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VOLUME 1 | ISSUE 5

DENTAL LEARNING

A PEER-REVIEWED PUBLICATION

Knowledge for Clinical Practice

Restoration of the Endodontically-Treated Tooth:
Treatment Planning Concepts For Optimal Results In Restorative Dentistry

Alan M. Atlas, DMD
Padma Raman, DMD




Foreword
Fiona M. Collins, BDS, MBA, MA — Page 2

Case Presentation
Howard E. Strassler, DMD — Page 18

INSIDE
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Foreword

Fiona M. Collins, BDS, MBA, MA

Restoring the endodontically-treated teeth requires consideration of multiple factors. First and foremost, this includes the determination, based on a full clinical history and examination, as to whether endodontic treatment and restoration is the best treatment for the patient or whether an alternative treatment would be more suitable.

The focus of *Restoration of the Endodontically-Treated Tooth* is the treatment planning and implementation of such treatment for long-term clinical success. This article provides an in-depth review of the factors involved and the alternative treatment modalities that can be utilized to restore these teeth.

As discussed in the article, endodontic and restorative therapies are both critical to the long-term failure of an endodontically-treated tooth when compromised. Factors addressed include the amount of tooth structure remaining, consideration of the ability to provide for a ferrule effect and the type of restoration.

Restoration of the Endodontically-Treated Tooth describes the types of restorations that are suitable under different clinical circumstances, as well the posts and cores that can be used and the scientific evidence supporting their use. Post designs, materials, and placement are thoroughly reviewed together with the scientific rationale for determining which type of post and placement is clinically suitable in a given situation and clinical guidelines for their use. Recent developments and the rationale for the use of fiber posts are also reviewed in detail, followed by discussion of core materials and adhesives.

A logical step-by-step systematic approach that results in effective and successful placement of posts and cores for definitive restorations is included in this article, concluding with clinical cases demonstrating these treatment modalities and their successful outcomes.

Dr. Fiona M. Collins
CE Editor

DENTAL LEARNING
10106 E. 79th St., Suite A, Tulsa, OK 74133

Restoration of the Endodontically-Treated Tooth:

Treatment Planning Concepts for Optimal Results in Restorative Dentistry

ABOUT THE AUTHORS

Dr. Alan M. Atlas received his DMD from the University of Pennsylvania School of Dental Medicine and serves there as Clinical Associate Professor, Co-Director of Restorative Dentistry Clinics, Director of Implant Dentistry and a Primary Care Unit Group Leader in the Department of Preventive and Restorative Sciences. He holds membership in the Academy of Osseointegration, Omicron Kappa Upsilon National Dental Honor Society and the International Association for Dental Research. Presently, Dr. Atlas is an internationally recognized lecturer focused on applying scientific-based protocols to clinical dentistry. He maintains a private practice dedicated to Esthetic and Comprehensive Restorative Dentistry located in Philadelphia, Pennsylvania. Dr. Atlas does not have a leadership position or a commercial interest with Dentsply Caulk, the provider of the unrestricted educational grant, or with products and services discussed in this educational activity. He can be reached at amatlas@dental.upenn.edu.

Dr. Padma Raman is in private practice in Philadelphia. Dr. Raman does not have a leadership position or a commercial interest with Dentsply Caulk, the provider of the unrestricted educational grant, or with products and services discussed in this educational activity. She can be reached at padma.raman@gmail.com.

EDUCATIONAL OBJECTIVES

The overall objective of this article is to provide the participant with an evidence-based guide to treatment planning and successful management of endodontically-treated teeth. Upon completing this course, the participant will be able to:

1. List and review the variables described in the literature for the long-term success of endodontic treatment;
2. List and describe both the conservation of tooth structure and ferrule effect;
3. Review protocols for the placement of pre-fabricated posts and core build-ups; and
4. Review protocols for the placement of indirectly fabricated cast post-and-cores.

ABSTRACT

Treatment planning the restoration of the endodontically-treated tooth should begin with a complete and comprehensive full mouth evaluation, in tandem with the tooth in question. Important considerations include the periodontal support, quality of root canal treatment, occlusal scheme, para-functional habits, available vertical space, age and gender of patient, and the intended function of the tooth: single restoration or abutment for an overdenture, fixed or removable partial denture.

Introduction

The successful restoration of the endodontically-treated tooth continues to be one of the most challenging procedures in dentistry. This is largely due to the complexity of the process and controversial selection of treatment choices that exist, and a large amount of dental literature deals with one or more of the components in this multifaceted equation.

Risk Assessment of the Carious Tooth

After excavation of all carious dentin and enamel, the tooth is significantly compromised due to the loss of structural integrity. The first critical treatment planning question then becomes an evaluation of the amount of healthy tooth structure that remains and whether there is enough to support the foundational core for the eventual coronal restoration. (Figure 1) Is the tooth salvageable or should an extraction be considered and an implant, fixed partial denture or removable partial denture be offered? Since dental implants are now mainstream, perhaps the clinician is less comfortable with the

