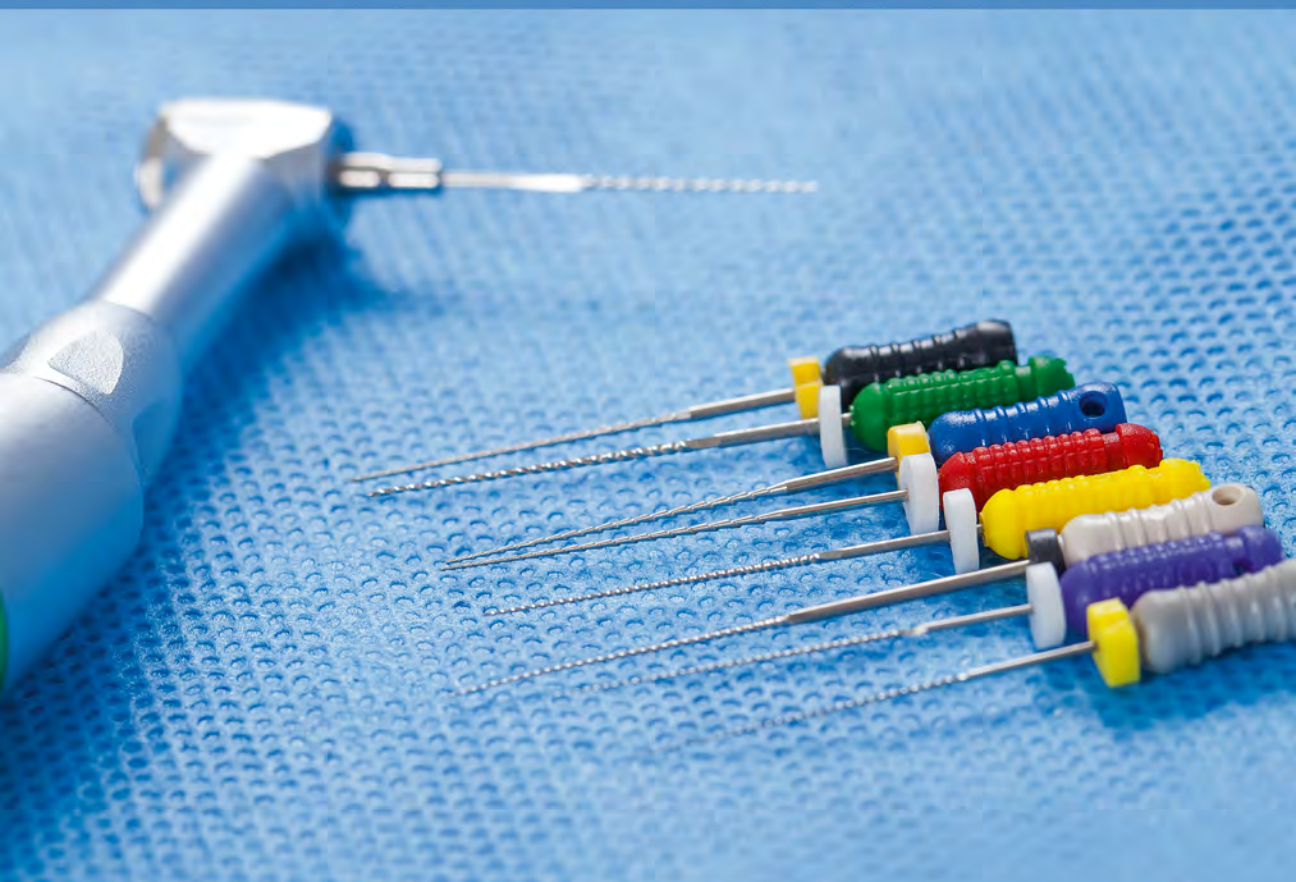


# Endodontics Review

SECOND EDITION



Brooke Blicher, DMD | Rebekah Lucier Pryles, DMD | Jarshen Lin, DDS



Endodontics Review, *Second Edition*





## Dedication

*This book is dedicated to Drs Daniel Green and Robert Amato, great mentors and educators who inspired our pursuit of excellence and love of evidence-based endodontics. May you all find your Drs Green and Amato.*



One book, one tree: In support of reforestation worldwide and to address the climate crisis, for every book sold Quintessence Publishing will plant a tree (<https://onetreplanted.org/>).

Library of Congress Control Number: 2022943270

A CIP record for this book is available from the British Library.  
ISBN: 9780867158311



© 2022 Quintessence Publishing Co, Inc

Quintessence Publishing Co, Inc  
411 N Raddant Road  
Batavia, IL 60510  
[www.quintpub.com](http://www.quintpub.com)

5 4 3 2 1

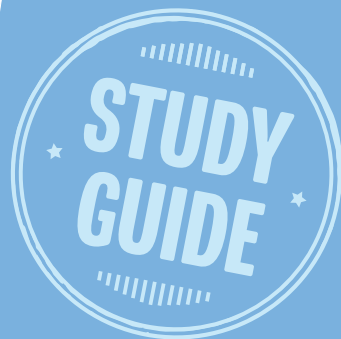
All rights reserved. This book or any part thereof may not be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, or otherwise, without prior written permission of the publisher.

Editor: Zach Kocanda  
Design: Sue Zubek  
Production: Angelina Schmelter

Printed in Croatia

# Endodontics Review

SECOND EDITION



## Brooke Blicher, DMD

Private Practice Limited to Endodontics  
White River Junction, Vermont

Clinical Instructor, Department of Restorative  
Dentistry and Biomaterials Sciences  
Harvard School of Dental Medicine

Assistant Clinical Professor  
Department of Endodontics  
Tufts University School of Dental Medicine  
Boston, Massachusetts

Instructor in Surgery  
Geisel School of Medicine at Dartmouth  
Hanover, New Hampshire

## Rebekah Lucier Pyles, DMD

Private Practice Limited to Endodontics  
White River Junction, Vermont

Assistant Clinical Professor  
Department of Endodontics  
Tufts University School of Dental Medicine

Clinical Instructor, Department of Restorative  
Dentistry and Biomaterials Sciences  
Harvard School of Dental Medicine  
Boston, Massachusetts

## Jarshen Lin, DDS

Director of Predoctoral Endodontics  
Department of Restorative Dentistry and  
Biomaterials Sciences  
Harvard School of Dental Medicine

Clinical Associate, Department of Surgery  
Division of Dentistry  
Massachusetts General Hospital  
Boston, Massachusetts



QUINTESSENCE PUBLISHING

Berlin | Chicago | Tokyo

Barcelona | London | Milan | Mexico City | Paris | Prague | Seoul | Warsaw

Beijing | Istanbul | Sao Paulo | Zagreb



# Contents

Preface *vi*

**1 Evidence-Based Dentistry 1**

**2 Microbiology 11**

**3 Pulpal and Periapical Anatomy  
and Physiology 29**

**4 Pulpal and Periapical Pathology 52**

**5 Medicine and Pharmacology 77**

**6 Diagnosis 105**

**7 Diagnosis of Non-Endodontic  
Disease Entities 132**



- 8 Treatment of Pulpal and Periapical Disease 150**
- 9 Traumatic Dental Injuries 226**
- 10 Cracked and Fractured Teeth 257**
- 11 Resorptive Dental Diseases 271**
- 12 Prognosis 288**
- 13 Complications 308**
- Index 333**



# Preface

We are pleased to offer the second edition of what became known as “The Orange Book” in certain circles to those seeking a literature-based discussion of endodontics. Whether this book will supplement your predoctoral or postdoctoral endodontics curriculum or guide self-study in general dental or specialty practice, we are proud to share the evidence-based *why* behind the diagnosis and delivery of endodontic care.

Evidence-based endodontics evolves as the literature changes. As new literature is published, including updated position statements and guidelines, practitioners must adapt their clinical practice. Many important updates have occurred in the field of endodontics research and clinical practice since the first edition was published in 2016. These updates have been incorporated into this second edition. That said, as the literature continues to advance, we encourage readers to stay abreast of changes to ensure delivery of the most up-to-date, evidence-based clinical care. This text provides the foundation to pursue this necessary continued self-study.



1

# Evidence-Based Dentistry

The practice of evidence-based dentistry requires that providers make treatment decisions based on a comprehensive and constantly evolving evaluation of the bodies of research and literature in their field. Practitioners must sift through the available resources with a discerning eye.

They must be able to justify their decisions and recommendations based on the highest-quality evidence available. Research published in peer-reviewed journals is considered to be unbiased and therefore most useful. Although textbooks and lectures are effective means of disseminating information, quality versions of these resources will refer back to primary resources in peer-reviewed journals. Consequently, it is imperative that providers familiarize themselves with the primary references cited in all examples. This chapter covers study design, measures of statistical significance and validity, and epidemiology. For a more in-depth review of research design and biostatistics, please refer to Hulley et al's *Designing Clinical Research* and Glaser's *High-Yield Biostatistics, Epidemiology, and Public Health*.



## Study Design

Beyond citing peer-reviewed journals as the ideal reference source, certain study designs are generally considered more scientifically sound. The Oxford Centre for Evidence-Based Medicine (OCEBM) outlines a hierarchy of levels of evidence by study design, illustrated in Fig 1-1.



**Fig 1-1** OCEBM hierarchy of levels of evidence by study design.

Systematic reviews, including meta-analyses, are considered the highest level of evidence, and their quality improves based on the compiled levels of evidence of the studies reviewed. Systematic reviews involve a comprehensive search and review of all of the literature on a topic, whereas a meta-analysis delves deeper by doing statistical analyses to make direct comparisons between studies. Depending on the variability of the statistics reported in the literature available on a topic, a meta-analysis may not be achievable.

Further algorithm-based criteria exist for rating the quality of evidence compiled in a systematic review or meta-analysis. The strength of recommendation taxonomy (SORT) grading system evaluates and categorizes systematic reviews and evidence-based clinical guidelines based on the quality, quantity, and consistency of the evidence included (Newman et al). Similarly, the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) system aims to summarize evidence addressing a question for use in producing systematic reviews and guidelines (Guyatt et al). Whether or not one of the above algorithms is included in a systematic review, it behooves the reader to take into account the quality of literature reviewed.

The Cochrane Collaborative produces systematic reviews that can be considered the gold standard for evidence-based medicine. The reviews are constantly updated with post-publication peer review and a strong conflict of interest policy. They may contain meta-analysis when homogenous data is available for comparison among the studies reviewed. Efforts are made by the Cochrane authors to focus on randomized controlled trials when possible to reduce effects of known and unknown confounders

as well as publication bias. If a Cochrane Review is available on a subject, its conclusions are considered the ultimate evidence-based take on a topic.

Beyond reviews, randomized controlled trials are considered the highest level of evidence when considering clinical research studies (OCEBM). Randomized controlled trials involve a planned intervention on a diseased population with matched controls. These studies are both resource- and time-intensive and are consequently difficult to perform. Furthermore, ethical concerns often arise in the discussion of this study type. Prior knowledge of superior intervention outcomes cannot be denied to a diseased population, and it is considered unethical to study certain populations, such as children or the disabled.

Cohort studies are considered next best among the levels of evidence hierarchy (OCEBM). Cohort studies are prospective and longitudinal, and they measure the incidence of new cases of a disease while assessing risk or protective factors. These types of studies can be resource-intensive and are not practical for rare outcomes.

Case-control studies follow cohort studies in the OCEBM hierarchy. This type of study compares past risk factors and exposures of cases with disease and controls without disease in a retrospective fashion. These studies are often less expensive to perform, less time-intensive, and can be useful to study rare outcomes. They are considered lower quality due to recall bias, difficulties with misdiagnosis, and assignment of controls.

Publications of case series or case reports represent the second-lowest level of evidence for observational studies (OCEBM). They involve a simple presentation of an outcome without provision of a control. Their importance comes from the introduction of novel disease presentations or treatments for further investigation.

Lastly, expert opinions offer the lowest level of evidence. Their utility is limited in the justification of evidence-based diagnosis and treatment. Rather, they serve to introduce innovation and new techniques, as clinical empiricism is oftentimes the starting point for further higher-level research.

## Statistics

Although a comprehensive review of biostatistics will not be addressed in this textbook, a review of the more commonly encountered concepts in biostatistics, particularly those encountered in later parts of this text, is presented here. Readers are encouraged to seek out further resources, particularly if questions arise during the reading of primary references.

