic to Latex or any other substances or materials? Yes _____ No _____

If so, please explain _____

If female, are you pregnant? Yes _____ No _____

Is there any other information that should be known about your health? _____

_____

Signed: Patient or Parent _____ Date: _____

FIG. 1-2 Succinct, comprehensive medical history form designed to provide insight into systemic conditions that could produce or affect the patient's symptoms, mandate alterations in treatment modality, or change the

even receive initial emergency treatment for pulpal or periapical symptoms in a general hospital.[93] On occasion, the chief complaint is simply that another clinician correctly or incorrectly advised the patient that he or she had a dental problem, with the patient not necessarily having any symptoms or any objective pathosis. Therefore, the clinician must pay close attention to the actual expressed complaint, determine the chronology of events that led to this complaint, and question the patient about other pertinent issues, including medical and dental history. For future reference and in order to ascertain a correct diagnosis, the patient's chief complaint should be properly documented, using *the patient's own words*.

Medical History

The clinician is responsible for taking a proper medical history from every patient who presents for treatment. Numerous examples of medical history forms are available from a variety of sources, or clinicians may choose to customize their own forms. After the form is completed by the patient, or by the parent or guardian in the case of a minor, the clinician should review the responses with the patient, parent, or guardian and then initial the medical history form to indicate that this review has been done. The patient "of record" should be questioned at each treatment visit to determine whether there have been any changes in the patient's medical history or medications. A more thorough and complete update of the patient's medical history should be taken if the patient has not been seen for over a year.[51,52]

Baseline blood pressure and pulse should be recorded for the patient at each treatment visit. Elevation in blood pressure or a rapid pulse rate may indicate an anxious patient who may require a stress reduction protocol, or it may indicate that the patient has hypertension or other cardiovascular health problems. Referral to a physician or medical facility may be indicated. It is imperative that vital signs be gathered at each treatment visit for any patient with a history of major medical problems. The temperature of patients presenting with subjective fever or any signs or symptoms of a dental infection should be taken.[57,80,105]

The clinician should evaluate a patient's response to the health questionnaire from two perspectives: (1) those medical conditions and current medications that will necessitate altering the manner in which dental care will be provided and (2) those medical conditions that may have oral manifestations or mimic dental pathosis.

Patients with serious medical conditions may require either a modification in the manner in which the dental care will be delivered or a modification in the dental treatment plan (Box 1-1). In addition, the clinician should be aware if the patient has any drug allergies or interactions, allergies to dental products, an artificial joint prosthesis, organ transplants, or is taking medications that may negatively interact with common local anesthetics, analgesics, sedatives, and antibiotics.[80] This may seem overwhelming, but it emphasizes the importance of obtaining a thorough and accurate medical history while considering the various medical conditions and dental treatment modifications that may be necessary before dental treatment is provided.

Several medical conditions have oral manifestations, which must be carefully considered when attempting to arrive at an accurate dental diagnosis. Many of the oral soft tissue changes that occur are more related to the medications used to treat the medical condition rather than to the condition itself. More common examples of medication side effects are stomatitis, xerostomia, petechiae, ecchymoses, lichenoid mucosal lesions, and bleeding of the oral soft tissues.[80]

When developing a dental diagnosis, a clinician must also be aware that some medical conditions can have clinical presentations that mimic oral pathologic lesions.[13,28,32,74,80,102,107,133] For example, tuberculosis involvement of the cervical and submandibular lymph nodes can lead to a misdiagnosis of lymph node enlargement secondary to an odontogenic infection. Lymphomas can involve these same lymph nodes.[80] Immunocompromised patients and patients with uncontrolled diabetes mellitus respond poorly to dental treatment and may exhibit recurring abscesses in the oral cavity that must be differentiated from abscesses of dental origin.[43,76,80,83] Patients with iron deficiency anemia, pernicious anemia, and leukemia frequently exhibit paresthesia of the oral soft tissues. This finding may complicate making a diagnosis when other dental pathosis is present in the same area of the oral cavity. Sickle cell anemia has the complicating factor of bone pain, which mimics odontogenic pain, and loss of trabecular bone pattern on radiographs, which can be confused with radiographic lesions of endodontic origin. Multiple myeloma can result in unexplained mobility of teeth. Radiation therapy to the head and neck region can result in increased sensitivity of the teeth and osteoradionecrosis.[80] Trigeminal neuralgia, referred pain from cardiac angina, and multiple sclerosis can also mimic dental pain (see also Chapter 17). Acute maxillary sinusitis is a common condition that may create diagnostic confusion because it may mimic tooth pain in the maxillary posterior quadrant. In this situation the teeth in the quadrant may be extremely sensitive to cold and percussion, thus mimicking the signs and symptoms of pulpitis. This is certainly not a complete list of all the medical entities that can mimic dental disease, but it should alert the clinician that a medical problem could confuse and complicate

BOX 1-1

Medical Conditions That Warrant Modification of Dental Care or Treatment

Cardiovascular: High- and moderate-risk categories of endocarditis, pathologic heart murmurs, hypertension, unstable angina pectoris, recent myocardial infarction, cardiac arrhythmias, poorly managed congestive heart failure[57,80,105]

Pulmonary: Chronic obstructive pulmonary disease, asthma, tuberculosis[80,129]

Gastrointestinal and renal: End-stage renal disease; hemodialysis; viral hepatitis (types B, C, D, and E); alcoholic liver disease; peptic ulcer disease; inflammatory bowel disease; pseudomembranous colitis[25,34,48,80]

Hematologic: Sexually transmitted diseases, HIV and AIDS, diabetes mellitus, adrenal insufficiency, hyperthyroidism and hypothyroidism, pregnancy, bleeding disorders, cancer and leukemia, osteoarthritis and rheumatoid arthritis, systemic lupus erythematosus[35,43,76,80,83,88,100,135]

Neurologic: Cerebrovascular accident, seizure disorders, anxiety, depression and bipolar disorders, presence or history of drug or alcohol abuse, Alzheimer disease, schizophrenia, eating disorders, neuralgias, multiple sclerosis, Parkinson disease[36,44,80]