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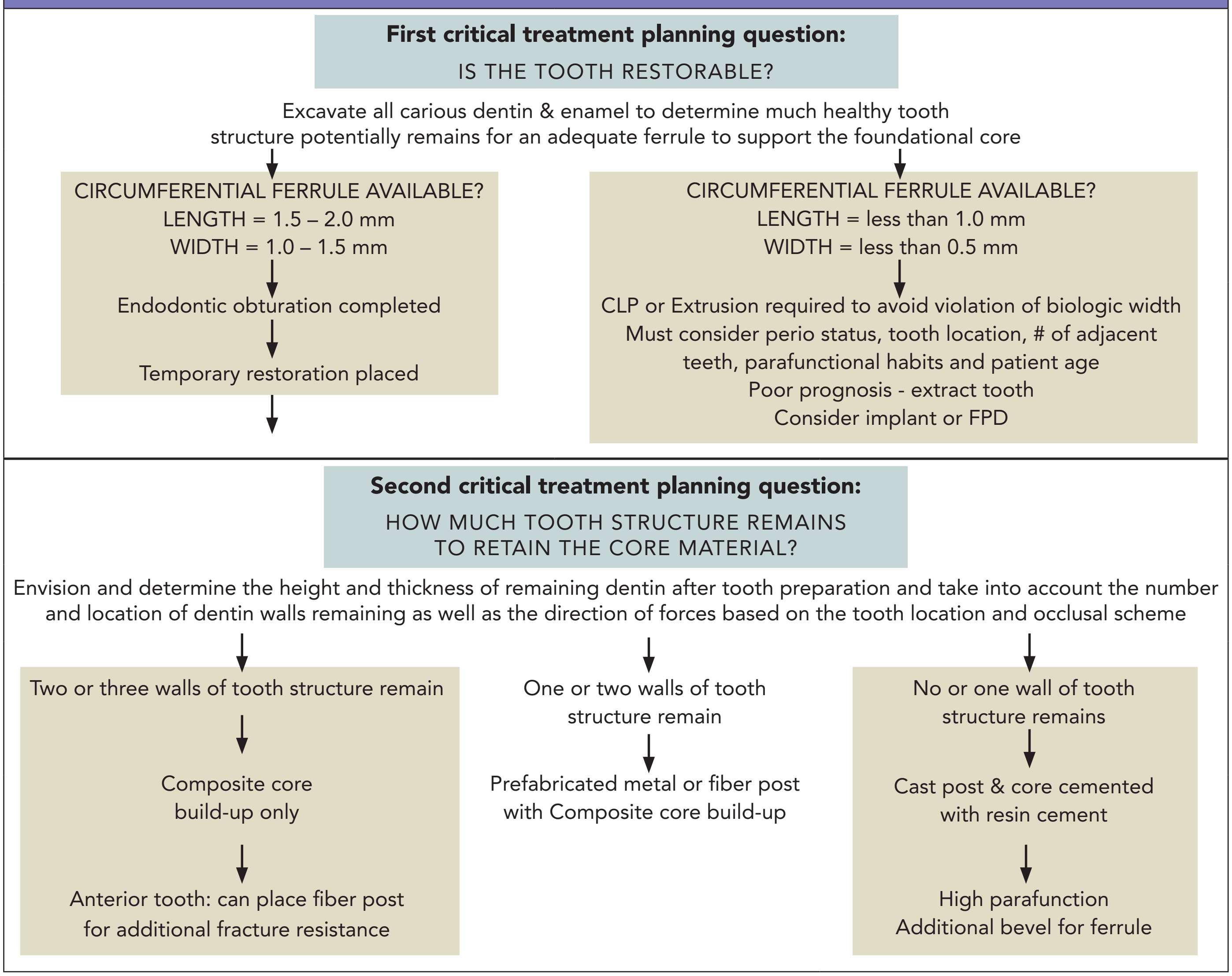
long-term outcomes of restoring the compromised tooth.

The successful long-term retention of endodontically-treated teeth relies on satisfactory endodontic and restorative treatment.[1] In their recent systematic review and meta-analysis, Gillen et al concluded that when either the quality of the coronal restoration or the quality of the root canal filling is completed inadequately it is equally contributive to an unsuccessful outcome.[1] This conclusion was contrary to the belief held for years that the coronal restoration had the greatest impact on continued clinical success.[2] There are many causative factors for the fracture of endodontically-treated teeth. (Figures 2 and 3) One study by Fennis et al[3] looked at 46,000 insurance claims and reported a greater occurrence of tooth fracture with endodontically-treated teeth. Ng et al.[4] concluded that four variables could improve the survival of endodontically-treated teeth: a crown restora-

Figure 1. Restoring the endodontically-treated tooth: Treatment planning flow chart



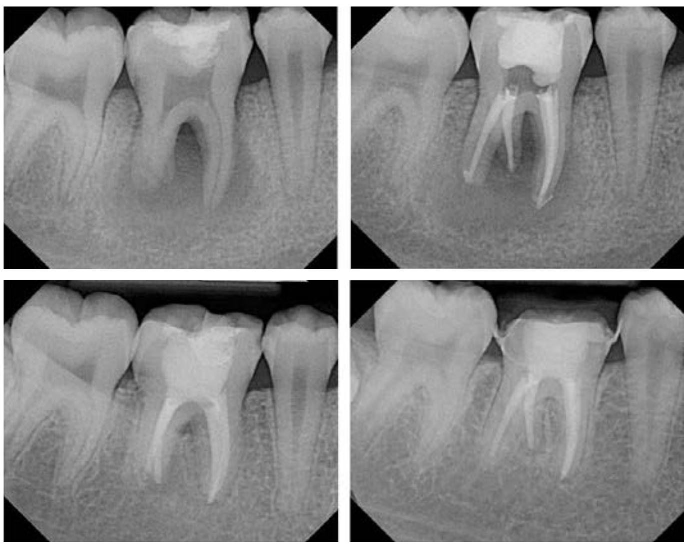
tion after root canal treatment, the presence of mesial and distal approximal contacts, the tooth not being used as an abutment for a fixed or removable partial denture and the tooth not being a molar.

Stresses attributed to the endodontic and restorative procedures, access cavity preparation, instrumentation and irrigation of the root canal, obturation, post space preparation, and post selection can be considered possible sources of tooth fracture.[5] Other factors that may be contributory to fracture or failure include post adhesion, cement selection, parafunctional habits, age and gender of the patient, the occlusal scheme and loads, and periodontal status. Setzer et al[6] performed a retrospective analysis of 50 teeth treated over a 6-year period with a minimum follow-up of four years, using full mouth series of radiographs. After examining the restorative, periodontal and endodontic parameters, they concluded that the only factors that significantly correlated with extraction or retreatment of endodontically-treated teeth were a reduced periodontal prognosis and a loss of attachment. Vire[7] and Fonzar[8] also concluded in their studies that the most common cause of extraction of endodontically-treated teeth was periodontal in nature.