## Measures of statistical significance

The ultimate goal of research is to test a hypothesis. Although absolute statements regarding proof or disproof of a hypothesis cannot be made based on limited populations and study parameters, researchers look to determine the likelihood that results support the hypothesis. Similarly, determination of cause and effect is extremely difficult to prove, requiring large-scale randomized controlled trials with longitudinal

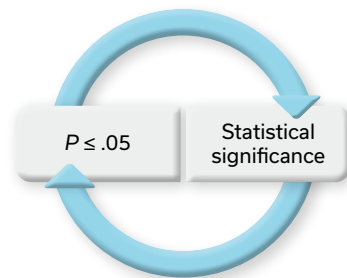
# 1 Evidence-Based Dentistry

follow-ups. Most studies fall short of determining causation but can identify associations or relationships between two factors. It is important in quoting literature to never overstate results.

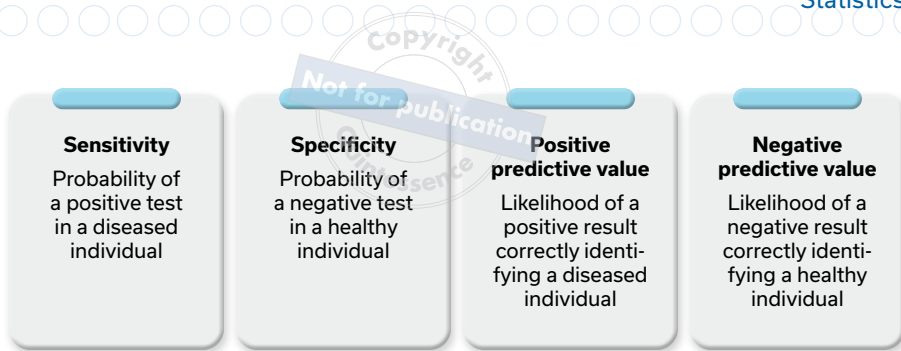
One way researchers can increase the odds of obtaining statistically significant results is to ensure that the sample population under study is both large and diverse enough to demonstrate outcomes. Although successful endodontic practice does not require an intimate understanding of the methods researchers use to determine the adequacy of sample sizes, familiarity with the concept of power to rule out errors in hypothesis testing is imperative. Well-designed research studies involve power calculations to ensure adequate sample sizes, and in critical review of literature articles, one should note if appropriate power calculations were made to justify the use of a particular sample size.

It is clear that the best means of measuring any parameter would be to draw data from every possible member of a population. As this is not realistic, study designs aim to draw a random sample that will be representative of the whole population. The larger the sample size, the more representative it will be of the varying parameters of the whole population. Sample size is inversely related to the likelihood for error (Glaser). Confidence limits, oftentimes described as a range between values called the *confidence interval*, are a means of inferring the likely range of a parameter factoring in possible errors related to a sample not being truly random and therefore representative of the whole population. The narrower the confidence interval, the more likely results are accurate, and the only way to narrow this is to increase sample size.

With samples selected and the experiment performed, results must be analyzed to determine their statistical relevance. The most common measure of statistical significance encountered in the endodontic literature is the *P value*. The *P value* refers to the likelihood of the outcome having occurred by chance. A *P value* less than or equal to .05 generally indicates statistical significance (Fig 1-2). In other words, with a *P value* of less than .05, the probability that the study results were obtained by chance is less than 5%. For example, in a retrospective case-control study performed by Spili et al investigating the outcomes of teeth with and without fractured nickel-titanium instruments, success was found in 91.8% of cases with retained fractured instruments compared with 94.5% success in controls. Statistical analysis using the Fisher exact test, a tool used to determine deviation from a null hypothesis, resulted in a *P value* of .49. This corresponds to a 49% chance that the difference in healing rates was due to chance. As the authors set the significance value at  $P = .05$ , the difference in healing rates obtained from the study was deemed statistically insignificant. In other words, the authors cannot prove that instrument separation led to a worse outcome.



**Fig 1-2** The relationship between *P value* and statistical significance. The *P value* describes the probability that results occurred by chance.



**Fig 1-3** The validity measures often encountered in the endodontic literature.

### Measures of validity

When new testing modalities are compared to the current standard, the validity or accuracy of the new approach must be verified. Sensitivity, specificity, and predictive values provide the means by which validity can be confirmed (Fig 1-3). These values are often encountered in descriptions of pulp sensitivity tests. Mainkar and Kim’s systematic review and meta-analysis on the diagnostic accuracy of varying pulp sensitivity and vitality testing methodologies provides an excellent example in the discussion of validity measures.

Understanding validity measures requires familiarity with the concepts of both true positive and negative results and false positive and negative results (Table 1-1). True positive and negative results correctly identify individuals as diseased or healthy. False positive and negative results incorrectly identify the individual’s disease status.

*Sensitivity* is defined as the ability of a test to detect diseased individuals. It is calculated by comparing the number of true positives detected by the test with the total number of diseased subjects, including the true positives plus false negatives. In Mainkar and Kim’s meta-analysis, they found that laser Doppler flowmetry (LDF) was the most accurate means of diagnostic testing, whereas heat testing was the least accurate means. Pooled sensitivity was 0.98 for LDF and 0.78 for heat testing. In other words, LDF correctly identified teeth with pulp necrosis 98% of the time, whereas heat testing only did so 78% of the time (Mainkar and Kim).

*Specificity* is defined as the ability of a test to correctly identify a healthy individual. It is calculated by comparing the number of true negatives detected by the test with the total number of nondiseased subjects, including the true negatives and false positives. In Mainkar and Kim’s meta-analysis, pooled specificity was 0.95 for LDF and 0.67 for heat testing. In other words, LDF correctly identified vital teeth 95% of the time, whereas heat testing only did so 67% of the time (Mainkar and Kim).

**Table 1-1 The possible outcomes of a test**

Test result	Disease present	Disease absent
Positive	True positive	False positive
Negative	False negative	True negative

## 1 Evidence-Based Dentistry

Predictive values describe the likelihood of the test to correctly identify health or disease. The *positive predictive value* is calculated as the proportion of true positives compared with positive results. The *negative predictive value* is calculated as the proportion of true negatives compared with negative results. Mainkar and Kim found positive predictive values of 0.94 versus 0.62 and negative predictive values of 1.00 versus 0.79 for LDF and heat testing, respectively. In other words, with LDF, a positive result (ie, no flow) corresponded to pulp necrosis 94% of the time, and a negative result (ie, flow) indicated the presence of vital pulp tissue 100% of the time, whereas with heat testing, a positive result (ie, no response to heat) correctly identified pulp necrosis only 62% of the time, and a negative result (ie, a response to heat) correctly identified vital pulp tissue only 79% of the time (Mainkar and Kim).

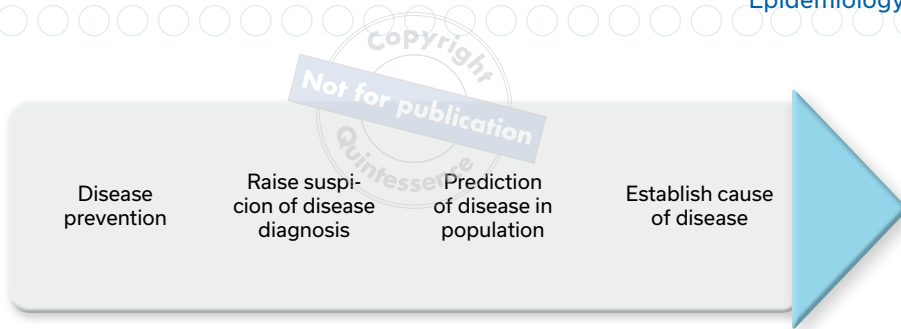
### Measures of risk

Development of evidence to support any particular practice in medicine and dentistry relies largely on the determination of certain risk factors for a disease or outcome (Fig 1-4). Knowledge of a risk factor can aid practitioners in diagnosing disease, preventing disease, predicting future incidence and prevalence of a disease, and even establishing the cause of a disease (Glaser) (Fig 1-5). The measures of risk—including relative risk, attributable risk, and odds ratio—all measure the effect of being exposed to a risk factor on the risk of experiencing a particular outcome. The particular type of risk measurement used is study dependent.

*Relative risk* states how many times exposure to the risk factor itself increases the chance of a particular outcome (Glaser). Numbers needed to treat (NNT) is a derivative of relative risk, measuring risk reduction by an intervention, and allows for comparison of different treatments. As an example, the Oxford Pain Group League table showed that 800 mg ibuprofen provided demonstrably superior pain relief in the treatment of acute apical abscess or symptomatic apical periodontitis compared to other oral analgesics (Richards). In a meta-analysis compiling high-quality data from numerous other studies, they reported an NNT of 1.6 for 800 mg ibuprofen versus 2.2 for both combinations of 60 mg codeine per 1,000 mg acetaminophen and 5 mg oxycodone per 500 mg acetaminophen. In other words, 1.6 patients needed to be treated with 800 mg ibuprofen to achieve 50% pain reduction, whereas 2.2 patients needed to be treated with the narcotic preparations to achieve the same results (Richards). Ibuprofen is therefore a better drug for reducing the risk of endodontic pain. *Attributable risk* states the additional incidence of an outcome that is attributable to the risk factor in question and is determined by subtracting the incidence of disease in



**Fig 1-4** The relationship between risk factors and disease.



**Fig 1-5** The importance of establishing risk factors.

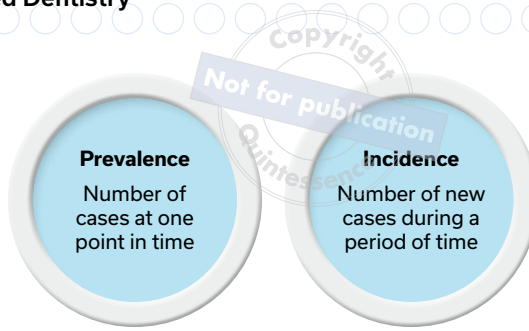
nonexposed patients from that in exposed patients. It is equivalent to the difference in *absolute risk* between the two groups.

Both relative risk and attributable risk can be determined utilizing prospective cohort studies (Glaser). As previously discussed, these studies are not always feasible due to cost, time required, and their inefficiency in looking at rare outcomes. Therefore, retrospective case-control studies, wherein subjects with disease are compared to matched subjects without, are oftentimes more feasible. If a higher proportion of subjects with disease were exposed to a certain risk factor than those without disease, that risk factor can be associated with the disease.

*Odds ratio* is the measure of this proportional risk, comparing the odds that a case was exposed to the risk factor to the odds that a control was exposed to the same risk factor. An odds ratio of 1 indicates that a case is no more likely to have been exposed to the risk factor than a control and suggests that the risk factor is not associated with the disease. An odds ratio of greater than 1 suggests that the risk factor is associated, and an odds ratio of less than 1 suggests that the factor may, in fact, be protective. As an example, Sim et al found that pulpal floor fractures were associated with tooth loss. They reported an odds ratio of 11, meaning that teeth with pulpal floor fractures were 11 times more likely to be lost in the 5 years following treatment than teeth without identifiable pulpal floor fractures.

## Epidemiology

Epidemiology involves the study of health and disease in populations. Descriptive statistics are used in epidemiology to determine the impact of health or disease measures on the population under study. Commonly reported descriptive statistics include both prevalence and incidence (Fig 1-6). *Prevalence* refers to the total number of people affected by a disease at a particular time point. *Incidence* refers to the number of new disease cases arising during a defined period of time.



**Fig 1-6** Descriptive statistics often encountered in the endodontic literature.

For example, Eriksen et al reviewed several European studies that reported the prevalence of apical periodontitis with a range from 26% to 70%. In other words, screening via periapical radiographs found that between 26% and 70% of patients sampled at one point in time had apical periodontitis. An additional example is found in a study by Lipton et al, which reported a 12% incidence of toothache in the US population in the preceding 6 months. Prevalence is a good measure for apical periodontitis because it develops slowly over a long time period, wherein it might be difficult to truly detect new cases. Incidence is a better measure for toothache because it generally has a rapid onset and decline, so a point-in-time assessment might miss many cases.

