Treatment Standards

Introduction

Endodontics is the branch of dentistry that is concerned with the morphology, physiology and pathology of the human dental pulp and periradicular tissues. Its study and practice encompass the basic clinical sciences including biology of the normal pulp, and etiology, diagnosis, prevention and treatment of diseases and injuries of the pulp and associated periradicular tissues as defined by the American Dental Association and American Association of Endodontists.

The American Association of Endodontists serves as a trusted and credible source for information on diagnosis of pulp and periapical pathosis, treatment planning, urgent/emergent treatment, vital pulp therapy, nonsurgical root canal treatment, surgical endodontics, regenerative endodontic procedures, and outcome assessment.

Treatment by the general dentist is expected to meet minimum standards as set out in guidelines the American Association of Endodontists has developed and published as "Standards of Practice." These guidelines were developed to assist educational institutions and organized dentistry in developing minimum educational requirements and practice standards in endodontic treatment.

The primary objective of endodontic treatment is to prevent and intercept pulpal/periradicular pathosis and to preserve the natural dentition when affected by pathosis. The practice model in the United States is predicated on general dentists having the basic knowledge and experience regarding endodontic treatment to perform the majority of nonsurgical root canal procedures on uncomplicated permanent teeth.

Despite similar predoctoral educational curricula, disparities exist in the levels of knowledge, competency and skill, and clinical experiences of general dentists. Over the past two decades there have been significant advances in technology, materials and endodontic treatment procedures. These include but are not limited to microscopy, rotary Ni-Ti files, ultrasonics, enhanced irrigation solutions and technologies, digital radiography, CBCT three-dimensional imaging, bioceramics, etc. **These changes have created a disparity in the quality of care provided by specialists versus general dentists on teeth with complicated anatomy and morphology.**

The effect of these developments on the standard of care remains unknown. Currently, general dentists perform approximately 75% of all nonsurgical endodontic procedures. While endodontists perform only 25% of the total root canal procedures, they treat 62% of the molars. With generalists performing the majority of the uncomplicated anteriors and premolars it appears that the predoctoral educational process and procedures in general practice should be concentrated on uncomplicated permanent teeth with specialists treating the more complicated molars.

Treatment is based on a thorough understanding and interpretation of all diagnostic information including patient history, clinical and radiographic examination. Following the establishment of a diagnosis, treatment planning should consider the following patient modifiers: the strategic importance of the tooth/teeth being treated; the periodontal status, structural integrity and restorability of the tooth; the long-term prognosis for success; and patient factors such as medical status, attitude and desires, motivation, anxiety, jaw opening, gag reflex, disease state, and financial resources.

The scope of endodontics in **general dentistry** includes:

- Differential diagnosis and treatment of pain and/or swelling of pulpal and/or periradicular origin
- Urgent/emergent treatment of pain and/or swelling to include the pharmacologic use of antibiotics, anti-inflammatory agents, analgesic drugs and incision for drainage of localized abscesses
- Urgent/emergent management of traumatic injuries to the dentoalveolar structures
- Vital pulp treatment to include stepwise caries excavation, indirect and direct pulp capping, and pulpotomy procedures
- Nonsurgical root canal treatment for the permanent dentition
- Bleaching of discolored dentin and enamel of teeth
- Treatment procedures such as post and/or cores involving the root canal space

STANDARD OF PRACTICE

General dentists should provide endodontic treatment consistent with contemporary endodontic standards, their knowledge and clinical experience, and technical skills. The standards of practice are constantly changing based on new evidence and technology. It is the responsibility of all practitioners to be life-long learners, in order to meet contemporary standards.

Self-evaluation is a critical component of life-long learning. Generalists should be able to critically evaluate their own competency as diagnosticians and clinicians and identify areas that require additional educational experiences. **Based on this evaluation each practitioner must be able to determine his or her own skill and learning in order to determine when the patient should be referred to the appropriate specialist for consultation/treatment.**

Methods of traditional education and the emphasis on facts are changing. Information technology has transformed the dental profession and placed emphasis on the evidence-based practice model. Contemporary methods of education emphasizing problem solving and critical thinking skills and stress professional interactions and the benefits of interdisciplinary care.

AAE Case Difficulty Assessment Form

Following examination and testing, a diagnosis is established, a treatment plan is formulated and the prognosis determined. The general dentist then must determine the degree of difficulty and associated risks. The AAE Case Difficulty Assessment Form provides a national protocol for accomplishing this assessment.

There are many factors that influence degrees of difficulty and risk of endodontic treatment. Recognition of these factors ***prior*** to the initiation of treatment helps practitioners to understand the complexities that may be involved in individual cases and prevents adverse outcomes due to avoidable procedural errors.

In determining the degree of difficulty, a general dentist should not undertake treatment of a case unless he /she is prepared to also manage complications that may arise in treatment.

AAE Endodontic Case Difficulty Assessment Form and Guidelines

Patient Information

Full Name

Street Address Suite/Apt

City State/Country Zip

Phone

Email

Disposition

Treat in Office: Yes No

Refer Patient to:

Date

Guidelines for Using the AAE Endodontic Case Difficulty Assessment Form

The AAE designed the Endodontic Case Difficulty Assessment Form for use in endodontic curricula. The Assessment Form makes case selection more efficient, more consistent and easier to document. Dentists may also choose to use the Assessment Form to help with referral decision making and record keeping.

Conditions listed in this form should be considered potential risk factors that may complicate treatment and adversely affect the outcome. Levels of difficulty are sets of conditions that may not be controllable by the dentist. Risk factors can influence the ability to provide care at a consistently predictable level and impact the appropriate provision of care and quality assurance.

The Assessment Form enables a practitioner to assign a level of difficulty to a particular case.

LEVELS OF DIFFICULTY

MINIMAL DIFFICULTY
Preoperative condition indicates routine complexity (uncomplicated). These types of cases would exhibit only those factors listed in the MINIMAL DIFFICULTY category. Achieving a predictable treatment outcome should be attainable by a competent practitioner with limited experience.

MODERATE DIFFICULTY
Preoperative condition is complicated, exhibiting one or more patient or treatment factors listed in the MODERATE DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for a competent, experienced practitioner.

HIGH DIFFICULTY
Preoperative condition is exceptionally complicated, exhibiting several factors listed in the MODERATE DIFFICULTY category or at least one in the HIGH DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for even the most experienced practitioner with an extensive history of favorable outcomes.

Review your assessment of each case to determine the level of difficulty. If the level of difficulty exceeds your experience and comfort, you might consider referral to an endodontist.