The restorative examination, together with an understanding of the alternative clinical protocols available (based on the current literature), play a pivotal role in the risk assessment and treatment planning of subsequent procedures for the patient. The quality and quantity of remaining tooth structure will guide the clinician to the best options for the patient. (Figure 1) Ferrari et al[9] concluded, in a randomized controlled trial of restored premolars with either a prefabricated or customized fiber post, that preservation of at least one coronal wall significantly reduced failure risk regardless of the restorative procedure. Ideally, endodontically-treated teeth must have 5 mm of tooth structure coronal to the alveolar crest – 3 mm required to maintain the soft tissue complex and 2 mm apical to the incisal aspect for structural integrity. Besides the requirements of endodontic treatment, caries excavation can result in severe loss of tooth structure, subgingival preparation and a violation of the biologic width (the dimension of the junctional epithelial and connective tissue attachment to the root above the alveolar crest).[10] A biologic width of at least 2-3 mm between the alveolar crest and the resultant crown margin is required. If this is not present, alternative treatment must be advised such as crown lengthening or root exposure via orthodontic extrusion. Either treatment modality may result in a successful clinical outcome in the absence of other adverse factors listed in Figure 1. However, crown lengthening can result in compromised esthetics and an unfavorable crown-to-root ratio and while orthodontic extrusion reduces these risks it can still result in a compromised crown-to-root ratio. For proper treatment planning to occur at the outset, the restorative dentist or endodontist (if the patient is referred to the specialist) must quantitatively assess the available tooth structure and incorporate all variables to envision the final restoration prior to commencement of the endodontic

Figure 2. Tooth fracture.

Figure 3. Tooth fracture.



Courtesy of Dr. Samuel Kractchman

Figure 4. Four-year sequence.

procedure. In Figure 4, a four-year sequence is demonstrated where the initial assessment may not have been favorable without taking into consideration other patient factors.

If an endodontist is performing the root canal treatment, there must be discussion with the restorative dentist regarding final treatment options to avoid doing unnecessary procedures and undermining patient expectations. As an example, a lone standing molar with sub-gingival caries that is to be utilized for a fixed or removable partial denture in an older male patient with nocturnal bruxism, high caries risk, periodontal loss of attachment and furcation involvement, may not be the ideal candidate for endodontic therapy. In this particular scenario, a dental implant may be the optimal long-term option, assuming its placement is feasible.

The Ferrule Effect

With all other patient factors being acceptable, the decision to pursue endodontic therapy will ultimately be based on the ability to preserve intact coronal and radicular tooth structure and to maintain adequate cervical tissue to provide a ferrule effect that is critical for optimization of the biomechanical behavior of the restored tooth.[11] The ferrule effect, first proposed by Rosen[12] in 1961, suggested using a 360º metal collar of the crown surrounding the parallel walls of the dentin extending beyond the gingival margin and coronal to the shoulder of the preparation. The net results are bracing of the crown over the tooth structure's increased resistance form, a reduction of internal tooth stresses and a protective effect against fracture. The evidence on the optimum requirements for the ferrule effect suggests that an improved prognosis could be gained if healthy dentin circumferentially extends 1.5 to 2.0 mm coronal to the margin of the crown. (Figure 5)[13-30] While the general consensus is that the dentin wall supporting the core should have a minimal thickness of 1 mm,[31] there are few studies to confirm this. If the ferrule effect cannot be accomplished with the full 360º circumference then a partial ferrule effect of at least 180º would be preferable to no ferrule. Ng et al[32] reported in an in vitro study that a 180º palatal axial wall was as effective as a 360º circumferential axial wall in providing fracture resistance to endodontically-treated anterior teeth with adhesively cemented crowns. The ferrule effect on multi-rooted teeth has not been studied enough to offer definitive conclusions.[11] It should also be noted that there is conflicting and controversial literature because of different methodologies and study designs in all aspects of the restoration of the endodontically-treated tooth. The ferrule effect is only part of the complex equation for success and the choice of the post and core system, cement luting agent and final crown substrate are also important. Nonetheless, the ferrule effect reduces the impact of each of these variables.[11]

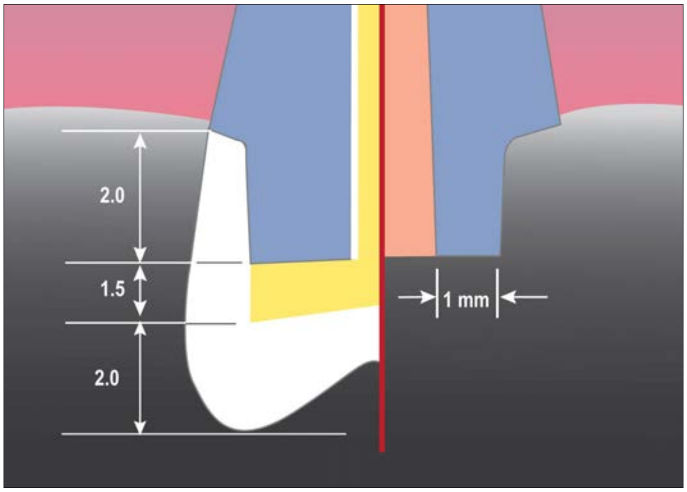


Figure 5. Optimum "Ferrule Effect" requirements.