Epidemiologic methods can be used to measure the economic burden of a disease. Rampa et al investigated the economics of hospital visits related to periapical abscess (PA) via a retrospective analysis of the Nationwide Emergency Department Sample, a stratified database of hospital emergency department (ED) discharges in the United States. They found that the incidence of ED visits increased from 460,260 in 2008 to 545,693 in 2014. The mean charge for each patient discharged directly from the ED was \$1,080.50, totaling \$3.4 billion across the United States. When these patients were hospitalized following their PA-related ED visit, the mean hospitalization charges were \$34,245, totaling \$5.7 billion across the United States. The majority of these patients were uninsured (40%) or insured by state-run Medicaid (30%). Following this trend, Roberts et al reported a 2% incidence of dental diagnostic codes in patients visiting EDs in the United States, higher among patients with Medicaid than commercial insurance and highest among those aged 18 to 34 years.

## Prognosis

Success rates of therapy are frequently utilized to justify treatment choices. Chapter 12 presents an in-depth discussion of endodontic success rates. Success can have multiple definitions depending on the context, and it is important to understand how each study defines success. Oftentimes, a distinction can be made between *success*, defined as the absence of symptoms and periapical pathology found on radiographic examination, and *survival*, referring to the absolute presence or absence of the tooth in the mouth without consideration of symptoms or pathology. When

examining primary sources, it is important to understand the authors' definition of success, as results will vary accordingly. Furthermore, the advent of newer imaging modalities like CBCT may alter our future definitions. Wu et al suggested that the lines between success and survival may be blurred once prognosis studies utilizing CBCT imaging become available because CBCT images will inevitably detect more lesions than traditional radiography. Of course, one must recognize that the above discussion, as well as most published research to date, relates to clinician and biology-based outcomes. Newer research in the field of patient-centered outcomes focuses on symptoms and economic factors rather than radiographic or histologic measures of healing (Montero et al, Riordain et al). All considerations are important for a comprehensive understanding of prognosis.

## Bibliography

### Introduction

Glaser AN. High-Yield Biostatistics, Epidemiology, and Public Health, ed 4. Philadelphia: Lippincott Williams & Wilkins, 2014.

Hulley SB, Cummings SR, Browner WS, Grady DG, Newman TB. Designing Clinical Research, ed 5. Philadelphia: Lippincott Williams & Wilkins, 2022.

### Study design

Guyatt GH, Oxman AD, Schünemann HJ, Tugwell P, Knottnerus A. GRADE guidelines: A new series of articles in the *Journal of Clinical Epidemiology*. *J Clin Epidemiol* 2011;64:380-382.

Newman MG, Weyant R, Hujuel P. JEBDP improves grading system and adopts strength of recommendation taxonomy grading (SORT) for guidelines and systematic reviews. *J Evid Based Dent Pract* 2007;7:147-150.

Oxford Centre for Evidence-Based Medicine. OCEBM Levels of Evidence. <https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebml-levels-of-evidence>. Accessed 29 October 2021.

### Statistics

Glaser AN. High-Yield Biostatistics, Epidemiology, and Public Health, ed 4. Philadelphia: Lippincott Williams & Wilkins, 2014.

Mainkar A, Kim SG. Diagnostic accuracy of 5 dental pulp tests: A systematic review and meta-analysis. *J Endod* 2018;44:694-702.

Richards D. The Oxford Pain Group League table of analgesic efficacy. *Evid Based Dent* 2004;5:22-23.

Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. *J Endod* 2005;31:845-850.

### Epidemiology

Eriksen HM, Kirkevang L, Petersson K. Endodontic epidemiology and treatment outcome: General considerations. *Endod Topics* 2002;2:1-9.

Lipton JA, Ship JA, Larach-Robinson D. Estimated prevalence and distribution of reported orofacial pain in the United States. *J Am Dent Assoc* 1993;124:115-121.

Rampa S, Veeratrishul A, Raimondo M, Connolly C, Allareddy V, Nalliah RP. Hospital-based emergency department visits with periapical abscess: Updated estimates from 7 years. *J Endod* 2019;45:250-256.

Roberts RM, Bohm MK, Bartoces MG, Fleming-Dutra KE, Hicks LA, Chalmers NI. Antibiotic and opioid prescribing for dental-related conditions in emergency departments: United States, 2012 through 2014. *J Am Dent Assoc* 2020;151:174-181.



# 1 Evidence-Based Dentistry

## Prognosis

Montero J, Lorenzo B, Barrios R, Albaladejo A, Mirón Canelo JA, López-Valverde A. Patient-centered outcomes of root canal treatment: A cohort follow-up study. *J Endod* 2015;41:1456-1461.

Riordain RN, Glick M, Mashhadani SSAA, et al. Developing a standard set of patient-centred outcomes for adult oral health—An international, cross-disciplinary consensus. *Int Dent J* 2021;71:40-52.

Wu MK, Shemesh H, Wesselink PR. Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment. *Int Endod J* 2009;42:656-666.



# Index

Page numbers followed by “f” indicate figures; those followed by “t” indicate tables

## A

- AAE. *See* American Association of Endodontists.  
AAOMR. *See* American Academy of Oral and Maxillofacial Radiology.  
AAOS. *See* American Academy of Orthopaedic Surgeons.
- Abscess(es)  
apical, 6, 123  
brain, 320–321, 321f  
characteristics of, 24, 89  
historical description of, 15  
immunoglobulin levels in, 63  
microabscesses, 60  
periapical, 8, 320
- Abscess theory, of cyst formation, 66, 66f
- Absolute risk, 7
- Accessory canals, 40f, 40–41
- Acellular cementum, 32
- Acetaminophen, 6, 86, 88, 88t
- Acetylcholinesterase, 33
- Acquired immune system, 58, 59f
- Acquired immunity, 59f
- Actinomyces*, 18
- Actinomycosis, 18, 326
- Acute apical abscess, 6, 123
- Adaptive immune system, 58
- A $\delta$  fibers, 32–33, 46, 59, 108, 132
- Adjunctive irrigation techniques, 164f, 164–165
- Adrenergic nerves, 33
- Aggregatibacter actinomycetemcomitans*, 15
- Aging  
cracked teeth secondary to, 265  
pulpal changes related to, 35–36, 36f
- Air emphysema, 320, 320f
- ALARA principle, 114
- Allergy  
hypersensitivity reactions, 321, 321f  
latex, 322  
local anesthetics, 78
- Allodynia, 111
- Allografts, 180, 180f
- Alloplasts, 180, 180f
- Alveolar bone, 36
- Alveolar fractures, 113, 229, 230–232, 238
- Alveolus, 36
- AM404, 86
- Amalgam, 178–179, 179t
- Amalgam retrofills, 296, 296f
- Ameloblastomas, 67, 143
- American Academy of Oral and Maxillofacial Radiology, 118, 118f
- American Academy of Orthopaedic Surgeons, 84
- American Association of Endodontists  
apexification as defined by, 187  
apexogenesis as defined by, 184  
avulsions and, 250  
Colleagues for Excellence, 79, 82, 118  
cone beam computed tomography indications, 118, 118f  
cracked tooth as defined by, 259  
dental dams, 155  
diagnostic terminology, 122, 122f  
flare-ups as defined by, 323  
fracture classification, 123, 124f, 231f, 326  
fractured tooth as defined by, 259  
implants and, 199  
pulp capping as defined by, 184  
pulp polyp as defined by, 125  
pulpotomy as defined by, 186  
radiographic examination guidelines, 233  
silver points, 173, 173f  
surgical operating microscope, 156  
Trauma Guidelines, 226, 260
- American Dental Association  
code of ethics, 200, 200f  
Council on Scientific Affairs, 81
- $\tau$ -Aminobutyric acid, 89
- Amoxicillin, 83t, 325
- Anachoresis, 13, 58
- Analgesics, 85–88, 88t
- Anemia, 90, 146
- Anesthesia. *See also* Local anesthesia.  
adjunctive techniques, 153–154, 154f  
intraosseous, 319  
mandibular, 152–153  
maxillary, 151  
pain control uses of, 155  
pain source identified using, 112  
palatal, 151  
pulpal, 151  
supplemental, 154

- Anesthesia buffering, 154–155
- Angiotensin converting enzyme 2 receptors, 93
- Ankylosis, 231, 250
- Anterior superior alveolar nerve, 46
- Antibiotic(s)
- after avulsion injuries, 242
  - bacterial resistance to, 81
  - commonly used, 83t
  - contraindications for, 79, 81f
  - dosage of, 82, 83t
  - drug interactions with, 83t
  - flare-up prevention and, 80
  - indications for, 79, 80f
  - pathogen susceptibility to, 81
  - in pregnancy, 95–96
  - prophylactic use of, 82–85, 84f, 181, 325
- Antibiotic pastes, 191–192
- Anticoagulation, 90
- Anticurvature filing technique, 159, 160f
- Anxiolytics, 89
- Apexification, 187f–188f, 187–189, 241, 300
- Apexogenesis, 184, 237, 299f
- Apical abscesses, 6, 123
- Apical foramen
- age-related changes in, 36
  - anatomy of, 40
  - arterial structures in, 34
  - constriction of, 40
  - electronic apex locator for
    - location of, 158
  - major, 40
  - minor, 40
- Apical periodontitis
- asymptomatic, 123
  - autotransplantation for, 297
  - bacteria and, 61–62, 62f, 63f, 228
  - biologic medications for, 92
  - bone resorption in, 64
  - cardiovascular disease and, 91
  - cellular responses in, 62
  - cytokines in, 63–64
  - diabetes and, 93
  - in end-stage renal disease, 96
  - estrogen deficiency and, 95
  - humoral responses in, 63–64
  - ibuprofen for, 6
  - immunomodulator drugs
    - and, 94
  - intentional replantation for, 297–298
  - lymphocytes in, 62
  - maternal, 95
  - nonsurgical root canal therapy
    - outcome affected by, 94, 290
    - outcomes affected by, 290, 293
    - pathology of, 61–62, 62f
    - post-retreatment, 293, 294f
    - post-treatment, 293f, 296f
    - in pregnancy, 95–96
    - prevalence of, 8
    - pulpal disease progression
      - to, 228
    - pulpal necrosis and, 12f, 62f
    - recurrent, 171
    - requirements for, 228, 228f
    - retrograde root canal therapy
      - for, 295
    - smoking and, 96–97
    - symptomatic, 123
  - Apical radiolucencies, 67, 68f, 293f
  - Apical segments, 263
  - Apical surgery, 177, 181, 295–296
  - Apical tissue, 122
  - Archaea, 18
  - Arteriovenous shunts, 35
  - Articaine, 78, 78t, 151, 155, 322–323, 323f
  - As low as reasonably achievable principle. *See* ALARA principle.
  - Asaccharolytic, 17
  - Aspergillus*, 19
  - Asymmetric dimethylarginine, 64
  - Asymptomatic apical periodontitis, 123
  - Atherosclerosis, 91
  - Attributable risk, 6–7
  - Atypical facial pain, 136–138, 137f
  - Atypical odontalgia, 136–137
  - Atypical species, in endodontic infections, 18f, 18–19
  - Augmentin, 83t, 191
  - Autogenous grafts, 180, 180f
  - Autotransplantation, 183–184, 297–298
  - Avulsions
    - description of, 233
    - in immature teeth with closed apex, 245–247
    - in mature teeth with closed apex, 244–245
    - periodontal ligament
      - maintenance in, 242
    - radiographic findings in, 235
    - replantation of, 241–242, 245–246
    - storage of tooth, 242, 242f, 244, 250
    - treatment of, 236t, 241–247, 243f  - Azithromycin, 83t
  - antibiotic resistance by, 81
  - apical periodontitis and, 61–62, 62f, 63f, 228
  - carious, 52
  - Gram-negative, 13, 20
  - Gram-positive, 13, 20
  - isolated species of, 16f, 16–17
  - multiple-visit therapy effects
    - on, 166
    - in periapical lesions, 64–65, 65f
  - Bacteroidetes phylum, 16
  - Bay cysts, 66–67
  - Beam-hardening artifacts, 116, 117f, 119, 262
  - Benzodiazepines, 89, 96
  - β agonists, 34
  - Beta-hemolytic streptococci, 17
  - Bioactive cements, 179, 179t
  - Biofilms, 15, 15f, 162, 326, 326f
  - Biologic width, 196, 196f
  - Bisphosphonate-related osteonecrosis of the jaw, 90
  - Bite testing, of cracked teeth, 265
  - Bitewing radiographs, 113, 113f
  - Biting pain, 111
  - Black-pigmented bacteroides, 17, 18f
  - Bleaching
    - internal, 193–194
    - intracoronaral, 275–276
    - nonvital, 301
  - Blood flow
    - to maxillary teeth, 43, 44f
    - pulpal, 34–36, 56, 59, 59f
  - Blood-forming cells, 36
  - Bone resorption, 64. *See also* Resorption.
  - Borrelia burgdorferi*, 94
  - Botulinum toxin, 134
  - Brain abscess, 320–321, 321f
  - Breast cancer, metastatic, 140, 141f
  - BRONJ. *See* Bisphosphonate-related osteonecrosis of the jaw.
  - Brown tumor, 146
  - Buccal infiltrations, 151, 153
  - Buccal nerve, 46
  - Buccal object rule, 114
  - Buccal space, 22
  - Buccal vestibule, 22
  - Buffering anesthetics, 154–155
  - Bupivacaine, 78t, 152, 155, 181
  - Burs, 172, 177–178, 295, 319
- ## C
- C3, 64
- C fibers, 32–34, 46, 59
- Calcifications, pulp, 141, 142f
- Calcitonin gene-related peptide, 30, 34, 56, 59