CRITERIA AND SUBCRITERIA	MINIMAL DIFFICULTY	MODERATE DIFFICULTY	HIGH DIFFICULTY
A. PATIENT CONSIDERATIONS			
MEDICAL HISTORY	☐ No medical problem (ASA Class 1*)	☐ One or more medical problem (ASA Class 2*)	☐ Complex medical history/serious illness/disability (ASA Classes 3-5*)
ANESTHESIA	☐ No history of anesthesia problems	☐ Vasoconstrictor intolerance	☐ Difficulty achieving anesthesia
PATIENT DISPOSITION	☐ Cooperative and compliant	☐ Anxious but cooperative	☐ Uncooperative
ABILITY TO OPEN MOUTH	☐ No limitation	☐ Slight limitation in opening	☐ Significant limitation in opening
GAG REFLEX	☐ None	☐ Gags occasionally with radiographs/ treatment	☐ Extreme gag reflex which has compromised past dental care
EMERGENCY CONDITION	☐ Minimum pain or swelling	☐ Moderate pain or swelling	☐ Severe pain or swelling

The contribution of the Canadian Academy of Endodontics and others to the development of this form is gratefully acknowledged.

B. DIAGNOSTIC AND TREATMENT CONSIDERATIONS

DIAGNOSIS	☐ Signs and symptoms consistent with recognized pulpal and periapical conditions	☐ Extensive differential diagnosis of usual signs and symptoms required	☐ Confusing and complex signs and symptoms: difficult diagnosis ☐ History of chronic oral/facial pain
RADIOGRAPHIC DIFFICULTIES	☐ Minimal difficulty obtaining/interpreting radiographs	☐ Moderate difficulty obtaining/interpreting radiographs (*e.g.*, high floor of mouth, narrow or low palatal vault, presence of tori)	☐ Extreme difficulty obtaining/interpreting radiographs (*e.g.*, superimposed anatomical structures)
POSITION IN THE ARCH	☐ Anterior/premolar ☐ Slight inclination (<10°) ☐ Slight rotation (<10°)	☐ 1st molar ☐ Moderate inclination (10-30°) ☐ Moderate rotation (10-30°)	☐ 2nd or 3rd molar ☐ Extreme inclination (>30°) ☐ Extreme rotation (>30°)
TOOTH ISOLATION	☐ Routine rubber dam placement	☐ Simple pretreatment modification required for rubber dam isolation	☐ Extensive pretreatment modification required for rubber dam isolation
CROWN MORPHOLOGY	☐ Normal original crown morphology	☐ Full coverage restoration ☐ Porcelain restoration ☐ Bridge abutment ☐ Moderate deviation from normal tooth/root form (*e.g.*, taurodontism microdens) ☐ Teeth with extensive coronal destruction	☐ Restoration does not reflect original anatomy/alignment ☐ Significant deviation from normal tooth/root form (*e.g.*, fusion dens in dente)
CANAL AND ROOT MORPHOLOGY	☐ Slight or no curvature (<10°) ☐ Closed apex (<1 mm in diameter)	☐ Moderate curvature (10-30°) ☐ Crown axis differs moderatel from root axis. Apical opening 1-1.5 mm in diameter	☐ Extreme curvature (>30°) or S-shaped curve ☐ Mandibular premolar or anterior with 2 roots ☐ Maxillary premolar with 3 roots ☐ Canal divides in the middle or apical third ☐ Very long tooth (>25 mm) ☐ Open apex (>1.5 mm in diameter)
RADIOGRAPHIC APPEARANCE OF CANAL(S)	☐ Canal(s) visible and not reduced in size	☐ Canal(s) and chamber visible but reduced in size ☐ Pulp stones	☐ Indistinct canal path ☐ Canal(s) not visible
RESORPTION	☐ No resorption evident	☐ Minimal apical resorption	☐ Extensive apical resorption ☐ Internal resorption ☐ External resorption

C. ADDITIONAL CONSIDERATIONS

TRAUMA HISTORY	☐ Uncomplicated crown fracture of mature or immature teeth	☐ Complicated crown fracture of mature teeth ☐ Subluxation	☐ Complicated crown fracture of immature teeth ☐ Horizontal root fracture ☐ Alveolar fracture ☐ Intrusive, extrusive or lateral luxation ☐ Avulsion
ENDODONTIC TREATMENT HISTORY	☐ No previous treatment	☐ Previous access without complications	☐ Previous access with complications (*e.g.*, perforation, non-negotiated canal, ledge, separated instrument) ☐ Previous surgical or nonsurgical endodontic treatment completed
PERIODONTAL-ENDODONTIC CONDITION	☐ None or mild periodontal disease	☐ Concurrent moderate periodontal disease	☐ Concurrent severe periodontal disease ☐ Cracked teeth with periodontal complications ☐ Combined endodontic/periodontic lesion ☐ Root amputation prior to endodontic treatment

*American Society of Anesthesiologists (ASA) Classification System Class 1: No systemic illness. Patient healthy. Class 2: Patient with mild degree of systemic illness, but without functional restrictions, e.g., well-controlled hypertension. Class 3: Patient with severe degree of systemic illness which limits activities, but does not immobilize the patient. Class 4: Patient with severe systemic illness that immobilizes and is sometimes life threatening. Class 5: Patient will not survive more than 24 hours whether or not surgical intervention takes place. asahq.org/clinical/physicalstatus.htm

TREATMENT PROCEDURES

A variety of endodontic techniques, materials and treatment philosophies present a challenge to dental practitioners, patients, governing bodies and other interested parties making decisions about the appropriateness and/or quality of endodontic care.

Endodontic treatment procedures should be of such quality that predictable and favorable results will occur with the understanding that in a biologic system treatment procedure that are appropriate may not always result in a successful outcome. Success is dependent on many variables that may preclude a successful outcome. These factors include but are not limited to the patient's medical and dental condition, patient compliance, variations in anatomy and morphology, and complications during the procedure.

When practitioners are presented with challenges during treatment that risk procedural errors and poor outcomes, consultation and referral are always valid options.

CONSIDERATIONS

General dentists must recognize that pulp and periradicular pathosis is primarily a microbial disease. Strict adherence to aseptic procedures to include the use of the rubber dam is required.

Nonsurgical root canal treatment must employ materials proven to be biocompatible. For example, the use of paraformaldehyde containing sealers and pastes are below the standard of care for endodontic treatment.

Nonsurgical Endodontics

UNCOMPLICATED MATURE PERMANENT TEETH

Nonsurgical root canal treatment is indicated primarily in cases of irreversible pulpitis and when pulp necrosis with and without periapical pathosis occurs. However, elective root canal treatment may be considered for restorative treatment planning and for overdentures or where teeth need to be preserved over extraction in patients who are receiving systemic treatments including head and neck radiation treatment, bisphosphonates, chemotherapy, and/or corticosteroids.

Endodontic treatment involves chemo-mechanical preparation of the root canal system to eliminate organic, inorganic and bacterial products and sealing of the radicular space with a biocompatible material (obturation). Root canal sealers are used in conjunction with the core filling material to establish an adequate three-dimensional seal and induce hard tissue formation in healing outcomes.