Conservation of Tooth Structure, Obturation and Coronal Seal

Proper endodontic and restorative treatment will result in a good prognosis in a treatable tooth if the patient practices effective oral hygiene, good dietary habits, and manages parafunctional habits. Without question, the key to the future prognosis will be conservation of the tooth structure during

Courtesy of Dr. Samuel Kractchman

Figure 6. Magnification of canals and access preparation.

caries excavation and endodontic access preparation. While it was previously thought that endodontically-treated teeth were more brittle than vital teeth and more prone to fracture,[33] further studies have led to the conclusion that the physical and mechanical properties of vital and pulpless teeth are similar.[34-37] Access preparation must be done carefully to preserve tooth structure, especially when searching for additional canals, and the advent of clinical microscopes aids visualization of the access under high power magnification. (Figure 6) Over-instrumentation of root canals, and the presence of noncircular canals and thin canal walls, may result in root fractures.[37] The extended use of high concentrations of canal irrigants such as EDTA and NaOCl, especially in combination, may also cause an increase in root fractures. Complete removal of irrigants is necessary before obturation and adhesion for post and core restorations.[37]

After obturation is complete, sealing off the endodontic filling material is essential to preventing the rapid movement of bacteria from saliva to the apex that would result in reinfection and the need for retreatment.[38-40] Interim restorations should be self-adhesive to protect against easy removal during mastication and strong enough to prevent tooth fractures. White or opaque glass ionomers or resin modified glass ionomers are preferred as they will endure during the temporization period and are easily visualized during removal from the tooth prior to placement of the definitive restoration – helping avoid the removal of excess tooth structure. If a post will not be placed, a layer of the interim glass ionomer restoration may be left over the pulp chamber and the tooth restored accordingly. If a post will be placed, the post space can be prepared at the time of obturation and a cotton pellet placed over the pulp chamber, then covered with an opaque glass ionomer material.[41] This results in easy access for post and core treatment when the patient returns for restorative treatment. (Figure 7) Permanent restorations should replace interim restorations promptly to prevent leakage and fractures.

Treatment Planning the Foundation and Definitive Restoration

In the treatment planning sequence (Figure 1), the next critical question is how many walls of tooth structure remain to retain the definitive restoration. When coronal tooth structure loss is minimal and the marginal ridges are intact, a bonded composite resin is appropriate to seal the access cavity.[42] This is a more likely scenario for a tooth in the anterior region, as the two main factors that distinguish anterior and posterior teeth are their dimensions and direction of forces. Lateral, horizontal or oblique forces generated at various angles less than 90° are more destructive than vertical loads and can lead to greater failure of restorations.[43] With respect to the access cavity for a posterior molar tooth, many other factors play pivotal roles in deciding whether to use only a direct composite resin restoration or to place a full coverage indirect restoration. (Figure 8)Will the composite resin restoration sufficient to withstand the masticatory forces of the patient or should the composite resin restoration be utilized as the foundational crown buildup? (Figure 9) For this determination, an understanding of occlusal patterns and para-functional habits is essential. It has been reported that the force of ordinary chewing forces ranges from 7 to 15 kg,[44] while the maximum

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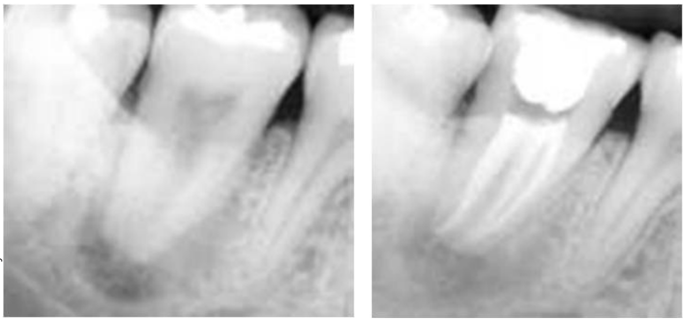


Figure 7. Interim restoration for post placement. Glass ionomer covering cotton pellet.

Figure 8. Access cavity after endodontic treatment.

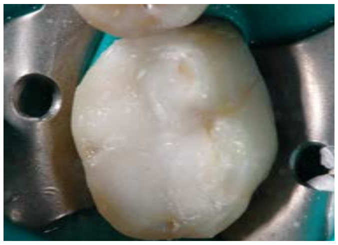


Figure 9. Access cavity restored with composite resin.

bite force can be as much as 90 kg.[45] Fracture loads in one in vitro study of the vertical and oblique forces necessary to induce failure of pulpless teeth were greater than regular chewing forces and the maximum bite force.[46] In posterior teeth, long cuspal heights and group function may generate greater lateral forces compared to canine protected occlusions.[31] Deep overbites, a horizontal envelope of function and extreme para-functional forces also may increase the possibility of fracture and tooth loss.

One retrospective and observational study of 220 endodontically-treated molars without crowns, 89% of which were restored with composite resin, resulted in 101 teeth with identified failures and survival estimates at 1, 2, and 5 years of 96%, 88% and 36 % respectively. When maximum tooth structure was retained for the direct composite restoration, the survival rate was 78% at 5 years.[47] Another study concluded that teeth with cuspal coverage had a 6 times greater survival rate than teeth without cuspal coverage.[48] The decision to place a crown or only place a direct composite restoration is dependent upon additional factors other than remaining tooth structure. In the treatment planning sequence, periodontal status, tooth location, number of adjacent teeth, requirement as a survey crown for a removable partial denture, para-functional habits, gender and the age of the patient are important diagnostic criteria to evaluate the requirement for a full coverage crown. Cusp preservation however does not always result in low fracture resistance in the long-term for the endodontically-treated tooth. Based on a review of the literature, endodontically-treated teeth can be recommended for single crowns and to a lesser degree as abutments for fixed partial dentures. On the other hand, the utilization of endodontically-treated teeth to support removable partial dentures is not considered a long-term predictable option.[37,49]

Table 1. Clinical factors in post and core fracture resistance
Periodontal support
Occlusal scheme and forces
Para-functional habits
Vertical space available for the crown
Age and gender of patient
Quality of endodontic treatment
Intended tooth function in the restorative scheme
Ferrule effect
Post preparation
Post material, length, and diameter
Post luting cement
Core material
Final crown preparation design
Crown material

Posts: Type, Preparation and Placement – the Scientific Evidence

A tooth with two or more walls missing after caries excavation and endodontic obturation requires placement of a dowel or post for retention of the core foundation and final coronal restoration. The detailed execution of this specific clinical procedure has been at the center of controversy regarding the need to utilize a post and then the type of post to utilize. There is a plethora of post materials available on the market today. Metal alloy and rigid post systems include laboratory-fabricated cast post cores and prefabricated stainless steel, titanium, ceramic and zirconia posts. Non-alloy and non-rigid post systems include laboratory-fabricated resin composite and ceramic post cores and prefabricated ceramic and fiber-reinforced polymer posts. Fiber posts are composed of unidirectional fibers of carbon, quartz or glass embedded in a resin matrix that offers strength and the ability to adhere to the cement.