- Calcium hydroxide  
 apexification using, 187f, 187–188  
 description of, 17, 238, 250  
 external cervical resorption treated with, 279–280  
 extrusion of, in periapical areas, 316  
 fracture risks, 257  
 interappointment, 264  
 intracanal uses of, 167–168  
 nonsurgical root canal therapy use of, 237  
 stem cells affected by, 191  
 Calcium hydroxide liners, 54, 237  
 Calcium silicate, 184  
 Calcium sulfate, 175  
 Canal isthmuses, 41  
 Cancellous bone, 36  
*Candida albicans*, 19  
 Canine space, 22  
 Canines, 38t–39t  
 Cannabinoid receptors, 86  
 Carbamazepine, 136  
 Cardiac pain, 138  
 Cardiovascular disease, 91  
 Caries  
 pathophysiology of, 52–53, 53f  
 pre-eruptive, 284  
 pulp inflammation caused by, 52–53  
 Carrier-based obturation systems, 169–170, 173  
 Case reports, 3, 284  
 Case series, 3  
 Case-control studies, 3  
 Catechol-O-methyltransferase gene, 109  
 Cause and effect, 3  
 Cavernous sinus thrombosis, 24  
 Cavit, 170  
 CBCT. *See* Cone beam computed tomography.  
 CD4+ T cells, 94  
 CDJ. *See* Cementodentinal junction.  
 Cefaclor, 191  
 CEJ. *See* Cementoenamel junction.  
 Cell(s)  
 apical periodontitis responses by, 62  
 in periapical granulomas, 65–66  
 periapical pathology responses by, 62, 62f  
 pulpal irritant responses by, 60  
 Cellular cementum, 32  
 Cementocytes, 32  
 Cementodentinal junction, 40, 158, 170, 178  
 Cementoenamel junction, 37, 120, 156, 192  
 Cementum  
 age-related changes in, 36  
 formation of, 32  
 tears of, 139, 139f  
 Central incisors, 38t–39t  
 Cephalexin, 83t  
 Cephalosporins, 83t  
 Cervical precementum, 276  
 Cervical root fractures, 257  
 Cervicogenic pain, 138  
 CGRP. *See* Calcitonin gene-related peptide.  
 CH. *See* Calcium hydroxide.  
 Chemotherapeutics, 92  
 Chief complaint, 106  
 Children, traumatic dental injuries in, 226  
 Chlorhexidine gluconate, 163–164, 164f, 167–168, 168f  
 Chloroform, 172  
 Chondroitin sulfate, 32  
 Chronic apical abscess, 123  
 Chronic maxillary sinusitis, 96  
 Chronic renal failure, 96  
 CHX. *See* Chlorhexidine gluconate.  
 Ciprofloxacin, 191  
 Clarithromycin, 83t  
 Clark's rule, 114  
 Clindamycin, 83t, 85  
 Clinical examination, 105–112  
 elements of, 106f  
 objective examination. *See* Objective examination.  
 subjective examination, 106  
 CMV. *See* Cytomegalovirus.  
 Coagulative necrosis, 185  
 Cochrane Collaborative, 2–3  
 Codeine, 6  
 Coefficients of thermal expansion, 265  
 Cohort studies, 3  
 Cold hypersensitivity, of cracked teeth, 265  
 Cold testing, 107–108  
 CollaCote, 175  
 Collagen, 32  
 Collagen fibrils, 31  
 Common carotid artery, 43  
 Complicated fractures, 231–232, 234f, 260  
 Complications  
 air emphysema, 320, 320f  
 allergy, 321–322  
 brain abscess, 320–321, 321f  
 endodontic surgery, 181–182  
 extrusion of materials beyond apex, 316f–317f, 316–318  
 failures, 325–326  
 flare-ups, 323–325. *See also* Flare-ups.  
 instrument separation, 309f–311f, 309–311  
 intraoperative, 119  
 intratreatment, 309–323  
 local anesthesia adverse reactions, 322–323, 323f  
 perforations, 311–314, 312f–314f  
 posttreatment, 323–328  
 regenerative endodontics, 193, 193f  
 sodium hypochlorite accident, 314–315, 315f  
 thermal injuries, 318–319, 319f  
 traumatic dental injuries, 249–251, 252f  
 Comprehensive medical history, 106  
 COMT gene. *See* Catechol-O-methyltransferase gene.  
 Concussion, 232, 234f, 236t, 239, 241  
 Condensing osteitis, 123, 145  
 Cone beam computed tomography  
 advantages of, 115, 117f  
 artifacts on, 116, 117f, 119  
 beam-hardening artifacts on, 116, 117f, 119, 262  
 computer algorithms, 115  
 costs of, 116  
 cracked teeth on, 266  
 description of, 9, 47, 113  
 disadvantages of, 116–117, 117f  
 endodontic failures evaluated with, 328  
 external cervical resorption on, 275  
 field of view, 116, 116t  
 fracture detection uses of, 258  
 image interpretation, 120–121, 121f  
 indications for, 113f, 118f, 118–119  
 intraoperative complications diagnosed using, 119  
 maxillary sinus mucositis on, 121f  
 mechanism of action, 115  
 mucositis on, 121, 121f  
 nonsurgical root canal therapy outcomes evaluated using, 292  
 previously treated teeth imaged using, 118  
 radiation dosages with, 116, 116t  
 root fracture evaluations, 119, 234–235  
 sinusitis evaluations, 96  
 two-dimensional dental radiographs versus, 115–116

- vertical root fractures on, 235, 262, 262f  
 working length determination using, 157
- Confidence interval, 4  
 Confidence limits, 4  
 Confidentiality of patient records, 200  
 Contact dermatitis, 321  
 Contrast-enhanced microCT, 258  
 Coronal discoloration, 274–275, 275f  
 Coronal flaring, 160, 161f  
 Coronal fractures, 53, 124, 266, 290  
 Coronal leakage, 195, 326, 326f  
 Coronally repositioned flaps, 177  
 Coronary artery disease, 91  
 Cortical bone, 36  
 COVID-19, 92–93  
 Cracked tooth/teeth  
   aging as cause of, 265  
   apical extension of, 267  
   bite testing of, 265  
   clinical presentation of, 265  
   cold hypersensitivity associated with, 265  
   cone beam computed tomography of, 266  
   crack depth and, 266  
   crestal bone loss associated with, 267f  
   definition of, 259  
   description of, 199  
   diagnosis of, 265  
   endodontic treatment of, 266, 290  
   imaging of, 266  
   nonbonded restorations and, 265  
   nonsurgical root canal therapy of, 267  
   periodontal bone loss associated with, 266  
   predisposing factors for, 257, 265  
   prevalence of, 257  
   probing depths associated with, 266  
   prognostic factors for, 267f  
   pulp necrosis effects on, 266  
   symptoms of, 264  
   treatment planning of, 265
- Cracked tooth syndrome, 53, 199, 199f, 259, 264  
 Cracks, fractures versus, 260  
 Craze lines, 231, 260. *See also* Infractions.  
 C-reactive protein, 64  
 Cribriform plate, 36  
 Cross-fence capillaries, 35  
 Crown fractures, 231, 231f, 234f, 236t, 260  
 Crown lengthening, 291  
 Crowned teeth, 54, 55f  
 Crown-root fractures, 124f, 231f, 232, 236t, 238, 260  
 Cryotherapy, 184  
 C-shaped root canals, 41–43, 43f  
 Cyclooxygenases, 86  
 Cysts  
   nasopalatine duct, 67, 143, 143f  
   periapical, 66f, 66–67, 114
- Cytokines  
   in apical periodontitis, 63–64  
   in bone resorption, 64
- Cytomegalovirus, 16, 19  
 Cytotoxic T cells, 62  
 Cytotoxins, 318
- D**
- Dam. *See* Dental dams; Rubber dams.  
 Danger space, 24  
 DE. *See* Dens evaginatus.  
 Deafferentation pain, 137  
 Decoronation, 250–251, 282  
 DEJ. *See* Dentinoenamel junction.  
 Denosumab, 277  
 Dens evaginatus, 41–42, 192f  
 Dens invaginatus, 41, 119  
 Dental dams, 155, 290  
 Dental history, 106  
 Dental pulp. *See* Pulp.  
 Dentin  
   anatomy and physiology of, 30–31  
   caries penetration into, 53f  
   classification of, 31, 31f  
   dehydration of, 54  
   dysplasia of, 142  
   embryology of, 30–31  
   facts about, 31f  
   odontoblast secretion of, 30  
   radicular, 261, 300  
   sensitivity of, 33f
- Dentinal hypersensitivity, 132  
 Dentinal tubules, 31, 33, 61, 178  
 Dentinoenamel junction, 31  
 Dentinogenesis, 29, 35  
 Dentition. *See also* Teeth; *specific teeth*.  
   arterial supply to, 43  
   neural pathways to, 45–46, 46f  
   primary. *See* Primary dentition.  
 Dermatan sulfate, 32  
 Dexamethasone, 154  
 DI. *See* Dens invaginatus.
- Diabetes, 93–94  
 Diagnosis  
   clinical examination for. *See* clinical examination for.  
   Clinical examination.  
   fractures. *See* Fracture(s).  
   periapical, 122f, 122–123  
   periapical lesions, 114  
   periodontal-endodontic lesions, 124–125, 125f  
   pulpal, 122, 122f  
   radiographic examination for. *See* Radiographic examination.
- Dialister invisus*, 21  
 Diazepam, 89  
 Diclofenac sodium, 154  
 Digital radiography, 114  
 DNA checkerboard analysis, 13  
 Doxycycline, 242  
 Drug interactions  
   with analgesics, 88t  
   with antibiotics, 83t
- Dual wavelength spectrophotometry, 110
- E**
- EAL. *See* Electronic apex locators.  
 EBV. *See* Epstein-Barr virus.  
 ECR. *See* External cervical resorption.  
 Ectodermal cells, 29  
 EDTA, 158, 163, 191  
 Ehlers-Danlos syndrome, 142, 142f  
 EIRR. *See* External inflammatory root resorption.  
 Electric pulp testing, 55, 107, 109, 110f, 151, 230  
 Electronic apex locators, 157f, 157–158  
 Embryology, of teeth, 29–30, 30f  
 EMD proteins. *See* Enamel matrix derivative proteins.  
 Emphysema, air, 320, 320f  
 Enamel  
   embryology of, 29–30  
   fractures of, 260  
   inner epithelium of, 29–30  
   outer epithelium of, 29–30  
 Enamel infraction, 231, 236t, 237  
 Enamel matrix derivative proteins, 183  
 Enamel-dentin fractures, 260  
 Enamel-dentin-pulp fractures, 260  
 Endocarditis, 84, 84f  
 Endodontic disease  
   in primary dentition, 302  
   radiographic entities that resemble, 141–147