Root Canal Disinfection

- ***Intent statement:*** A practicing dentist should be able to safely and effectively utilize standard disinfection protocols in the irrigation and medication of root canal spaces.

The primary etiologic agents of apical periodontitis are microorganisms and their byproducts that have invaded the pulpal space and established multispecies biofilm communities in the root canal system. Biofilms are involved in all stages of root canal infection and can be found on root canals walls, in dentinal tubules, and on extraradicular surfaces.

The clinical management of infected root canals undergoing nonsurgical root canal treatment involves instrumentation and disinfection. Instrumentation disrupts biofilms which colonize infected soft and hard tissues, and provides access for irrigation and exposure to antimicrobial solutions for disinfection of the root canal system. Disinfection is achieved by the use of both antimicrobial agents and the mechanical flushing action of irrigation, with the goal being the disruption, displacement and removal of pulpal remnants, microorganisms, metabolic byproducts, debris and the smear layer created during instrumentation. When treatment is provided over multiple appointments, interappointment intracanal medicaments provide additional opportunities for disinfection.

The development of irrigation and disinfection clinical protocols in current use has been based primarily on the findings reported in classic studies that used methods of aerobic and anaerobic culturing of viable microorganisms. More recent studies using molecular and advanced imaging techniques have shown the endodontic microflora to be significantly more complex than can be shown by culture methods, and that biofilms and debris can remain in inaccessible areas of the root canal system, regardless of clinical techniques used during treatment. Taken together, these studies have established that disinfection rather than sterilization of infected root canals is a reasonable and achievable expectation. The overall goal is to provide an environment that will enable healing.

IRRIGANTS AND MEDICAMENTS

The ideal irrigant should be an effective antimicrobial agent and organic tissue solvent, nonirritating, stable and easily stored. It should be active in the presence of blood and serum, nonstaining, nonantigenic, nontoxic, have low surface tension, and be nondestructive to dentin, apical tissues and endodontic instruments. Ideally, it should remove the smear layer and disinfect dentinal tubules. Substantivity (persistence of effect) may be desirable as long as residue is not left that could interfere with root canal obturation. Irrigants ideally should be convenient and inexpensive. There is no single solution currently available that possesses all of the aforementioned desirable qualities.

Irrigants currently used for endodontic treatment are may be categorized as:

1. **Antimicrobial agents [e.g. sodium hypochlorite (NaOCl), chlorhexidine (CHX)]**
   The most commonly used antimicrobial irrigant is NaOCl, an oxidizing agent that releases chlorine in the form of hypochlorous acid (HOCl). NaOCl has a dose-dependent effect on polymicrobial biofilms, with higher concentrations being more effective. NaOCl is an excellent organic tissue solvent and can be used to remove the organic component of the smear layer. Continuous exchange of fresh solution and agitation enhances the tissue dissolution capability of NaOCl. A major disadvantage of NaOCl is its toxicity, particularly in the event of extrusion into the periradicular tissues.
   Chlorhexidine is a cationic bisbiguanide with concentration-dependent antibacterial and substantivity properties. It is available in both liquid and gel form. While CHX has a broad spectrum of antimicrobial activity, it lacks tissue solvent properties, and is less effective against biofilms than NaOCl.

2. **Demineralizing agents [e.g. ethylenediaminetetraacetic acid (EDTA)]**
   During instrumentation, dentin demineralization can be facilitated by the action of chelating agents such as EDTA which are capable of forming soluble nonionic chelates with metallic ions, such as calcium found in hydroxyapatite crystals. Chelating agents assist in the negotiation and enlargement of severely constricted or obstructed root canals, as well as the removal of the inorganic component of the smear layer immediately prior to root canal obturation. EDTA is typically used as a buffered solution, with or without a surfactant or antiseptic.

3. **Combinations of agents, with or without detergents, antibiotics, antiseptics and future directions**
   The flow of antimicrobial agents can be enhanced by the addition of surfactants that decrease surface tension thereby potentially enabling better penetration and access to narrower, confined portions of the root canal system. Solutions with low antimicrobial activity may be combined with antiseptics to enhance their usefulness. In the near future, advanced research with nanoparticles and energy activation of solutions will help future clinicians meet the challenges of biofilm tenacity and the complexity of root canal systems.

Medicaments should be placed as interappointment intracanal dressings if treatment is completed over multiple visits. Medicaments can reduce the microbial count of species remaining in the root canal system, prevent regrowth and detoxify endotoxin. Even for the vital tooth undergoing nonsurgical root canal treatment over multiple visits, the placement of intracanal medicaments can help mitigate the consequences of inadvertent contamination or unanticipated leakage of the interim restoration. When used, the medicament should entirely fill the canal to allow for optimal efficacy.

Currently, calcium hydroxide [$Ca(OH)_2$] is the primary choice of intracanal medicament. In addition to its antimicrobial action, the alkaline pH of $Ca(OH)_2$ facilitates dissolution of organic tissues and bacterial products such as endotoxin. $Ca(OH)_2$ can be placed as a slurry (powder mixed with a liquid such as saline or sterile water) or as a proprietary paste via syringe, lentulo, or paper point delivery. It should be noted that $Ca(OH)_2$ can be highly toxic if expressed into the neurovasculature tissues so delivery method should be based on the clinical parameters of each case.

It should be noted that no particular antimicrobial irrigant or medicament can claim to result in superior healing outcomes. As such, decisions on which irrigant(s) to employ may be based on factors such as clinicians' skill, efficiency of treatment, case selection and costs incurred.

IRRIGATION DELIVERY

The aim of irrigation is to physically disrupt and debride the root canal. Intracanal irrigation provides a stream of chemicals to induce antimicrobial activity, demineralization, tissue dissolution, lubrication, bleaching and hemorrhage control. The current or force created by irrigation carries debris towards the orifice; the efficacy of this process is influenced by factors such as surface area, volume of solution and solution exchange. Irrigation should be employed at each instrument change with the total volume of irrigating solution dependent on the size, shape and number of canals. Irrigants should be confined to the root canal space.

Current irrigation delivery techniques are categorized as follows:

1. **Needle and syringe ("conventional," "positive pressure")**
   The most common irrigation technique utilizes needle and syringe delivery. Effectiveness is dependent on the depth of insertion of the needle and is improved with increased apical size and taper of the root canal. Needle gauge should be based on case selection and canal size. Canals need to be enlarged sufficiently for the needle to be placed loosely in the canal to the desired depth. This will depend on factors including root length, curvature and apical anatomy. Clinicians must avoid placing excessive pressure on the syringe during irrigation, and ensure that the needle is not bound in the canal nor inserted too deeply into the canal of a tooth with a wide-open apex. Slow injection using side-venting needles and constant movement in small, vertical amplitudes can help prevent hydrostatic buildup.
2. **Negative pressure**
   The rationale behind negative pressure irrigation delivery is to reverse the direction of irrigant flow away from the apex thereby minimizing the risk of apical extrusion of irrigant compared to other approaches.
3. **Energy activated devices used alone or as supplementary methods**
   Activation systems (sonic and ultrasonic) aim to enhance the movement of irrigant solutions within the confines of the root canal space in order to disrupt biofilms and debris, and facilitate their removal.