The in vitro and clinical studies comparing prefabricated posts versus cast posts have yielded conflicting results.[31] There are many variables and few randomized control trials have investigated the fracture resistance of different post and core systems. [50] (Table 1)

This dilemma is best illustrated by a recent randomized clinical trial that concluded that glass fiber posts are superior to metal screw posts,[51] with the authors acknowledging that there was statistical uncertainty due to different luting agents being employed with conventional cementation for the metal post, and adhesive cementation for the fiber post based on manufacturer's instructions. In addition, post assignment was randomized by patient and not tooth type. Until test parameters are standardized, the scientific evidence on the fracture resistance of endodontically-treated teeth with posts will remain controversial.[5]

Post placement alters the stresses placed on the tooth, in particular the root dentin.[52] Therefore, the type of post placed may play a critical role in the biomechanical performance and fracture resistance of the restored tooth. Theoretically, matching physical properties of the post to the root dentin, such as the stiffness (modulus of elasticity), coefficient of thermal expansion and compressive strength, could help reduce stresses and potential fractures.[42,53-56] Failure of a non-rigid post usually occurs within the post or the core and does not result in tooth fractures. On the other hand, posts with a higher modulus of elasticity (such as metals) have higher failure loads compared to more flexible posts,[57-59] but their failure could lead to catastrophic root fracture.[46,57,58,60] Toman et al[61] concluded that teeth restored with resin cemented silica-coated titanium posts and composite cores had higher fracture resistance than teeth restored with resin-cemented zirconia or glass fiber posts (with or without silica coating) and composite cores. This indicates another variable, not commonly studied, of luting metal posts with specific protocols to enhance the adhesive result. Other studies reported no significant difference in fracture resistance of restored teeth whether fiber or metal posts were used.[62-64] To complicate things further, Dejak and Młotkowski[65] reported that cast metal posts resulted in lower stresses in the dentin of the restored teeth than did fiber resin posts. Lower stresses were present in the luting cement and the cement-dentin interface around cast posts than around fiber resin posts. In contrast, the results of an analysis by Al-Omiri et al[66] concluded that posts with a similar modulus of elasticity to dentin and smaller diameters were associated with better stress distribution. The core material and the length of the coronal post extension had less effect on stress distribution than placing the coronal restoration on sound dental tissue. This conclusion is resonated in other studies that found that the presence of a ferrule is a significant factor in improving resistance to fracture regardless of the type of post utilized.[22,23,26,27,67-70]

Post Material Selection: Clinical Guidelines

The determination of the best post to use is based on tooth location, occlusal loads and habits, remaining tooth structure, age, gender of the patient and whether the tooth is to support a single crown or is to be used as an abutment for a fixed or removable partial denture. The height and thickness of the remaining dentin after tooth preparation must be determined and the number and location of dentin walls remaining taken into account, as well as the direction of forces based on the tooth location and occlusal scheme.[31] How much of a ferrule effect can be accomplished? (Figure 10)

If there is a lack of coronal dentin for crown preparation, an adhesively cemented cast metal post/core with a minimum 180° ferrule effect on the palatal aspect for anterior teeth, and for posterior teeth a minimum ferrule effect at the interproximal aspect, should be used. If high para-function exists, then placement of a bevel at the palatal aspect of an anterior crown preparation without encroachment on the biologic width will help preserve esthetics, structural integrity and fracture resistance. For posterior teeth in high para-function

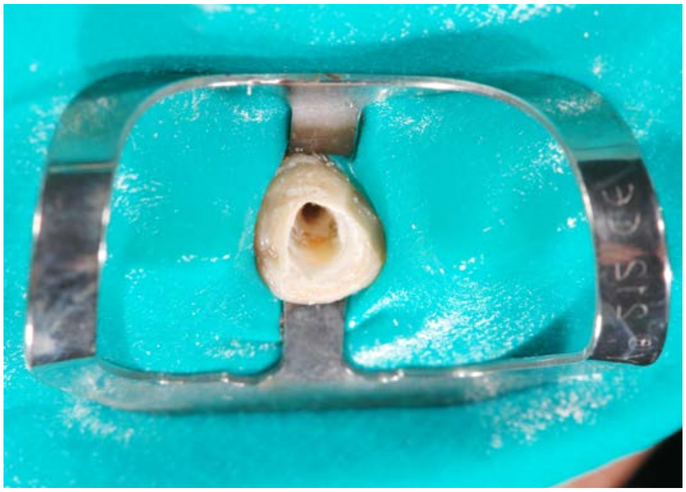


Figure 10. Determination of post type.

or with periodontal involvement, a 360º bevel can be carefully placed without violation of the biologic width to insure fracture resistance.