- Endodontic flare-ups. *See* Flare-ups.
- Endodontic infections
- anatomical distribution of, 21–25
  - atypical species in, 18f, 18–19
  - consequences of, 24
  - historic perspectives on, 58
  - isolated species in, 16f, 16–17
  - overview of, 14
  - pathways of, 22–23, 24t
  - patterns of spread for, 22–23, 23f, 24t
  - polymicrobial, 14
  - primary, 20f, 20–21
  - secondary, 20f, 20–21
  - viruses, 19, 19f
- Endodontic lesions, 124
- Endodontic microbiology. *See* Microbiology, endodontic.
- Endodontic surgery. *See also* Surgical root canal therapy.
- blood loss during, 175
  - calcium sulfate use in, 175
  - complications of, 181–182
  - follow-up care after, 194
  - grafts, 180–181
  - guided surgical approaches, 174–175
  - healing after, 182, 182f
  - hemostasis for, 175, 176f
  - indications for, 174
  - membranes, 180–181
  - nonsurgical retreatment versus, 174
  - outcomes of, 295–297, 296f–297f
  - postoperative management of, 181
  - resection, 177–178
  - retrofilling, 178–179, 179t
  - retropreparation, 177–178
  - soft tissue healing after, 182
  - surgical site exposure, 176–177
  - suturing, 180
  - tools and techniques used in, 174
- Endodontic treatment
- apexification, 187f–188f, 187–189, 300
  - bacteremias after, 82–83
  - cracked teeth treated with, 266
  - digital radiography uses in, 114
  - failure of, 325–326
  - follow-up care, 194
  - fracture risks, 257
  - implants versus, 198–199
  - internal bleaching, 193–194
  - local anesthesia for, 151–155, 154f
  - nonsurgical retreatment, 171–173, 172f–174f, 294, 294f
  - nonsurgical root canal therapy. *See* Nonsurgical root canal therapy.
  - persistent pain after, 327–328, 328f
  - pulp capping, 184–186, 185f, 298
  - pulpal necrosis treated with, 240–241
  - pulpotomy, 186–187, 187f, 299
  - regenerative endodontics, 189–193, 190f, 192f–193f, 301f
  - in restored teeth, 54, 55f
  - success rates for, 288
  - surgery. *See* Endodontic surgery.
  - traumatic dental injuries treated with, 237
- Endodontically treated teeth. *See also* Previously treated teeth.
- nonsurgical retreatment in, 171–173, 172f–174f, 294, 294f
  - periodontal disease effects on, 125
  - restoration of
    - biologic width, 196, 196f
    - implants for, 198–199
    - indications for, 195
    - posts, 197–198, 198f
    - reasons for, 194–195, 196f
    - success rates for, 289
- EndoSequence Bioceramic Root Repair Material putty, 296
- Endosolv R, 172
- Endotoxin, 13, 13f
- EndoVac system, 165
- End-stage renal disease, 96
- Enterococcus faecalis*, 17, 17f, 20–21, 163, 167–168
- Epidemiology, 7–8
- Epinephrine, 78, 78t, 171, 175
- Epithelial rests of Malassez, 66
- Epstein-Barr virus, 16, 19
- EPT. *See* Electric pulp testing.
- Erythromycin, 83t
- Estrogen deficiency, 95
- E/TEST, 81
- Ethics, 200, 200f
- Eugenol, 170–171, 171f, 317
- Evidence, levels of, 2f
- Expert opinions, 3
- External apical root resorption, 251
- External carotid artery, 43
- External cervical resorption
- calcium hydroxide for, 279–280
  - classification of, 277f–278f, 277–278
  - cone beam computed tomography of, 275
  - coronal discoloration associated with, 274–275, 275f
  - denosumab and, 277
  - description of, 19, 273–274
  - diagnosis of, 275
  - etiologies of, 275–277, 277f
  - external approach to, 278–280, 279f
  - genetic predisposition to, 276–277
  - Heithersay's classification of, 277f, 277–278
  - herpes virus and, 276
  - idiopathic, 276
  - imaging of, 275f
  - intentional replantation for, 280, 280f
  - internal approach to, 279–280
  - intracoronary bleaching and, 276
  - nonsurgical root canal therapy for, 278, 279f
  - orthodontics as cause of, 275–276
  - Patel's classification of, 278, 278f
  - pathogenesis of, 274, 274f
  - pericanalar resorption-resistant sheet in, 274
  - periodontal therapy and, 276
  - phases of, 274
  - risk factors for, 277f
  - treatment of, 278–281, 279f–280f
  - trichloroacetic acid for, 278–280
  - untreatable, 280, 280f
  - varicella zoster virus and, 276
  - viruses associated with, 276
- External inflammatory root resorption, 237, 250, 252f, 281, 281f
- External jugular vein, 44
- External root resorption
- antibiotics for prevention of, 242
  - inflammatory, 281, 281f
  - orthodontic treatment and, 55–56
- Extracellular connective tissue, 32
- Extraradicular infections, 15
- Extremophiles, 18
- Extrinsic luxation, 233, 234f, 236t, 239
- F**
- Facial artery, 43
- Failure of endodontic therapy, 325–326
- Falls, 227

- False negative, 5, 5t  
 False positive, 5, 5t  
 Fascial spaces, 21–22, 24, 24t, 47  
 FCOD. *See* Florid cemento-osseous dysplasia.  
 Federal laws, 200  
 Ferric sulfate, 302  
 Ferrule effect, 196–197  
 Fibro-osseous tissue, 274  
 Fibrovascular tissue, 274  
 Firmicutes phylum, 16, 21  
 FISH. *See* Fluorescent in situ hybridization.  
 Fisher exact test, 4  
 Flaps, 180  
 Flare-ups  
   antibiotics for prevention of, 80  
   definition of, 324–325  
   in diabetes, 93  
   factors associated with, 324f  
   incidence of, 68, 323  
   local anesthetics for, 325  
   management of, 325, 325f  
   predictors for, 324  
   risk factors for, 324f  
 Florid cemento-osseous dysplasia, 143, 145–146, 146f  
 Fluorescent in situ hybridization, 13  
 Focal infection theory, 12, 58  
 Focused examination, 107  
 Foramen ovale, 46  
 Foramen rotundum, 45  
 Foreign body reaction, 317  
 Formaldehyde, 172, 186  
 Formocresol, 186, 302  
 Fracture(s)  
   alveolar, 113, 229, 232, 238  
   categories of, 123, 124f  
   cervical root, 257  
   complicated, 231–232, 234f, 260  
   coronal, 53, 124, 266, 290  
   cracks versus, 260  
   crown, 124f, 231, 231f, 234f, 236t, 260  
   crown-root, 231f, 232, 236t, 238, 260  
   description of, 326  
   diagnostic testing for, 112, 258  
   enamel, 260  
   enamel-dentin, 260  
   enamel-dentin-pulp, 260  
   endodontic treatment as cause of, 257  
   longitudinal, 123, 261, 263  
   as pulpal irritant, 53  
   radiographic findings, 234f, 234–235  
   root. *See* Root fractures.  
   staining of, 112  
   terminology associated with, 259–260  
   traumatic, 257, 259f, 259–260  
   types of, 123, 124f  
   uncomplicated, 231–232, 234f, 260  
   vertical root. *See* Vertical root fractures.  
 Fracture necrosis, 266–267, 267f  
 Fractured tooth, 259. *See also* Fracture(s).  
 Fungal infections, 18  
 Furcation, 111, 111f  
*Fusobacterium nucleatum*, 16
- G**  
 GAGs. *See* Glycosaminoglycans.  
 GCS. *See* Glasgow Coma Scale.  
 Gelfoam, 175  
 Generalized radiographic changes, 112  
 Gentlewave System, 310  
 Glasgow Coma Scale, 229  
 Glass-ionomer cements, 170, 278  
 Glide path maintenance, 158–159  
 Glycosaminoglycans, 32  
 Gnotobiotic, 11  
 Gow-Gates technique, 152  
 Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) system, 2  
 Grafts, 180–181  
 Gram-negative bacteria, 13, 20  
 Gram-positive bacteria, 13, 20  
 Granulomas, 65–66, 66f, 67, 114  
 Greater palatine nerve, 46  
 Growth factors, 29, 190  
 “Guided access” technology, 157  
 Guided surgery, 174–175  
 Gutta-percha, 108–109, 169–170, 172, 179, 238, 261, 296, 317–318, 322
- H**  
 HAART. *See* Highly active anti-retroviral therapy.  
 Hand instruments, 160  
 Hank’s balanced salt solution, 242, 244, 250  
 Head and neck lymphatic drainage, 45  
 Headaches, 134–135, 135f  
 Healing  
   after pulp capping, 185  
   pulpal. *See* Pulpal healing.  
   after root fractures, 239f  
   soft tissue, 182  
   surgical, 182, 182f  
 Health Insurance Portability and Accountability Act, 200  
 Heat testing, for pulp sensitivity, 6, 108–109, 110f  
 Helper T cells, 62, 62f  
 Hemiparesis, 135  
 Hemoglobin A, 90  
 Hemoglobin A1c, 93  
 Hemopoietic cells, 36  
 Hemostasis, 175, 176f  
 Hepatitis, 94  
 Herpes simplex virus, 19, 276  
 Herpes zoster, 146  
 HERS. *See* Hertwig’s epithelial root sheath.  
 Hertwig’s epithelial root sheath, 30, 40, 187  
 Heterotopic pain, 138  
 HHV. *See* Human herpesvirus.  
 Highly active anti-retroviral therapy, 94  
 HIPAA. *See* Health Insurance Portability and Accountability Act.  
 HIV, 19, 94  
 Hodgkin lymphoma, 95  
 Hollow tube theory, 58  
 Horizontal incisions, 176–177, 177f  
 Horizontal root fractures, 123, 124f, 263f, 263–264  
 HPV. *See* Human papillomavirus.  
 HSV. *See* Herpes simplex virus.  
 Human herpesvirus, 19  
 Human immunodeficiency virus. *See* HIV.  
 Human papillomavirus, 19  
 Hyaluronate, 32  
 Hypercementosis, 145  
 Hyperparathyroidism, 147  
 Hyperplastic pulpitis, 125  
 Hypersensitivity reactions, 321, 321f  
 Hypothesis testing, 3
- I**  
 IADT. *See* International Association of Dental Traumatology.  
 Iatrogenic perforations, 311–314  
 Ibuprofen, 6, 85–87, 88t, 107  
 ICD. *See* Implantable cardiac defibrillators.  
 ICOP. *See* International Classification of Orofacial Pain.  
 ICRR. *See* Invasive cervical root resorption.  
 Immature necrotic teeth, 300–301, 301f