No particular irrigation delivery technique can claim to induce superior healing success. Decisions on which system to employ may be based on factors such as clinicians' skill, efficiency of treatment, case selection and costs incurred.

ESSENTIAL CONSIDERATIONS WITH THE USAGE OF NAOCL AS AN IRRIGANT

1. In the event that NaOCl is extruded into the periradicular tissues, the patient may experience immediate severe pain, bleeding, ecchymosis and, potentially, long-term paresthesia. If a predisposing risk for irrigant extrusion into the periradicular tissues is suspected, such as open apices, root perforation or vertical root fracture, clinicians should proceed with caution, or consider using a less toxic irrigant.
2. The higher the concentration of NaOCl, the greater its antimicrobial activity, but also the greater its toxicity and potential adverse effect on biomechanical properties of dentin. If clinicians prefer to use lower concentrations, antimicrobial activity can be facilitated by using higher volumes and increasing the frequency of irrigation.
3. The majority of information on the clinical usage of NaOCl has been obtained on concentrations of between 0.5% to ~6%; the efficacy and toxicity associated with higher concentrations is not known.

FINAL CONSIDERATIONS IN ROOT CANAL DISINFECTION

1. The use of rubber dam is mandatory to avoid microbial contamination of the root canal system during treatment, to retract tissues and protect the patient, prevent aspiration or swallowing of instruments, and limit aerosols.
2. While many current concepts about root canal irrigation and irrigants evolved in earlier times, the fundamental goals of disinfection, tissue debridement, lavage and lubrication remain unchanged.

3. The majority of clinical studies have used NaOCl as an irrigant delivered via conventional irrigation techniques that flushed the canal without the application of energy; these studies have formed the basis for treatment outcome estimations.
4. The best approach to controlling microbes during endodontic treatment is the use of aseptic technique, effective debridement, local antimicrobials, systemic antibiotics only if indicated, and optimal apical and coronal seal.

Access Preparation and Instrumentation of Root Canal Systems

ACCESS CAVITY PREPARATION

- ***Intent statement:*** A practicing dentist should be able to predictably access the pulp chamber for the purpose of performing root canal treatment by locating all main canal orifices.
- ***Intent statement:*** A practicing dentist when accessing a pulp chamber should be able to minimize excessive removal of tooth structure and structural damage to the treated tooth, including prevention of perforations.

PURPOSE OF ACCESSING THE PULP CHAMBER

All intracanal procedures require a preparation through the coronal structure in a prescribed location and opening of the pulp space. The ultimate goal of this step is to expose the pulp chamber and radicular space for subsequent instrumentation, irrigation, debridement and antimicrobial treatment. Therefore, it is essential that all canal orifices are identified and rendered accessible.

Following treatment, all root canal-treated teeth must receive a definitive restoration to protect the remaining tooth structure and promote longevity and function. To fulfill this objective, it is essential that the coronal access opening be made with the least damage to dental structures.

INFORMATION GATHERING PRIOR TO ACCESS

In order to prepare an access cavity appropriately, that is in the correct orientation and location, preoperative knowledge of the tooth anatomy and morphology must be considered by the clinician regarding the number and location of canal orifices, and the incidence and configuration of anatomical variations within any given tooth. Towards this goal, well-angulated preoperative radiographic images are mandatory to facilitate a safe and efficient access; negotiation of the root canal system; and to minimize the risk of procedural errors that may result from unexpected anatomical complexity or an inappropriate orientation. Periapical films and bite-wings (for posterior teeth) provide an initial direction and alignment of pulp chamber and root canal position. Although two radiographs with different angulations are often sufficient to develop a 3-D image of the tooth to be treated, cone beam computed tomography (CBCT) images may be necessary to evaluate the existence of extra canals, complex morphologies, curvatures and/or dental developmental anomalies.

Images should be studied carefully, and coronal access aided by enhanced magnification and lighting in complicated cases is warranted and appropriate. Currently, the use of the dental operating microscope is the highest achievable level of lighting and magnification and is justified when pulpal complexity and natural deposition of mineral reduces prognosis and affects a successful outcome. **Cases with anatomical and morphologic complexity and potential clinical challenges beyond a practitioner's skill level should be referred to a colleague with specialty skills in endodontics.**

PERFORMING THE ACCESS PREPARATION

For optimal aseptic conditions, a rubber dam must be in place before commencing access cavity preparation. Yet, there are rare clinical situations in tooth alignment or rotation, particularly where treatment is undertaken by inexperienced clinicians, when accessing before rubber dam isolation for cleaning and disinfection may have benefits; however, the rubber dam must be applied prior to introducing endodontic files and instruments and canal preparation. Standardized access cavity outlines for each tooth help to mitigate some of the risks involved. These risks include perforation as well as inappropriate and excessive tissue loss.

Appropriate access provides a convenience form, in which the smallest possible dimensions of an access cavity are dictated by the precise location of canal entrances on the pulpal floor. The concept of a so-called straight-line approach to an orifice and further to the primary curvature of the root canal is relevant to minimize procedural errors during subsequent treatment procedures. A large access with divergent walls is not required for the use of contemporary flexible and fatigue-resistant root canal instruments.

Access preparation is more readily achieved with magnification, enhanced lighting, and appropriate instruments. Many teeth have suffered considerable tissue loss prior to endodontic intervention, and it may be even more important in such cases to adopt a thoughtful, deliberate, and conservative approach to access in order to avoid further unnecessary tissue loss and structural weakening.

In most generalist practices, practitioners are encouraged to work as conservatively as reasonable. Clinical steps include establishing the appropriate coronal outline form with a high speed handpiece under water cooling and penetration into the pulp chamber towards the largest pulp horn. The outline is then refined, including unroofing the chamber with a non-end cutting bur which is unlikely to damage the chamber floor or walls or by using a slow speed handpiece. When the dental operating microscope is available, conventional high- and low-speed burs may be less desirable, and practitioners may prefer to selectively unroof the chamber with specially designed ultrasonically energized tips that improve visual access, while providing high cutting efficiency, combined with safety and control. Specifically designed endodontic burs and micro-instruments are available to facilitate such procedures under microscopic magnification and illumination.

DETRIMENTAL OUTCOMES DURING ACCESS

A perforation on access, either towards the furcation in multi-rooted teeth, or towards the periodontal ligament in other locations, significantly reduces the outcome of the overall treatment. However, subtler structure loss is also associated with reduced prognosis for long-term retention of root canal-treated teeth. Endodontically treated teeth are more frequently extracted because of fracture than because of persistent apical pathosis and efforts to maintain tooth structure are beneficial.