When only one to two walls of dentin remain, for both anterior and posterior teeth either an adhesively cemented prefabricated metal or fiber post with a composite resin core buildup foundation can be used. Minimal radicular tooth structure will require fiber posts because they offer approximately the same modulus of elasticity as dentin and forces would be distributed more evenly in the shorter root, resulting in fewer root fractures. As an example, a short fiber post might be placed in the palatal canal of maxillary molars and in the distal canal of mandibular molars.[71] Endodontically-treated anterior teeth with minimal loss of tooth structure can be treated with porcelain or composite veneers and an adhesively placed fiber post and composite core. D'Arcangelo et al[72] showed that fiber posts significantly increased mean maximum load values for endodontically-treated teeth restored with either composite or porcelain veneers compared to no fiber post placement. When in doubt, place a fiber post. Recent evidence suggests that fiber posts may actually strengthen the root.[46,72-81]

Post Length, Diameter and Design: Clinical Guidelines

Post length and its effect on fracture resistance will depend on numerous factors including periodontal status and bone level, root length, crown height, luting with adhesive cements, ferrule effect, and utilization of a full coverage restoration.[5] Preserving the obturation seal is critical to avoid bacterial microleakage; a minimum of 4–6 mm of apical gutta-percha should be retained and the post and core restoration placed immediately to avoid contamination.[82-88] The post length below the alveolar crest should be equal to the length above the alveolar crest and the post should end midway between the alveolar crest and the apex.[89,90] Long roots with healthy bone levels enable greater apical root canal filling material to be retained, and teeth affected by periodontal disease and bone loss require longer posts than teeth with typical healthy bone levels. Fracture resistance and stress analysis studies have demonstrated better results when longer posts of any category were utilized.[59,91,92] Post diameter also plays an important role in fracture resistance; small diameters are suggested to preserve dentin around the post.[93-95] Post diameters of no more than one third the root width, at least 1.75 mm of retained dentin around posts, and a post to root diameter of 1:4 have been recommended.[96-98] With the advent of adhesive post placement, the need for tapered threaded posts has declined; parallel, serrated or roughened posts adhesively cemented have been reported to have greater fracture resistance than threaded tapered posts.[99-101]

Post Adhesion and Placement: Clinical Guidelines

Adhesion of posts

Adhesion of the selected post to the luting cement and adhesion of the luting cement to the root dentin in the canal both play a significant role in the outcome of the restoration. As expected, there is wide range of opinions and scientific evidence related to both factors. Although many techniques have been established for improving the bond at the post and core interface, breakdown of the bond between the post and resin cement at the dentin interface is often the cause of failure.[102,103] A recent study concluded that several variables, including post type, composite cement and post-surface pre-treatment, may affect the cement–post interface, making guidelines for clinical protocols difficult to establish.[104] Silane coupling agents have been recommended to form a chemical bridge between the glass phase of the fiber post and resin matrix of the composite core or luting resin, although studies have revealed conflicting results.[105-109] Some fiber-reinforced posts have highly cross-linked polymers in the matrix without functional groups to chemically interact with silane.[102] Other fiber posts have a smooth surface which restricts micromechanical interlocking with adhesive resin cements, and purely adhesive failure modes have been recorded at the composite-post resin interface.[110,111] In this situation, airborne particle abrasion or sandblasting with 50-µm aluminum oxide at 2.8 bar (0.28 MPa) pressure for 5 seconds has been shown to remove the outer layer of resin, exposing the glass fiber available for chemical interaction and increasing the surface area of the post for better micromechanical retention to the cement.[112] Another option is the use of silicate-coated alumina particles to create a silicate layer imbedded onto the post surface following a process referred to as tribo-chemical coating. The surface can then be treated with silane, establishing micromechanical retention and chemical bonding.[113-116]

Other methodologies used to increase the surface area and bond strength of the fiber post include the application of hydrogen peroxide and phosphoric acid. A recent study by de Sousa Menezes et al[117] concluded that application of 24% hydrogen peroxide for one minute increased the bond strength of resin to the posts without damaging the glass fibers or affecting post integrity. Albashaireh and co-workers concluded that application of 36% phosphoric acid for 15 seconds before cementation produced no significant improvement in post retention whereas airborne-particle abrasion of the surface of the post using 50- μm alumina particles at 2.5-bar pressure (36.3psi) for 5 seconds significantly improved post retention.[118]

Chemical bonding to precious and non-precious metal can be enhanced by metal primers containing proprietary monomers that simultaneously bond to the metal atoms and copolymerize with resin monomers. Utilizing adhesive placement of cast posts and pre-fabricated metal and titanium posts with resin cement instead of conventional cements has improved clinical outcomes.[119-124] Light airborne particle abrasion or sandblasting with a micro-etcher using aluminum oxide or silica coated alumina followed by the appropriate primer (silane or alloy) may enhance the adhesion of the post to the resin composite luting cement. However, it is difficult to standardize sandblasting with a micro-etcher and this should be used with caution; it is considered too aggressive for fiber posts by several authors, with the risk of significantly modifying their shape and fit within the root canals.[107,114-116] Additional studies are needed to confirm one methodology over another.

Dentin Bonding

Three strategies exist for bonding to root dentin: 1) etch-and-rinse adhesives with a separate acid etching step to remove the smear layer, (2) self-etch adhesives using acidic monomers to simultaneously infiltrate and demineralize dentin, and (3) self-adhesive resin cements without a separate adhesive step ; the bond to dentin is via micromechanical retention, physical adhesion and chemical interaction with hydroxyapatite.[125]

Notwithstanding recent advances in dentin bonding systems, adhesion in the deep and narrow root canal remains technique sensitive and difficult to accomplish. Several studies have shown frequent failure of adhesion at the dentin-adhesive or post-adhesive interface at 10—15 MPa, well below the established baseline of 20 MPa.[126-129] The materials used during an endodontic procedure create a thick smear layer, consisting of debris, sealer, and gutta-percha, that reduces adhesion of the post to the intra-radicular dentin.[130]

The difference in the bonding performance of adhesives and adhesive luting cements in intra-coronal cavities versus post spaces may be explained by the differences in the configuration factor (C-factor). The C-factor is the ratio of bonded to unbonded surface areas in a restoration, and composite resins volumetrically shrink as they polymerize which results in shrinkage stress to the bonded substrate.[131] If the C-factor is high, the stress development may exceed the bond strength of the bonding agent. Bouillaguet et al[126] reported the micro-tensile bond strength of adhesive cements to unconfined flat dentin to be significantly superior to the same cements confined to intact root canals. The researchers concluded that lower post-space adhesion may be attributed to the high C-factor exceeding 200 as opposed to an estimated C-factor of 1 to 5 for intracoronal restorations. The root depth could also contribute to lower bonding effectiveness due to a reduced depth of cure and lower cure due to increased distance from the polymerization source.[132]

Using a post and core system lends itself to efficiency in the placement of posts and cores. Organizationally, having all of the materials at hand in one place provides for a logical set-up and saves time chair side. From a clinical perspective, it also ensures that all of the materials being used are compatible with each other for a safe and effective treatment.