- Immunoglobulins  
 in apical periodontitis, 63  
 in periapical cysts, 66  
 Immunologic theory, of cyst formation, 66, 66f  
 Implantable cardiac defibrillators, 158  
 Implants, 198–199  
 Incidence, 7–8, 8f  
 Incisions, 176–177, 177f  
 Incisive nerve, 46  
 Incisors, 38t  
 Infection  
 endodontic. *See* Endodontic infections.  
 historic perspectives on, 58  
 non-endodontic, 139–141  
 persistent, 325–326  
 primary, 20f, 20–21  
 secondary, 20f, 20–21, 325–326  
 Zones of Fish for containment of, 12, 12f  
 Infective endocarditis, 84, 84f  
 Inferior alveolar artery, 43  
 Inferior alveolar nerve  
 anesthetic block of, 85, 89, 152–153, 155  
 description of, 46  
 radiographic images of, 121f  
 Inferior alveolar vein, 44  
 Infiltrations, 151  
 Inflammatory bowel disease, 94  
 Informed consent, 150  
 Infractions, 123, 124f, 231, 236t, 237, 259–260  
 Infraorbital artery, 43  
 Inhalational anxiolytics, 89  
 Innate immune system, 58, 59f  
 Inner enamel epithelium, 29–30  
 Instruments/instrumentation  
 description of, 159–161  
 irrigation with, 161–164, 162f  
 master apical file, 161  
 nickel titanium, 309, 309f  
 rotary, 160, 309  
 separation of, 309f–311f, 309–311  
 smear layer created by, 161  
 stainless steel, 309  
 ultrasonic, 319  
 Intentional replantation, 183–184, 280, 280f, 297–298  
 Interleukin-1 $\alpha$ , 63  
 Interleukin-1 $\beta$ , 60, 63  
 Interleukin-2, 91  
 Interleukin-6, 63–64  
 Interleukin-8, 63  
 Interleukin-10, 63  
 Intermediate Restorative Material, 170  
 Internal bleaching, 193–194  
 Internal carotid artery, 43  
 Internal jugular vein, 44  
 Internal root resorption, 125, 250–251, 252f, 272–273, 273f  
 International Association of Dental Traumatology, 235–237, 259, 263  
 International Classification of Headache Disorders, 134  
 International Classification of Orofacial Pain, 133  
 International Headache Society, 133–134  
 Intracanal medicaments, 167–168, 168f, 191–192  
 Intracoronal bleaching, 275–276  
 Intraoperative complications, 119  
 Intraoral examination, 107  
 Intraosseous anesthesia, 319  
 Intrapulpal nerves, 32–34, 33f  
 Intrasulcular incisions, 176, 177f  
 Intrusive luxation, 233, 234f, 236f, 240, 240f  
 Invasive cervical root resorption, 273  
 Invasive root resorption, 250–251  
 IRM. *See* Intermediate Restorative Material.  
 Irreversible pulpitis, 58, 60, 79–80, 86, 92, 122, 155, 237, 266, 284f, 299  
 Irrigation  
 adjunctive techniques for, 164f, 164–165  
 irrigants used in, 15, 161–164, 162f, 190–191  
 passive ultrasonic, 165  
 sodium hypochlorite for, 162f, 162–163  
 Irritants, pulpal. *See* Pulpal irritant(s).  
 Isolated species, in endodontic infections, 16f, 16–17
- J**
- Jaw  
 bisphosphonate-related osteonecrosis of, 90–91  
 malignancies of, 144, 144f  
 radiolucencies of, 145, 145f  
 radiopacities of, 145–146, 146f
- K**
- K305, 151  
 Ketorolac, 86  
 Kidney stones, 96  
 Kovanaze, 151  
 K-shell absorption edge, 116
- L**
- $\beta$ -Lactams, 81, 83t  
*Lactobacillus*, 21, 52  
 Langerhans cell histiocytosis, 143  
 Laser Doppler flowmetry, 5–6, 110  
 Lateral canal, 40, 40f  
 Lateral condensation, 170  
 Lateral incisors, 38t–39t  
 Lateral luxation, 233, 234f, 236f, 239  
 Lateral pharyngeal space, 24–25  
 Latex allergy, 322  
 Laws, 200  
 LDF. *See* Laser Doppler flowmetry.  
 Leakage, coronal, 195, 326, 326f  
 Ledermix, 237  
 Left subclavian vein, 45  
 Lesser palatine nerve, 46  
 Leukocytes, 60  
 Levels of evidence, 2f  
 Lidocaine, 78t, 95, 152, 155  
 Lingual artery, 43  
 Lingual nerve, 46, 323  
 Lipopolysaccharide, 13, 60, 64, 162, 168  
 Local anesthesia. *See also* Anesthesia.  
 adjunctive techniques, 153–154, 154f  
 adverse reactions to, 322–323, 323f  
 agents used in. *See* Local anesthetics.  
 buffering of, 154–155  
 mandibular anesthesia, 152–153  
 maxillary anesthesia, 151  
 Local anesthetics  
 allergies to, 78  
 duration of action, 78  
 flare-ups managed with, 325  
 hemostatic uses of, 175  
 indications for, 77  
 lipid solubility of, 78  
 paresthesias after, 322  
 properties of, 78  
 types of, 78t  
 Localized radiographic changes, 112  
 Longitudinal root fractures, 123, 261, 263, 266  
 LPS. *See* Lipopolysaccharide.  
 Ludwig angina, 24  
 Luxation-type injuries  
 follow-up of, 241



radiographic findings in, 235  
 treatment of, 236f, 239–241  
 types of, 232–233  
 Lyme disease, 94–95  
 Lymph nodes, 45, 45f  
 Lymphatics  
   maxillofacial, 45, 45f  
   pulpal, 35  
 Lymphocytes, 62  
 Lymphoma, 95

## M

Macrolides, 83t  
 MAF. *See* Master apical file.  
 Magnification, 156, 156f  
 Malignancies, 144, 144f  
 Mandibular anesthesia, 152–153  
 Mandibular nerve, 46, 318  
 Mandibular osteomyelitis, 140f  
 Mandibular teeth  
   canines, 39t  
   incisors, 39t  
   infections of, 23, 24t  
   innervation of, 46  
   molars, 39t  
   premolars, 39t  
   surgical anatomy of, 47  
   venous drainage from, 44  
 Masserann technique, 173  
 Master apical file, 161  
 Matrix metalloproteinase 9, 60  
 Maxillary anesthesia, 151  
 Maxillary artery, 43  
 Maxillary nerve, 46  
 Maxillary sinus  
   maxillary root protrusion  
     into, 47  
   mucositis of, 121f  
   surgical anatomy of, 47  
 Maxillary sinusitis of endodontic  
   origin, 96  
 Maxillary teeth  
   anesthesia for, 151  
   arterial supply to, 43, 44f  
   canines, 38t  
   incisors, 38t  
   infections of, 22–23, 24t  
   innervation of, 45–46  
   molars, 38t  
   premolars, 38t  
   root canal anatomy in, 38t  
   root protrusion into maxillary  
     sinus by, 47, 121  
   venous drainage from, 44  
 Maxillary vein, 44  
 Maxillofacial region  
   anatomy of, 43  
   arterial supply to, 43, 44f  
   lymphatics of, 45, 45f  
   neuroanatomy of, 45–46  
   surgical anatomy of, 47  
   venous drainage, 44  
 Measures  
   of statistical significance, 3–4  
   of validity, 5f, 5–6  
 Medical history, 106  
 Medication(s). *See* Pharmacology;  
   *specific medication.*  
 Medication-related osteonecrosis  
   of the jaw, 90–91  
 Membranes, 180–181  
 Menopause, 95  
 Mental foramen, 47, 113, 120, 120f  
 Mental nerve  
   anesthetic blockade of, 152  
   description of, 46  
 Mental space, 22  
 Mepivacaine, 78t  
 Mesenchymal cells, neural crest-  
   derived, 29  
 Mesial root isthmus, 41  
 Meta-analyses, 2  
 Metastases, 140, 141f, 144, 144f  
 Methotrexate, 90  
 Methylene blue dye, 178, 265  
 Metronidazole, 81–82, 83t, 191  
 Microabscesses, 60  
 Microbial succession, 20, 60  
 Microbiology, endodontic  
   history of, 12  
   overview of, 11  
   research methods, 13  
 Microbiome, 14  
 MicroCT, 115  
 Microleakage, 170  
 Microscope, surgical operating,  
   156, 156f, 295, 311  
 Middle superior alveolar nerve, 45  
 Migraine headaches, 134–135  
 Mineral trioxide aggregate  
   apexification using, 188, 188f,  
     300, 300f  
   perforating resorptive defects  
     treated with, 273  
   perforation repair using, 313–  
     314, 314f  
   properties of, 179t  
   pulp capping using, 184–185,  
     298  
   pulpal healing promoted with,  
     54  
   pulpotomy using, 186–187, 187f,  
     299, 302  
   retrofilling uses of, 178–179,  
     192, 264, 296  
 Minocycline, 191  
 MMP9. *See* Matrix  
   metalloproteinase 9.  
 Mobility assessments, 111, 112f

Molars, 38t–39t  
 Molecular research, 14  
 Molecular techniques, 13  
 Mouth guards, 252  
 MRONJ. *See* Medication-related  
   osteonecrosis of the jaw.  
 MSEO. *See* Maxillary sinusitis of  
   endodontic origin.  
 MTA. *See* Mineral trioxide  
   aggregate.  
 Mucositis, 96, 121, 121f  
 Multiple myeloma, 95  
 Multiple-visit therapy, 165–167,  
   324  
 Myofascial pain, 134  
 Myofascial pain syndrome, 134

## N

Nasopalatine duct cysts, 67, 143,  
 143f  
 National Dental Practice-Based  
   Research Network study, 265  
 Necrosis. *See* Fracture necrosis;  
   Pulpal necrosis.  
 Negative predictive value, 5f, 6  
 Neural crest-derived mesenchymal  
   cells, 29  
 Neuralgia-inducing cavitational  
   osteonecrosis, 137  
 Neurofibromatosis, 146  
 Neurokinin A, 34  
 Neuropathic pain, 135–136, 136f  
 Neuropeptide Y, 30, 34  
 Neuropeptides, 59  
 Neurovascular pain, 138  
 Next-generation sequencing, 13  
 NGS. *See* Next-generation  
   sequencing.  
 Nickel titanium alloys, 160  
 Nickel titanium instruments, 309,  
   309f  
 NICO. *See* Neuralgia-inducing  
   cavitational osteonecrosis.  
 Nitrous oxide, 89, 96  
 NMDA receptors, 89  
 NNT. *See* Numbers needed to treat.  
 Nonbonded restorations, 265  
 Non-endodontic diseases  
   headaches, 134–135, 135f  
   pain. *See* Pain.  
 Non-endodontic infections,  
   139–141  
 Non-Hodgkin lymphoma, 95  
 Noninfectious swelling, 141  
 Nonodontogenic pain, 327  
 Nonresorbable membranes,  
   180–181  
 Nonsteroidal anti-inflammatory  
   drugs

- drug interactions, 88t  
mechanism of action, 86  
respiratory disease exacerbated by, 88
- Nonsurgical retreatment, 171–173, 172f–174f, 293–294, 294f, 297
- Nonsurgical root canal therapy  
access preparation, 156–157  
cracked teeth treated with, 267  
external cervical resorption treated with, 278, 279f  
failure after, 294f  
glide path maintenance, 158–159  
in HIV patients, 94  
instrumentation, 159–161  
intracanal medicaments, 167–168, 168f  
intraoperative complications of, 292  
irrigation, 161–164  
isolation, 155  
magnification, 156, 156f  
multiple-visit therapy, 165–167, 324  
obturation, 169f, 169–170, 173  
outcomes of, 289t, 289–293, 293f  
patency, 158–159, 159f  
prognostic rates for, 289t, 289–293, 293f  
single-visit therapy, 165–167, 166f  
temporary restorations, 170–171  
tooth extraction after, 92  
working length determination, 157f, 157–158
- Nonvital bleaching, 301
- NPY. *See* Neuropeptide Y.
- NSAIDs. *See* Nonsteroidal anti-inflammatory drugs.
- NSRCT. *See* Nonsurgical root canal therapy.
- Numbers needed to treat, 6
- Nutritional deficiency theory, of  
cyst formation, 66, 66f
- O**
- Objective examination  
cold testing, 107–108  
electric pulp testing, 107  
elements of, 107  
focused examination, 107  
intraoral examination, 107  
periodontal examination, 111, 111f  
periodontal ligament assessment, 111  
pulp sensitivity tests, 107–109  
Oblique root fractures, 263
- Obturation  
nonsurgical root canal therapy  
uses of, 169f, 169–170, 173  
overextension of materials used in, 317, 317f
- Occlusal adjustment, 57, 57f
- Occlusal forces, 57
- Occupational Health and Safety Administration, 200
- OCEBM. *See* Oxford Centre for Evidence-Based Medicine.
- Ochsenbein-Luebke technique, 176
- Odds ratio, 7
- Odontoblasts, 30, 282
- Odontoclasts, 271
- Odontogenesis, 29, 186
- Odontogenic pain, 86, 90, 107
- Oehler's dens invaginatus  
classification, 41, 42f
- OHSA. *See* Occupational Health and Safety Administration.
- Ophthalmic vein, 44
- Opioid receptors, 86
- Oral cancer screening, 107
- Orofacial trauma, 227, 247
- Orthodontic treatment  
external cervical resorption caused by, 275–276  
pulpal tissue affected by, 55f, 55–56  
root resorption and, 56
- Osteoblasts, 64
- Osteocalcin, 30
- Osteoclastogenesis, 274
- Osteoclasts, 64
- Osteoconductive grafts, 180
- Osteogenic grafts, 180
- Osteoinductive grafts, 180
- Osteomyelitis, mandibular, 140f
- Osteonecrosis  
bisphosphonate-related  
osteonecrosis of the jaw, 90–91  
neuralgia-inducing cavitation, 137
- Osteosarcoma, 144f
- Osteotomy, 174, 177, 319
- Outcomes  
apexification, 300, 300f  
apical periodontitis effects on, 290, 293  
endodontic surgery, 295–297, 296f–297f  
factors that affect, 288  
nonsurgical retreatment, 293–294, 294f
- nonsurgical root canal therapy, 289t, 289–293, 293f  
surgical root canal therapy, 295, 296f  
vital pulp therapy, 298–299
- Outer enamel epithelium, 29–30
- Oxford Centre for Evidence-Based Medicine, 2–3
- Oxford Pain Group League, 6, 87
- Oxymetazoline, 151
- P**
- P* value, 4, 4f
- Pacemakers, 109
- Pain  
analgesics for, 85  
anesthesia for control of, 155  
atypical facial, 136–138, 137f  
biting, 111  
cardiac, 138  
cervicogenic, 138  
deafferentation, 137  
heterotopic, 138  
hydrodynamic theory of, 33  
myofascial, 134  
neuropathic, 135–136, 136f  
neurovascular, 138  
nonodontogenic, 327  
odontogenic, 86, 90, 107  
persistent, 327–328, 328f  
phantom tooth, 137  
postoperative, 86, 155, 158, 163  
in pregnancy, 95  
psychogenic, 138  
referred, 133  
selective anesthesia testing for, 112  
sinus, 134
- Painful post-traumatic trigeminal neuropathy, 136
- Palatal anesthesia, 151
- Palpation tenderness, 111
- Panoramic radiographs, 113, 113f
- Papilla-based incision, 176–177
- Parachloroaniline, 164, 164f
- Paraformaldehyde, 186
- Paraformaldehyde-containing sealers, 318
- Parafunctional habits, 264f
- Paresthesias, 323
- Paroxysmal hemicrania, 135
- Partial pulpotomy, 186, 299
- Passive step-back technique, 159, 160f
- Passive ultrasonic irrigation, 165, 168
- Patency, 158–159, 159f
- Patient record confidentiality, 200
- PCO. *See* Pulp canal obliteration.