These contemporary concepts in access cavity design change the current focus from coronally divergent preparations to the selective preservation of dentin, prioritizing the removal of caries and restorative material ahead of tooth structure. However, the focus on dentin preservation should not mean that treatment goals must be compromised, and access preparation should not be so restrictive as to impede the location and entry of instruments into all canal orifices for safe and efficient cleaning and shaping procedures. Cavities cut within restorative materials such as composite or amalgam can often be slightly larger. Complete removal of existing restorative materials in their entirety provide a better coronal seal and allow a more complete understanding of the remaining tooth structure and restorability of the tooth following treatment.

MEASURING COMPETENCE

Competence in accessing root canal systems is demonstrated by the following skills:

- Appropriate preoperative evaluation of anatomy and morphology and the analysis of the skill level necessary to predictably find and reveal all canal orifices
- Understanding structural parameters and the prognosis for adequate ferrule related to dentin height and width at the restoration interface
- Designing and creating access cavities with respect to specific internal anatomy and orientation in the oral cavity of the patient
- Preparing coronal access preparations that preserve tooth structure, are centered in the coronal position, are measured for depth and long axis orientation, permit location and instrumentation of all canals, and prevent perforations (lateral and furcal)

ROOT CANAL PREPARATION

- ***Intent statement:*** A practicing dentist performing root canal preparation should be able to determine and maintain an appropriate working length.
- ***Intent statement:*** A practicing dentist performing root canal preparation should be able to prepare a canal to width conducive to debridement, subsequent antimicrobial treatment, and obturation.
- ***Intent statement:*** A practicing dentist performing root canal preparation should be able to avoid procedural mishaps, including but not limited to, damage to major vascular and/or neural structures, canal transportation, ledge formation, canal blockage, file fracture, and perforation.

PURPOSE OF THE PREPARATION OF ROOT CANALS

Clinical procedures for root canal instrumentation have two fundamental goals: to preserve the natural dentition for the lifetime of the patient (retention) and to treat or prevent apical periodontitis (healing). These are not mutually exclusive goals and both are important. There is solid evidence that débriding all canals to working length demonstrates competence in treating apical periodontitis while committing over-preparation errors or filling beyond the confines of the root canal system impedes success and significantly reduces prognosis for retention.

The purpose of shaping is to facilitate debridement and disinfection and to provide space for the placement of obturation materials. The main technical objectives of shaping are to maintain the apical foramen in its original position, allowing it to remain as small as possible, and to develop a continuously tapering funneled preparation from the canal orifice to the apex allowing the tapered shape to provide apical resistance during obturation.

METRICS OF CANAL PREPARATION: APICAL WIDTH AND LENGTH

Based on studies of apical anatomy, the ideal apical point of termination, also known as working length, has been established empirically to be 0.5 to 1.0 mm from the radiographic apex. Contemporary clinical evidence lists significant adverse factors that influence success such as the creation of a ledge or perforation, preoperative periradicular disease, and incorrect length of the root canal preparation and subsequent filling more than 2.0 mm short of the radiographic apex or obturation materials extruded and not confined to the canal space.

Traditionally the working length has been determined with periapical radiographs, however, it is recommended that an electronic apex locator is used in conjunction with verifying radiographs to approximate the location of the apical constriction and terminate canal preparation accordingly. The decision of where to terminate the preparation in a specific case will be based on knowledge of apical anatomy, tactile sensation, radiographic interpretation, information from apex locators, the presence of apical bleeding, and occasionally the patient's response.

DEGREE OF APICAL ENLARGEMENT

Generalizations may be made regarding tooth anatomy and morphology, although ***each tooth is unique.*** Because morphology is variable, there can be no standardized apical canal size. Rather, the degree of enlargement is dictated by the initial canal size, the irrigation regime and the obturation technique employed. A sufficient canal size is currently required for mechanical debridement and to place antimicrobial solutions into contact with the root canal system.

However, as dentin is removed from the canal walls, the root becomes less resistant to fracture and the risk of preparation errors increases. For example, narrow thin roots, such as in mandibular incisors, may not be enlarged to the same degree as bulkier roots, such as maxillary central incisors or canines. Likewise, many canals in multirooted teeth such as mesial canals in mandibular molars and buccal canals in maxillary molars are delicate and curved limiting canal preparation size. In molars, the radicular wall thickness towards the furcation can be 1.0 mm or less. Apical canal enlargement must not be done at the expense of coronal dentin.

ELIMINATION OF ETIOLOGY

In cases of root canal treatment of teeth with vital pulp tissue (irreversible pulpitis and elective treatment procedures), complete removal of the tissue and creating sufficient space for obturation materials is the objective. With pulpal necrosis, root canal walls are typically covered with a polymicrobial bacterial biofilm, extending into secondary anatomy such as fins, isthmuses and accessory canals. A variety of microbial species can also penetrate deep into dentinal tubules.

The development of nickel-titanium instruments has dramatically changed the techniques of cleaning and shaping; these instruments have been rapidly adopted by clinicians around the world. The primary advantage to using these flexible instruments is a significant reduction in the incidence of preparation errors.

Neither hand instruments nor rotary files have been shown to completely debride the canal system. Mechanical enlargement of the canal space dramatically decreases the presence of microorganisms present in the canal, but cannot render the canal sterile. Therefore, the use of antimicrobial irrigants is essential in addition to mechanical preparation techniques. These irrigants are delivered by a needle-and-syringe system and may effectively extend within the main canal space. However, the presence of dentin debris in accessory canal spaces and the complexity of most root canal systems remain impediments to effective irrigation.

DETRIMENTAL OUTCOMES OF CANAL PREPARATION

With ineffective length control, files may be overextended and directly impact the periodontal ligament and strategic structures such as the mental and inferior alveolar nerves, and maxillary sinus. Likewise, errors in canal preparation, resulting in canal perforations either at midroot or in the apical canal third, can lead to the extrusion of irrigation solutions or filling material and secondarily damage structures. Other preparation errors, such as instrument fracture, as well as canal transportation, ledge and blockage formation, are impediments to complete debridement. Instrumentation must only be performed after proper understanding of canal complexities and with consideration of the specific instruments that are used.

MEASURING COMPETENCE

Competence in shaping of root canals is demonstrated by the following skills:

- Ability to predictably enlarge canal spaces to mechanically remove vital or necrotic tissues and microorganisms; provide effective space for antimicrobial solutions and intracanal medicaments, and the insertion and condensation of obturation materials.
- Conscious determination and maintenance of an exact apical end point and restricting canal preparation to the confines of the root canal
- Selecting instruments and treatment sequences that minimize damage to radicular structures
- In-depth understanding of the development of procedural errors and ways to avoid these
- Patient-oriented decision making when recognizing procedural errors

Endodontic Obturation

Shaping any root canal system promotes disinfection and obturation and is the cornerstone of nonsurgical endodontics. All healing outcomes, both long- and short-term, center on the technical quality and attention to detail invested in these steps.