Core Materials and Composite Post Cementation

Resin-based luting cements are reported to have higher bond strengths and significantly increased post retention, as well as to help strengthen the endodontically-treated tooth, compared with conventional and glass-ionomer cements.[133-137] Since light penetration with a curing device is reduced in the root canal area, the use of dual-cure, self-cure or self-adhesive resins is advocated. Self-adhesive luting agents have been introduced to simplify the luting procedure and eliminate the need for an adhesive bonding agent.

Recent techniques utilize the composite core material to simultaneously lute the post and perform the core buildup in one step to minimize time and technique sensitivity. Updated delivery systems, lower viscosity and control over placement and setting times simplify the adaptation of dual-cured composite resin core materials in the pulp chamber and canal for post placement. Light polymerized, dual-cured composites have demonstrated improved bond strength, modulus of elasticity, hardness, color stability and lower solubility than self-cured systems when compared in vitro.[138] Some studies resulted in the authors concluding that waiting 30 seconds before light curing the dual-cured core material resulted in reduced volumetric shrinkage and microleakage.[139-141] It is important to utilize the correct adhesive system with dual-cured composites. Most one bottle etch-and-rinse or self-etch adhesives are compatible with light-cured composites only, and a universal or dual-cured adhesive bonding agent system should be utilized for dual-cured luting cements and dual-cured composite core materials. A recent study concluded that the combination of a universal etch-and-rinse adhesive system 2nd core buildup material showed higher bond strengths than another etch-and-rinse adhesive and core build-up combination as well as a self-etch adhesive and luting cement combination.[142]

Step-By-Step Clinical Protocols for Post and Core Restoration
Placement

The sections below discuss clinical protocols for placement of a prefabricated post and core (A – Prefabricated Metal Post and B- Prefabricated Fiber Post). Using a post and core system ensures ease of use and comptatibility for fiber posts and cores.

Placement of Prefabricated Fiber and Metal Posts

Two cases will be presented detailing the direct placement

Figure 11. Endodontic treatment completed for tooth #11.

Figure 12. Endodontic treatment completed for tooth #6.

Figure 13a and b. Rubber dam placement for prefabricated metal post.

Figure 14a. Gates-Glidden for prefabricated metal post placement.

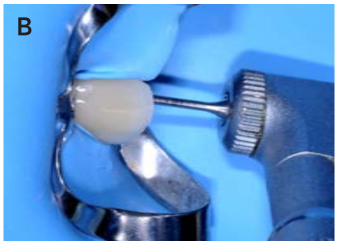


Image 14b. Gates-Glidden drill.

of a prefabricated metal or resin post and core. All procedures should be performed under rubber dam isolation, good magnification and illumination. (Figures 11-13)

a. Clinical protocol for post space preparation.

The sequential steps are as follows:

1. Remove all residual gutta percha, root canal sealer and temporary material from the tooth using micro brushes with alcohol.
2. Verify the drill path and length radiographically, to avoid perforation and to maintain an adequate apical seal of at least 4-6 mm.
3. Determine the appropriate diameter and depth of post
4. Remove gutta percha to the preplanned extent using a warm plugger or Gates-Glidden drill. (Figure 14a,b) Start with the smallest drill (#1), then sequentially the next size drill, and up to #3 or #4 depending on the diameter of the root canal.
5. Begin drilling the post space starting with the post drill size corresponding to the last Gates- Glidden drill used.
6. Select the post (see section on types of posts and selection criteria) and verify its length radiographically. (Figure 15, 16)

b. Clinical protocol for post surface preparation.

Following post selection and verification, the post is reduced coronally to its optimal size for core retention. This methodology is preferred to reducing the post height after placement in order to minimize stresses on the post by the diamond and handpiece after cementation. The post is decontaminated with alcohol and sandblasted lightly with a Micro-etcher (2.5-bar pressure - 36.3psi) for 3-5 seconds with 50-μm alumina oxide, or Cojet.

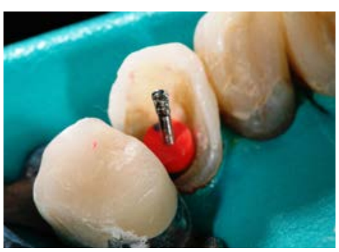


Figure 15. Selected metal post for radiographic verification.

Figure 16. Selected fiber post and corresponding post space drill.

Fiber posts can alternatively be immersed in 24% hydrogen peroxide for 1 minute. The post is then ultrasonically cleaned for 5 minutes followed by cleansing with alcohol to ensure a clean surface for adhesion. Stainless steel posts, cast posts and titanium posts are then treated with an alloy primer for 30 seconds and air-dried for 5 seconds. Ceramic posts, fiber posts and zirconia posts are instead treated with a silane coupling agent for 30 seconds and air-dried for 5 seconds.

c. Clinical protocol for adhesion to tooth structure.

A 2% chlorhexidine gluconate solution is then used to cleanse the chamber and canal space followed by drying with paper points. (Figure 17) If necessary, a matrix can be placed to confine the core material and enhance its adaptation to the post and remaining tooth structure. The canal space is then etched with 34% phosphoric acid tooth conditioning gel for 10 seconds, rinsed well and dried with a cotton point to keep the dentin slightly moist. Two coats of a dual-cured bonding agent are agitated onto the root dentin with a small micro brush. Then, the excess is picked up with a dry micro brush or cotton point, and the surface air-dried and light-cured. The manufacturer's recommendations must be followed, especially regarding the duration of contact with the tooth substrate, number of applications, intensity of air drying and duration and intensity of light-curing.