- PCOD. *See* Periapical cemento-osseous dysplasia.
- PCR. *See* Polymerase chain reaction.
- PDAP. *See* Persistent dentoalveolar pain disorder.
- PDL. *See* Periodontal ligament.
- Peer-reviewed journals, 1
- PEIR. *See* Pre-eruptive intracoronal resorption.
- Penicillin VK, 81–82, 83t
- Peracetic acid, 168
- Percocet, 88t
- Percussion sensitivity, 231
- Percussion tenderness, 111
- Perforations, 311–314, 312f–314f
- Periapical abscess, 8, 320
- Periapical actinomycosis, 18, 326
- Periapical cemento-osseous dysplasia, 143, 144f
- Periapical cysts, 66f, 66–67, 114
- Periapical diagnoses, 122f, 122–123
- Periapical granulomas, 65–66, 66f, 67, 114
- Periapical index score, 194
- Periapical inflammation, 13, 13f
- Periapical lesions
  - bacteria in, 64–65, 65f
  - borders of, 113
  - cysts, 66f, 66–67
  - diagnosis of, 114
  - frequency of, 68
  - granulomas, 65–66, 66f, 67, 114
  - histologic evaluation of, 65
  - types of, 67, 68f
- Periapical pathology
  - apical periodontitis, 61–62, 62f
  - cellular responses to, 62, 62f
  - humoral responses to, 63–64
- Periapical radiographs, 113, 113f, 116t, 118, 121f, 234
- Periapical radiolucencies, 142–143, 147f
- Periapical tissues, 62, 62f
- Pericanalar resorption-resistant sheet, 274
- Periodontal disease
  - chronic maxillary sinusitis and, 96
  - orofacial infections caused by, 139
  - pulpal tissue affected by, 56
- Periodontal examination, 111, 111f
- Periodontal ligament
  - accessory canals and, 40, 40f
  - assessment of, 111
  - calcium hydroxide effects on, 167
  - collagen fibers of, 36
  - composition of, 36
  - luxation-type injuries, 235
  - odontoclasts in, 271
  - surgical healing and, 182
  - traumatic dental injury effects on, 250
  - widening of, 142, 262
- Periodontal pocket depths, 111
- Periodontal probing depths, 261, 290
- Periodontal-endodontic lesions, 124–125, 125f
- Periodontitis
  - apical. *See* Apical periodontitis.
  - pulpal tissue affected by, 56, 57f
- Periorbital space, 22, 24
- Periosteal necrosis, 182
- Persistent dentoalveolar pain disorder, 137
- Persistent idiopathic facial pain, 136–137
- Persistent infections, 325–326
- Persistent pain, 327–328, 328f
- Personal protective equipment, 93
- Phantom tooth pain, 137
- Pharmacology
  - analgesics, 85–88, 88t
  - antibiotics. *See* Antibiotic(s).
  - anxiolytics, 89
  - local anesthetics, 77–78, 78t
- Phentolamine mesylate, 78
- PHI. *See* Protected health information.
- Photodynamic therapy, 164f, 164–165
- PIFP. *See* Persistent idiopathic facial pain.
- Plasma cells, 60, 95
- Platelet-rich fibrin, 187
- Platelet-rich plasma, 181
- PMN. *See* Polymorphonucleocyte infiltrate.
- Polymerase chain reaction, 13
- Polymorphonucleocyte infiltrate, 182
- Polymyalgia rheumatica, 138
- Porphyromonas*
  - description of, 17, 18f
  - P. gingivalis*, 16
- Positive predictive value, 5f, 6
- Post(s)
  - bone loss adjacent to apical terminus of, 262
  - in endodontically treated teeth, 197–198, 198f
  - perforation of, 313f
  - removal of, 171–172
- Posterior superior alveolar nerve, 45
- Posterior superior alveolar vein, 44
- Postoperative pain, 86, 155, 158, 163
- PPDs. *See* Periodontal probing depths.
- PPE. *See* Personal protective equipment.
- Predentin, 56
- Predictive values, 5f, 6
- Preeclampsia, 95
- Pre-eruptive caries, 284
- Pre-eruptive intracoronal resorption, 284, 284f
- Pregnancy, 95–96
- Premolars, 38t–39t
- Pressure resorption, 282–283, 283f
- Prevalence, 7–8, 8f
- Previously initiated therapy, 122
- Previously treated teeth. *See also* Endodontically treated teeth.
  - cone beam computed tomography of, 118
  - definition of, 122
- Prevotella* sp.
  - P. melaninogenica*, 17, 21
  - P. nigrescens*, 17
- Price, Weston, 12, 58
- Prilocaine, 78t, 152, 322–323, 323f
- Primary dentin, 31, 31f
- Primary dentition
  - endodontic disease in, 302
  - necrosis in, 302
  - traumatic dental injuries in, 247–248
- Primary infections, 20f, 20–21
- Primary intention, 180
- Prions, 19
- Probiotics, 82
- Prognosis, 8–9
- Prognostic rates. *See* Success rates.
- Prostaglandins, 63
- Prosthetic joints, 84f, 84–85
- Protected health information, 200
- Proton pump, 17
- PRP. *See* Platelet-rich plasma.
- PRRS. *See* Pericanalar resorption-resistant sheet.
- Psychogenic pain, 138
- Pterygoid venous plexus, 44
- Pterygomandibular space, 22, 24
- PUI. *See* Passive ultrasonic irrigation.
- Pulp
  - adrenergic nerves of, 33
  - age-related changes in, 35–36, 36f
  - anatomy of, 32
  - arterial structures in, 34
  - autonomic nerves of, 33
  - bacterial contamination of, 14, 14f
  - blood flow in, 34–36, 56, 59, 59f
  - calcification of, 141, 142f

- collagen composition of, 32  
 composition of, 32  
 description of, 122  
 diagnoses associated with, 122, 122f  
 embryology of, 30  
 extracellular connective tissue of, 32, 32f  
 immunology of, 60–61  
 lymphatics of, 35  
 necrosis of. *See* Pulpal necrosis.  
 orthodontic treatment effects on, 55f, 55–56  
 periodontitis effects on, 56, 57f  
 sensory nerves of, 32–34, 33f  
 stimulation of, 34, 34f, 53  
 vasculature of, 34–36, 35f  
 vasodilation of, 34  
 vital pulp therapy. *See* Vital pulp therapy.
- Pulp canal obliteration, 249–250, 252f
- Pulp capping, 184–186, 185f, 298
- Pulp chamber anomalies, 141
- Pulp polyp, 125
- Pulp revascularization therapy, 237
- Pulp sensitivity  
 description of, 33, 33f, 92  
 loss of, 110  
 testing for  
 baseline, 230  
 cold testing, 107–108  
 electric pulp testing, 55, 107, 109, 110f, 230  
 epidemiology of, 110t  
 fluid changes caused by, 109f  
 heat testing, 6, 108–109, 110f  
 in luxation-type injuries, 241  
 radiation therapy and, 92  
 validity measures in, 5
- Pulp stones, 92, 96, 142f
- Pulp vitality testing, 109–110, 110f, 230
- Pulpal anesthesia, 151
- Pulpal floor fractures, 267
- Pulpal healing  
 pulpal necrosis and, 16  
 restorative materials and, 54
- Pulpal inflammation  
 caries as cause of, 52–53  
 development of, 60  
 leukocytes in, 60  
 posttraumatic, 228
- Pulpal irritant(s)  
 caries as, 52–53  
 cellular responses to, 60  
 fractures as, 53  
 humoral responses to, 60  
 immune responses activated by, 58–59, 59f  
 neurovascular responses to, 59  
 occlusal forces as, 57  
 orthodontic treatment as, 55–56  
 periodontal disease as, 56, 57f  
 restorative treatment as, 53–55  
 thermal insults as, 55
- Pulpal necrosis  
 apical periodontitis and, 12f, 62f  
 cracked teeth affected by, 266  
 definition of, 122  
 herpes zoster and, 146  
 in horizontally fractured tooth, 263, 263f  
 intrusive luxation and, 240  
 medication-related  
 osteonecrosis of the jaw as cause of, 91  
 microbial succession, 60  
 pulpal healing and, 16, 239  
 pulpal irritants as cause of, 58–59  
 after traumatic dental injuries, 249–250
- Pulpal pathology  
 description of, 58–59  
 fractures as cause of, 53  
 histology of, 61  
 neurovascular responses to, 59  
 signs and symptoms, 61
- Pulpectomy, 316f
- Pulpitis  
 hyperplastic, 125  
 irreversible, 58, 60, 79–80, 86, 92, 122, 155, 237, 266, 284f, 299  
 reversible, 60, 122, 132
- Pulpotomy, 186–187, 187f, 299, 302
- Pyrosequencing, 20–21
- ## Q
- QMix, 163
- Quantitative light-induced fluorescence, 258
- Quorum sensing, 15
- ## R
- Racellet pellets, 175
- Radiation therapy, 92
- Radicular dentin, 261, 300
- Radiographic examination  
 bitewing radiographs, 113, 113f  
 cone beam computed tomography. *See* Cone beam computed tomography.  
 digital radiography, 114  
 panoramic radiographs, 113, 113f  
 periapical radiographs, 113, 113f, 116f, 118, 121f, 234  
 radiographic changes, 114  
 radiology principles, 112  
 systematic approach, 112, 112f  
 traumatic dental injuries, 233  
 two-dimensional dental radiography, 114–115, 115f
- Radiology, 112
- Randomized controlled trials, 2–3
- RANK-L. *See* Receptor activator of nuclear factor kappa-B ligand.
- Rapid antibiotic sensitivity test, 81
- RAST. *See* Rapid antibiotic sensitivity test.
- Ratner bone cavities, 137
- Reactionary dentin, 31
- Receptor activator of nuclear factor kappa-B ligand, 64
- Rectangular flap, 177
- Referred pain, 133
- Refrigerant spray, 107
- Regenerative endodontics, 189–193, 190f, 192f–193f, 300f
- Relative risk, 6–7
- Renal compromise, 96
- Renal failure, chronic, 96
- Renal osteodystrophy, 96
- Reparative dentin, 31, 54
- Replacement resorption, 250–251, 252f, 282, 282f
- Replantation  
 of avulsed teeth, 245–246  
 intentional, 183–184, 280, 280f, 297–298
- Research, 13
- Resection, 177–178
- Resilon, 169
- Resin-modified glass ionomers, 54
- Resorbable membranes, 180–181
- Resorcinol, 172
- Resorption  
 in apical periodontitis, 64  
 cytokine involvement in, 64  
 description of, 271  
 external apical root, 251  
 external cervical. *See* External cervical resorption.  
 external inflammatory root, 237, 252f, 281, 281f  
 internal root, 250–251, 252f, 272–273, 273f  
 invasive cervical root, 273  
 invasive root, 250–251  
 malignancies as cause of, 144, 145f  
 orthodontic therapy and, 56  
 pathogenesis of, 271, 272f  
 pre-eruptive intracoronal, 284, 284f