Most importantly, clinicians should continually evaluate any treatment step, and the scientific and clinical evidence supporting the treatment for its impact on overall outcomes, clinical healing, as well as the outcome of long-term retention of the natural dentition over the course of the patient's lifetime.

There is solid evidence that debriding all canals to working length is efficient in treating apical periodontitis, while committing preparation errors or filling beyond the confines of the root canal system is detrimental to this healing process.

- ***Intent statement:*** A practicing dentist must be able utilize obturation techniques and materials that protect the patient from untoward outcomes, and maximize the potential for healing and well-being.
- ***Intent statement:*** A practicing dentist must demonstrate well-prepared and filled root canals that display a homogenous radiopaque appearance, free of voids and filled to working length.
- ***Intent statement:*** A practicing dentist must protect the patient by avoiding overfill in the presence of vulnerable structures or neurovascular anatomy.

Molar endodontics is inherently more difficult than root canal treatment for central maxillary incisors for several reasons, notably the more complex anatomy and the location of the teeth in the patients' mouth, among other factors such as anesthesia. Any anatomical complexity, no matter its position in the arch or the tooth requires that the successful clinician will consider the specific patient's needs and be competent to manage the unusual or untoward occurrence.

ESSENTIAL CONSIDERATIONS IN EFFECTIVE OBTURATION

Only a well-prepared canal system can provide ideal conditions for appropriate obturation. A well-shaped and well-debrided canal system will potentially create the conditions for healing periapical tissues. Because a root canal system is inaccessible to the body's immune system, best practice dictates that root canals should be filled as completely as possible in all dimensions, in order to prevent ingress of nutrients or oral microorganisms. None of the established techniques for root canal filling provides a definitive coronal, lateral, and apical seal. For this reason, a permanent coronal restoration should be placed as soon as feasible after the endodontic treatment.

Ideally, a root canal filling should seal all foramina leading to the periodontium, be without voids, be adapted to the instrumented canal walls, and end at the apical terminus. The following considerations will help to provide a fluid-tight seal of the cleaned and prepared root canal system in order to protect periradicular tissues from bacterial recontamination.

There are many clinically acceptable materials and techniques for root canal filling; the spectrum of root canal fillings includes:

1. Sealer (cement/paste/resin) only.
2. Sealer and a single cone of a stiff or flexible core material
3. Sealer coating combined with three-dimensional lateral compaction of core materials
4. Sealer coating combined with three-dimensional warm compaction of core materials
5. Sealer coating combined with carrier-based core materials

It is important to recognize that many states in the U.S. adhere to the "respectable minority rule." Just because a treating dentist uses different materials or performs a procedure differently, it does not make the dentist's treatment below the standard of care. However, paraformaldehyde pastes and holistic dentistry that advocates and recommends wholesale extraction of endodontically treated teeth or removal of all metallic fillings, claiming systemic harm, are unacceptable and disrespected minority views.

Studies have shown paste-only techniques are subject to volume shrinkage during their set. As such, the material pulls away from the walls as it sets and the resultant loss of interface adhesion leaves gaps and/or channel formations between the dentin wall and the set sealer. Controlling length and density is difficult and extrusion is a major risk. With the increased risk of extrusion, the toxicity of certain sealers such as paraformaldehyde-containing pastes is a great concern.

Several of these techniques have shown comparable success rates regarding apical bone fill or healing of periradicular lesions, so that a clinician may choose from a variety of techniques and approaches that work best for each specific case and/or clinician. All of these recommended techniques utilize a solid core material as well as sealer. The following lists the main steps in root canal obturation:

1. Choosing a technique for obturation
2. Selection of master cones and/or sealer strategy
3. Canal drying and sealer application
4. Adapting the cone to the canal and verifying the position and fit
5. Obturating the apical portion (lateral and vertical compaction)
6. Completing the obturation process
7. Assessing the quality of the overall obturation

No particular technique can claim superior healing success. Decisions on which system to employ may be based on such factors as clinicians' skill, efficiency of treatment, case selection, simplicity of procedures involved and costs incurred.

All root canals to be filled should be assessed before choosing a technique. In the presence of open apices or procedural errors such as apical transportation from the original canal position, and also in teeth with apices in close proximity to the mandibular canal or the sinus, there is the potential for overfills and serious injury. In general, canals should only be filled when the patient is asymptomatic, there are no signs or symptoms of pathosis, and the canal can be dried.

Before solid core materials or gutta-percha cones may be tried in a root canal, they should be disinfected by submerging them in an NaOCl solution.

Most sealers are toxic in the freshly mixed state, but this toxicity is reduced after setting. When in contact with tissues and tissue fluids, zinc oxide eugenol-based sealers are absorbable while resin-based materials typically are slow to absorb or are not readily absorbed. Some byproducts of sealers may adversely affect and delay healing. Therefore, sealers should not be routinely extruded into the periradicular tissues. Recent development of bioceramic sealers holds promise of being biocompatible and tolerant of residual moisture in the canal.

Cones are available in several tapers with the goal to fit cones to the best wall contact at working length, as indicated by the sensation of tug-back, or resistance to pulling the cone out. If a cone is too tapered for the preparation, it will make contact with the canal wall coronally with the fit being short of length. If it is not tapered enough, it will be loose, and will appear crimped at the tip. A good primary fit with apical tug-back of a master cone is one adjusted to fit both the apical size and the taper of the preparation. This is critical to promote a good obturation.

Prepared and filled canals should demonstrate a homogenous radiopaque appearance, free of voids and filled to working length. The fill should approximate canal walls and extend as much as possible into canal irregularities such as an isthmus, ribbon-shaped spaces or a C-shaped canal system. The fill of accessory canals is not predictable and not a prerequisite for success. In order to avoid overextension of root filling material into the periapical tissue, and specifically in the mandibular canal or maxillary sinus, it is recommended to accurately determine working length to prevent destruction of the apical constriction.

For infected root canal systems, the best healing results are achieved when the working length is between 0.5 to 1.0 mm from the tip of the root as visible on a radiograph. In posterior endodontics, determination of apical canal anatomy is often difficult. It may be appropriate for second mandibular molars that are in close proximity to the mandibular canal to de-emphasize patency and even block apical foramina to avoid large overfills. Large overfills may be an impediment to healing and in the worst case may be associated with nerve damage and permanent patient injury (paresthesia and dysesthesia).

ADDITIONAL IMPORTANT OBTURATION CONSIDERATIONS

Thermoplastic obturation using heat-softened gutta-percha can fill accessory canals and communications, promoting movement of softened gutta-percha into lateral canals and isthmuses. This allows for the filling of canals with a higher volume of core material. On the other hand, it can also result in material extrusion into the periapical area because of the enhanced flow characteristics, especially in cases where the apical foramen has inadvertently been overinstrumented. Confining the root filling to the canal space has predictably shown higher success rates. **The responsibility to avoid overfills in the presence of vulnerable structures or neurovascular anatomy is the responsibility of the clinician. There is no acceptable defense for any operator when a patient's health and well-being is harmed by a lack of clinician diligence.**

CAUTIONS IN OBTURATION SAFETY

An *"injection only"* technique is not recommended in medication placement or obturation because of the danger of overfill. If the operator chooses this option, the apical fill of 3-4 mm should always be verified by radiograph for placement and density before proceeding with the rest of the fill.

Carrier-based systems create an apically directed hydraulic pressure during application to the canal. While these systems create a dense filling, care must be taken to:

1. Not use large amounts of sealer
2. Insert the carrier slowly
3. Verify working length to avoid overfilling

Avoid Overfilling: Gross overextension of obturation materials usually indicates faulty technique.

1. When selecting a filling technique it is important to consider adjacent anatomical structures and the patency (level) of the root canal. There are considerable differences in viscosity of obturation materials between lateral compaction and warm filling techniques and one must be confident in his/her approach.
2. Maintaining apical patency is advocated by many clinicians, but if the passage of instruments to patency length is not restricted to small instruments (#10 or #15) one will destroy (widen) the apical constriction.
3. Because thermoplastic gutta-percha filling techniques are so effective in filling unusual canal aberrations, they have become the technique of choice for endodontists.

4. The thermoplastic method emphasizes heating the gutta-percha to increase its flow characteristics, but when that flow is not controlled one is apt to extrude large amounts of filling material into the periapical tissues. This potential for overfilling can be particularly dangerous when the mandibular nerve, the maxillary sinus, or the opened apical foramen is at risk.

FINAL CONSIDERATIONS IN OBTURATION

Prior to treatment one must closely inspect and evaluate the tooth/roots internal anatomy as well as their root-tip relationship with maxillary and mandibular structures.

1. Does this tooth have an open apex (immature development and apical resorption)? Other factors include root length, root width, canal size, mineralization, internal resorption, etc. Do the roots extend into the maxillary sinus or approximate the mandibular canal? Is the degree of canal curvature greater than 30 degrees? Does the root exhibit an "S" shaped morphology? These questions can identify teeth where routine endodontic techniques may not meet the demands of a case and referral is in order.
2. Are the materials biocompatible? Certain sealers are neurotoxic. Sealers that contain paraformaldehyde or other mutagenic or carcinogenic substances must be avoided.
3. Though a little sealer extrusion may be well-tolerated and absorbed by the periapical tissues over time, prevention is in order. Toxicity will be destructive if compacted into periradicular tissues, the maxillary sinus or the mandibular canal.
4. Working length should be confirmed electronically and radiographically and maintained throughout instrumentation. The apical constriction (cementodentinal junction or CDJ) may involve multiple constrictions, be apically narrowing over several millimeters, or not exist.
5. Tactile readings alone are not dependable. A negotiating file may bind anywhere along the canal length and be misinterpreted as the constriction.
6. The object of instrumentation is to provide a glide path and a prepared apical constriction for the insertion and compaction of gutta-percha. Poor length control leads to overinstrumentation and overfilling.

PREVENTING OBTURATION MISHAPS

1. It is essential to image and clearly identify radiographically the roots and surrounding jaw structures in order to understand the third dimension and risks of overfill.
2. It is critical to use obturation materials that are well-tolerated by the body after therapy, rather than unsafe formulations such as paraformaldehyde pastes that should not be used in the good and safe practice of endodontics.
3. The clinician must practice careful and judicious shaping strategies that use multiple confirmations of working length (electronic, radiographic, tactile and paper points), in order to take serious precaution against overinstrumentation.
4. It is important to use "resistance form" in controlling overfills. This "resistance form" can be imparted during canal preparation by producing funnel-form, tapered preparations and by selecting gutta-percha cones to match those canal shapes which will resist the obturation forces which promote extrusion.
5. When using thermoplastic techniques, it is important to respect the flow characteristics of the materials and the heat energy used.
6. The use of paste-fillers and syringes for applying endodontic sealers should not be used when there is close proximity to neural structures and control is compromised.
7. In cases of extreme proximity to the neurovascular anatomy, the importance of creating a clean dentin plug or bioceramic barrier at the patent apical terminus should be carefully planned when the risk of extrusion is considerable.

Endodontic Retreatment

Periapical pathosis and/or persistent symptoms associated with a previously endodontically treated tooth or development of periradicular pathosis in cases where a lesion was not present indicates persistent disease. Persistent disease following initial root canal treatment does not necessitate nor obligate tooth extraction. Clinical assessment and/or enhanced imaging often reveals the etiology of failure. Once the cause for pathosis is identified, corrective action can be taken.

Incomplete treatment, missed canals, poor obturation, and coronal leakage are common causes that can be corrected with retreatment procedures. Procedural errors such as perforation, apical transportation, ledging, loss of length, and separated instruments may not be correctable with a nonsurgical retreatment approach and are best treated with surgery by an endodontic specialist. **Retreatment cases vary in complexity, and require enhanced knowledge and technical skills to remove coronal restorative materials such as posts and cores and obturation materials in addition to remaining necrotic tissues and microbes. To accomplish these tasks varied specialized instruments and armamentaria are required. The procedures are precise and microscopy is often necessary. In addition, they are time consuming, and have a slightly decreased prognosis compared to initial root canal treatment. However, in general, referral to an endodontic specialist is preferred over extraction and will provide the best long result for the patient.**

The general dentist must be able to ascertain the success and failure of endodontic treatment procedures and recommend appropriate corrective treatment options or consult with a specialist.

Restoration of the Endodontically Treated Tooth

It is a common belief that endodontically treated teeth are more brittle due to loss of moisture in the dentin. Yet research shows that moisture loss may only slightly affect the collagen of dentin and that an endodontically treated tooth's susceptibility to fracture is primarily caused by a loss of structure due to caries, prior restorations, fractured cusps and the access cavity and not the loss of moisture. In addition, aging of dentin promotes the replacement of collagen by hydroxyapatite which makes a tooth more susceptible to fracture by decreasing the dentin's elasticity. Therefore, the strongest tooth with the best restorative prognosis is one that retains maximum structural integrity of dentin and enamel with minimal preparation and a "protective" restoration.

- ***Intent statement:*** A practicing dentist must be able to recognize that a final restoration of an endodontically treated tooth is considered an integral part of the endodontic treatment which is not considered finished until the tooth is restored in a timely and adequate fashion.
- ***Intent statement:*** A practicing dentist must be able to decide the appropriate restorative strategy for an endodontically treated tooth by evaluating tooth type, the extent and distribution of tissue loss, as well as type and material of the final restoration.