- pressure, 282–283, 283f  
 replacement, 250–251, 252f, 282, 282f  
 surface, 281  
 after traumatic dental injuries, 250–251  
 types of, 125–126, 272f
- Resource-intensive studies, 3
- Restorative treatments  
 endodontic therapy after, 54, 55f  
 pulpal tissue affected by, 53–55  
 quality of, 291  
 temporary, 170–171, 195
- Retrofilling, 178–179, 179t, 264, 296, 296f
- Retropreparation, 177–178
- Reversible pulpitis, 60, 122, 132
- Rheumatoid arthritis, 92
- Rickets, 142, 146
- Risk, 6–7
- Risk factors  
 disease and, relationship between, 6f  
 for external cervical resorption, 277f  
 for flare-ups, 324f  
 importance of establishing, 7f  
 for traumatic dental injuries, 227f
- Root amputation, 297
- Root apex, 40
- Root canal(s)  
 accessory, 40–41  
 anatomy of, 37–43  
 configuration of, 37, 38t–39t  
 C-shaped, 41–43, 43f  
 maxillary, 38t  
 variants of, 41–43  
 Vertucci's classification system for, 37, 37f
- Root canal filling materials, 197
- Root canal space, 41
- Root canal therapy. *See* Nonsurgical root canal therapy; Surgical root canal therapy.
- Root fractures  
 characteristics of, 231f, 232  
 classification of, 260–261  
 cone beam computed tomography detection of, 119  
 healing after, 239, 239f  
 horizontal, 234f, 263f, 263–264  
 longitudinal, 123, 261, 263, 266  
 oblique, 263  
 radiographic findings of, 234f  
 treatment of, 236t, 238
- types of, 259f, 259–260  
 vertical. *See* Vertical root fractures.
- Root resorption. *See* Resorption.
- Root ZX apex locator, 157
- Root-end surgery, 319, 323
- Rotary instruments, 160, 309
- Rubber dams, 155, 294, 326
- “Russian Red” removal, 172, 172f
- S**
- Saccharolytic, 17
- SARS-CoV-2. *See* Severe acute respiratory coronavirus 2.
- Scalloped submarginal incisions, 176
- Scleroderma, 142
- Sealer, 172, 317, 317f
- Second order neurons, 46
- Secondary canal, 40, 40f
- Secondary dentin, 31, 31f
- Secondary infections, 20f, 20–21, 325–326
- Semilunar flaps, 176
- Sensitivity, 5, 5f
- Sensory nerves  
 of pulp, 32–34, 33f  
 stimulation of, 34, 34f
- Sensory neurons, 93
- Separated instruments, 309f–311f, 309–311
- Severe acute respiratory coronavirus 2, 92
- Sialophosphoprotein, 30
- Sickle cell anemia, 90, 146
- Signaling molecules, 29
- Silver points, 173, 173f
- Simvastatin, 64, 186
- Single-unit implants, 198
- Sinus pain, 134
- “Sinus precautions,” 181
- Sinusitis, 96, 318
- Smear layer, 161
- Smoking, 96–97
- Sodium hypochlorite  
 accidents involving, 314–315, 315f  
 antimicrobial uses of, 190–191  
 chlorhexidine gluconate and, 164f  
 properties of, 162f, 162–163
- Sodium perborate walking bleach technique, 194
- Soft tissue healing, 182
- SORT grading system. *See* Strength of recommendation taxonomy grading system.
- SP. *See* Substance P.
- Specificity, 5, 5f
- Spirochetes, 18
- Splinting, 235–236, 236f, 236t
- Split roots, 263
- Stafne bone cavities, 67
- Stainless steel instruments, 309
- State laws, 200
- Statistics  
 measures of statistical significance, 3–4  
 measures of validity, 5f, 5–6
- Stem cells, 191
- Step-down technique, 159, 160f
- Strength of recommendation taxonomy grading system, 2
- Streptococci, 17
- Streptococcus* spp  
*S. epidermidis*, 21  
*S. mitis*, 17  
*S. mutans*, 21, 52
- Stressed pulp syndrome, 53
- Study design, 2–3
- Subclavian vein, 44
- Subjective examination, 106
- Sublingual space, 22, 24
- Subluxation, 232, 234f, 236t, 239
- Submandibular space, 22, 24
- Submarginal incisions, 176, 177f
- Submental space, 22, 24
- Subodontoblastic capillary plexus, 34
- Substance P, 30, 34, 57, 59
- Success rates  
 for endodontic surgery, 295–297  
 for endodontic treatment, 288  
 factors that affect, 288  
 for nonsurgical retreatment, 293–294, 294f  
 for nonsurgical root canal therapy, 289t, 289–293, 293f  
 for pulpotomy, 299  
 for surgical root canal therapy, 295  
 for vital pulp therapy, 298–299
- Success versus survival, 8–9
- Sulcular perforations, 314
- Sulfur granules, 18
- Super EBA, 178–179, 179t, 296
- Superoxol, 194
- Supplemental anesthesia, 154
- Suppressor T cells, 62, 62f
- Surface resorption, 281
- Surgery  
 endodontic. *See* Endodontic surgery.  
 maxillofacial anatomy, 47  
 Surgical endodontics. *See* Endodontic surgery.  
 Surgical operating microscope, 156, 156f, 295, 311  
 Surgical root canal therapy. *See also* Endodontic surgery.

- healing after, 297  
 nonsurgical retreatment versus, 297  
 outcomes of, 295, 296f  
 radiographic imaging of, 297f  
 success rates for, 295  
 techniques used in, 295  
 Surgical site exposure, 176–177  
 Surgical, 175  
 Survival versus success, 8–9  
 Suturing, 180  
 Swelling, noninfectious, 141  
 Swept-source optical coherence tomography with cross-sectional imaging, 258  
 Symptomatic apical periodontitis, 123  
 Systematic reviews, 2
- T**
- T cells, 62, 62f  
 TA. *See* Temporal arteritis.  
 Talon cusp, 42  
*Tannerella forsythia*, 15, 20–21  
 Targeted endodontic microsurgery, 175  
 Teeth. *See also* Mandibular teeth;  
 Maxillary teeth; Primary dentition; *specific teeth*.  
 arterial supply to, 43  
 avulsed. *See* Avulsions.  
 cracked. *See* Cracked tooth/teeth.  
 embryology of, 29–30, 30f  
 microcracks in, 228  
 neural pathways to, 45–46, 46f  
 thermal sensitivity of, 53  
 Telehealth, 93  
 Temporal arteritis, 138  
 Temporary restorations, 170–171, 195  
 TEMS. *See* Targeted endodontic microsurgery.  
 Tension-type headaches, 135  
 Tertiary dentin, 31, 31f  
 Test outcomes, 5t  
 Tetracalcium aluminoferrite, 179, 179t  
 Tetracycline, 81, 83t, 96  
 Tetrafluoroethane, 107  
 Thermal injuries, 318–319, 319f  
 Thermal insults, 55  
 Thermal sensitivity tests, 108  
 Thermography, 110  
 Third molar extractions, 155  
 Third order neurons, 46  
 Thoracic duct, 45  
 Tissue engineering, 190  
 TN. *See* Trigeminal neuralgia.  
 Tooth cracks. *See* Cracked tooth/teeth.  
 Tooth fractures. *See* Fracture(s).  
 Tooth preparation, 54  
 Tooth Slooth, 265  
 Tooth stiffness, 195  
 Trabeculae, 36, 182  
 Tramadol, 85  
 Transillumination, 112, 265  
 Trapezoidal flap, 177  
 Traumatic dental injuries  
 acute priority, 229, 229f  
 age of patient and, 227, 228f  
 avulsions  
 description of, 233  
 in immature teeth with closed apex, 245–247  
 in mature teeth with closed apex, 244–245  
 periodontal ligament maintenance in, 242  
 radiographic findings in, 235  
 replantation of, 241–242, 245–246  
 storage of tooth, 242, 242f, 244, 250  
 treatment of, 236t, 241–247, 243f  
 in children, 227  
 complications of, 249–251, 252f  
 delayed priority, 229, 229f  
 description of, 126  
 diagnosis of  
 clinical examination, 230–231  
 clinical findings, 231f–232f, 231–233  
 data necessary for, 229  
 periradicular testing, 230  
 primary survey in, 228  
 secondary survey in, 228–229  
 systematic approach for, 229, 230f  
 endodontic therapy for, 237  
 epidemiology of, 227  
 evidence-based management of, 226  
 external inflammatory root resorption and, 281  
 falls as cause of, 227  
 fractures. *See also* Fracture(s).  
 classification of, 259f  
 horizontal root, 264  
 radiographic findings, 234f, 234–235  
 treatment of, 237–239  
 types of, 231–232, 259, 259f  
 guidelines for, 226, 260  
 incidence of, 227, 257  
 luxation-type injuries  
 follow-up of, 241  
 radiographic findings in, 235  
 treatment of, 236t, 239–241  
 types of, 232–233  
 mouth guards for prevention of, 252  
 pathophysiology of, 228  
 postoperative instructions for, 247–248  
 prevalence of, 257  
 prevention of, 252  
 in primary dentition, 247–248  
 prioritization of, 229, 229f  
 prognosis for, 248, 249t  
 pulpal inflammation after, 228  
 pulpal necrosis after, 249–250  
 radiographic examination, 233  
 radiographic findings, 233–235, 234f  
 resorption after, 250–251  
 risk factors for, 227f  
 splinting of, 235–236, 236f, 236t  
 subacute priority, 229, 229f  
 treatment of, 235–248, 236t  
*Treponema* spp, 18  
 Triangular flap, 177  
 Triazolam, 89  
 Tricalcium silicate, 179  
 Trichloroacetic acid, 278–280  
 Trigeminal autonomic cephalalgias, 135  
 Trigeminal ganglion, 46  
 Trigeminal nerve, 45  
 Trigeminal neuralgia, 135  
 Trigeminothalamic tract, 46  
 Triptans, 134  
 True cysts, 66–67  
 Tumor necrosis factor- $\alpha$ , 60, 63  
**Two-dimensional dental radiography**, 114–115, 115f
- U**
- Ultrasonic instruments, 319  
 Ultrasonic retropreparations, 178  
 Ultrasonic vibration, 171–172  
 Uncomplicated fractures, 231–232, 234f, 260  
 Unmyelinated C fibers, 32–33
- V**
- Validity, 5f, 5–6  
 Varicella zoster virus, 19, 97, 276  
 Vasculature, pulpal, 34–36, 35f  
 Vazirani-Akinosi technique, 152  
 Venous drainage, 44  
 Venous-venous anastomoses, 35  
 Vertical condensation, 169  
 Vertical releasing incision, 177  
 Vertical root fractures

## Index

- bacterial ingress via, into dental pulp, 258
  - bone loss areas associated with, 262
  - clinical presentation of, 261–262
  - cone beam computed tomography of, 235, 262, 262f
  - description of, 123, 124f
  - endodontic therapy failure caused by, 326, 327f
  - factors associated with, 261
  - imaging of, 262, 262f
  - periodontal probing depths associated with, 261–262
  - prognosis for, 263
  - radiographic findings in, 261f, 262
  - Vertucci's root canal classification system, 37, 37f
  - Vibrothermography, 258
  - Vicodin, 88t
  - Viruses, 19, 19f, 276
  - Vital pulp therapy
    - pulp capping, 184–186, 185f, 298
    - pulpotomy, 186–187, 187f, 299
    - purpose of, 184
    - success rates for, 298–299
  - Vitamin D–resistant rickets, 142, 146
  - VZV. *See* Varicella zoster virus.
- W**
- Working lengths, 157f, 157–158
- X**
- Xenografts, 180, 180f
- Z**
- "Zones of Fish," 12, 12f