In determining prognosis, restoration of endodontically treated teeth must be considered as an integral part of the endodontic treatment, since it plays a major role in the long-term success of the procedure, as well as in tooth longevity. In order to maximize the chances of success, the distinctive characteristics of endodontically treated teeth need to be carefully considered, as well as the recent advances in adhesion, digital technologies, and biomaterials. From the founding of the specialty until the mid-1980's, success was thought to be dependent on the apical seal. Should leakage occur, it was thought fluids would enter the apical canal space, stagnate, break down, and re-enter the tissues causing apical inflammation and disease. It is now known that treatment failure is not due to "apical percolation" but coronal bacterial leakage. Placement of a definitive coronal restoration must be considered part of the obturation process to eliminate recontamination.

Root canal treatment should not be considered finished until the tooth in question is restored in a timely and adequate fashion. It is clear from the literature that any delay between endodontic treatment and tooth restoration should be as brief as possible, since numerous studies report that there is notably reduced survival after endodontic treatment for teeth restored with temporary restorations, compared to those receiving a permanent restoration.

Providing a fluid-tight seal, preventing bacterial leakage, and protecting the remaining tooth structure will provide long-term stability following the root canal treatment. While only one of many factors that the restorative dentist needs to fulfill, failure to restore the tooth adequately is unacceptable. In general dental practice, patient expectations are related to the restoration of masticatory function, esthetics, the longevity of the restoration, and to more practical factors such as chairside time or the cost of the restorative procedure.

While cuspal coverage is typically recommended in the posterior dentition following root canal procedures, this may not be necessary in some instances, since such a decision should depend on the amount of remaining coronal tissue. In teeth with minimal structural tissue loss, intact marginal ridges, a conservative access preparation, and no pre-existing cracks, the clinician may consider a direct intracoronal bonded restoration as a valid option. It is less expensive for the patient, conserves tooth structure, is faster and efficient, and the patient leaves the practice with a permanent restoration in a single appointment.

Dental materials and techniques have evolved greatly over the last decades. In particular, resin-based composites, which can be micromechanically and chemically bonded to the dental tissues, have become more and more reliable. By tradition, some dentists continue to use metal posts to retain bonded composite restorations while they accordingly should be replaced by fiber-reinforced resin-based posts which are more protective of remaining structure; or possibly by no posts at all. This is supported by the fact that a ferrule should be obtained on all endodontically treated teeth. If a 2 mm ferrule can be obtained for any protective restoration, a post is not needed to retain a bonded buildup. A ferrule is generally considered to be extremely important to prevent dislodging forces that will lead to coronal leakage. Cusps should be covered if structural loss has damaged marginal ridges or undermined coronal walls.

Root canal treatment itself does not seem to significantly weaken dental structures; increased susceptibility to fracture appears to be due, in the majority, to coronal and pericervical hard tissue removal. Three major technological developments are challenging the way endodontically treated teeth have been restored:

1. Adhesive dentistry and the development of increasingly more dependable dental adhesives
2. The rise of digital technology, enabling the rapid and reliable design and manufacture of cuspal-coverage restorations in practice
3. The development of biomaterials, with characteristics more compatible to replaced tissues

Restorative concepts should be specific to each tooth type, since each is submitted to very different challenges during function. Molar teeth are mostly challenged by axial forces of high intensity. Since root canal treatment weakens teeth due to loss of structure, there is a particular need to adequately protect endodontically treated posterior teeth against tooth fracture. The major cause for increased susceptibility to fracture of endodontically treated teeth appears to be the loss of hard tissue. Endodontically treated teeth often undergo additional dentin removal in the process of the restoration in creating a post space as well as preparation for full crowns and occlusal reduction of thin dentin walls. In this regard, it is quite telling that a major cause of further tissue damage is dentistogenic. In light of this paradox, it is important to weigh the necessity or rationale of additional tissue sacrifice.

Generally, goals of the restoration of teeth after endodontic treatments can be summarized in three main objectives: to restore tooth function, to prevent infection or reinfection of the root canal space by providing a fluid-tight seal and to protect the remaining tooth structure against further tissue damage.

RESTORATION OF ANTERIOR TEETH

The type of final restoration recommended for an anterior tooth after endodontic therapy is determined by the amount of remaining tooth structure. If the only loss of tooth structure results from a conservative access preparation, a bonded composite is adequate. If the tooth is weakened by a large or misdirected access preparation or proximal caries and/or restoration, a crown should be considered as the final restoration. A post is necessary when the remaining tooth structure (after crown preparation) will not retain the core. A post should be avoided whenever possible in order to reduce the possibility of root fracture.

RESTORATION OF POSTERIOR TEETH

The average person can exert enormous forces on posterior teeth, or about nine times the amount of force that is exerted on anterior teeth during closure. This force can result in over 200 pounds per square inch of stress applied to posterior restorations. Therefore, cusps of posterior teeth must be protected against vertical fracture. Proper restoration of posterior teeth involves two phases: core placement and crown placement.

CONTEMPORARY POST PHILOSOPHY

The function of a post is to retain a core restoration. The function of a core restoration is to retain a crown. If core retention is not necessary, a post is not indicated. To reduce the potential of vertical root fracture a post should be placed only when necessary for core retention. The most important factor influencing whether a post will be necessary is the amount of supporting tooth structure remaining after crown preparation and the development of a ferrule. If three supporting walls of dentin remain, a post is not necessary. All metal posts, regardless of design or type of cement used, transmit forces developed during mastication to the root of the tooth, and thus, can promote fracture over time if the root is structurally compromised. Nonmetal posts offer a more compatible material to be placed adjacent to dentin to prevent the fracture problem associated with metal posts. These posts are bonded in the canal and have some degree of flexibility (similar to the modulus of elasticity of dentin).

BIOMIMETIC RESTORATION

The research and study of interdisciplinary materials science is termed "biomimetics." Inherent in the definition of biomimetics in dentistry is the recovery or mimicking of the biomechanics of the original tooth by the restorative material. Traditional restorative techniques have incorporated corono-radicular materials that were more diverse in their behavior when compared to dentin. Since many endodontically treated teeth are restored with numerous material components (e.g., gold, stainless steel, ceramic, composite, alloy) the potential for these materials to behave differently than dentin under dynamic function or thermal expansion may affect the resultant modulus of elasticity, tensile and compressive strength of each tooth and its remaining structure. Choosing restoratives with similar material traits to dentin is a strong trend in dentistry and in the rehabilitation of endodontically treated teeth.

In summary, a full crown is not universally required after root canal treatment. Evidence does indicate that placement of a crown following nonsurgical root canal treatment does enhance the restorative prognosis primarily by providing cuspal protection. Factors such as tooth type, extent and distribution of tissue loss, as well as type and material of the final restoration need to be considered to decide the appropriate restorative strategy for an endodontically treated tooth to last a lifetime. Universal crown placement after root canal treatment is probably overtreatment.

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