Figure 17. Use of paper point.

d. Clinical protocol for placement of core material.

Placement of the core

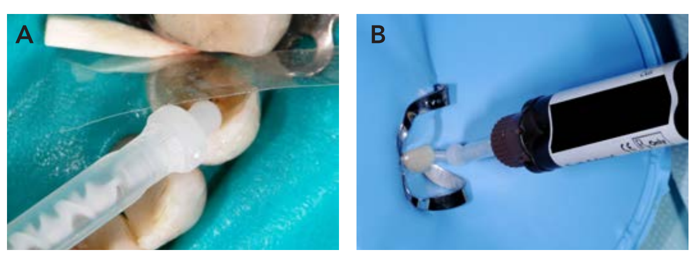


Figure 18a and b. Injection of dual-cured core build-up material for fiber and metal post cementation.

material involves a number of steps, as follows:

1. Inject a dual-cured core build-up material into the prepared post space, using a small, fine tip to minimize void formation
   a. Insert the tip until it reaches the coronal part of the root canal filling
   b. While injecting the material, gradually move the tip coronally from the base of the post channel until the post space is filled to the brim (Figure 18)
2. Immediately seat the metal primer- or silane-treated post into the post space and move it up and down to remove any air bubbles
3. Hold the post firmly in position for at least 30 seconds and then light-cure it for 20 seconds with an LED curing light (Figure 19)
4. Add the composite core to the newly-placed post, using the same dual-cure core material that was applied into the post space (Figure 20)
   a. Place the core material around the post head in 2 mm increments and light-cure after a 30 second delay for each increment
   b. After the final 2 mm increment has been placed, after a 30-second delay the core is light-cured again for the duration and intensity specified by the manufacturer
5. Ensure that the post is completely covered by the core material

Following these steps, the restoration is contoured, polished and finished and the occlusion is verified. After final radiographic verification, the tooth is ready for crown preparation, if indicated. (Figure 21)

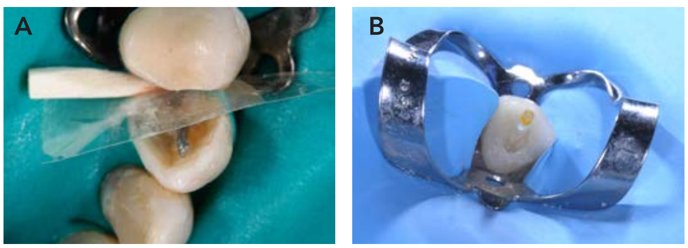


Figure 19a and b. Dual-cured core material light-cured for post cementation before core build-up performed.

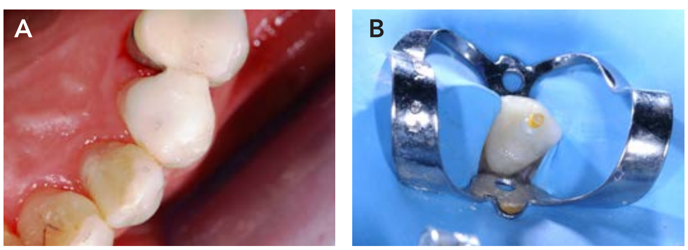
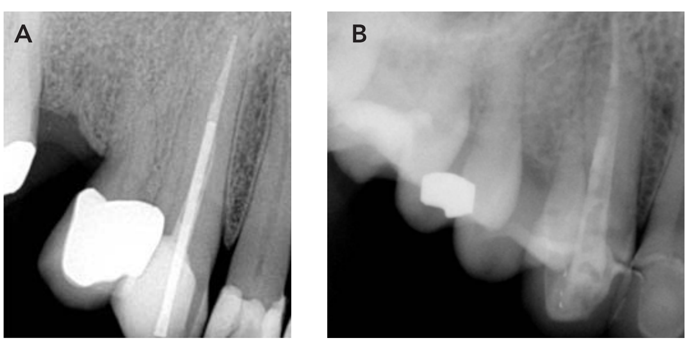


Figure 20a and b. Fiber post and completed.



Figures 21a and b. Final radiographs of metal and fiber post cemented and build-up with dual-cured composite resin.

Placement of Cast Post and Core

a. Clinical protocol for post space preparation

For a cast post and core, steps 1 through 5 for preparation of the post space are identical to those described above for the prefabricated post and core. The procedures should be performed under rubber dam isolation, good magnification and illumination. (Figures 22, 23) The final step is verification of the final post space radiographically, using a prefabricated metal post to do so. Following this, the tooth is ready for an impression.

b. Impression for the cast post and core

The clinical steps for the impression are as follows:

1. Dry the post space with a cotton point


Figure 22. Gates Glidden Drill with rubber stop to insure correct post length measurement.

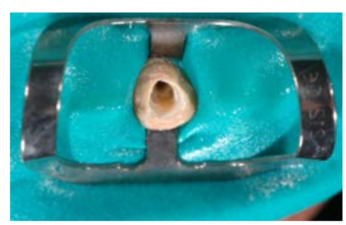


Figure 23. Rubber dam isolation to prevent contamination.

2. Cut the metal post that was utilized for radiographic verification down to the appropriate size and bend its coronal aspect slightly so that it will engage the impression material
3. Syringe light-body VPS impression material into the post space
4. Place the metal post into the post space and move it up and down to remove any air bubbles and ensure maximum adaptation
5. Place heavy-body VPS impression material into the custom tray.
6. Place the custom tray intraorally (Figure 24) and make the impression
7. Fabricate the interim provisional crown
8. Cement the provisional crown using a non-eugenol temporary cement and be sure to obtain a complete seal to protect the tooth during the interim phase of post fabrication

The laboratory will make a master cast of the impression for the wax-up of the cast post and core restoration, and the post and core is cast in Type III gold and inspected on the master model. (Figures 25, 26, 27, 28)

c. Clinical protocol for adhesion to tooth structure

Placement of the cast post and core restoration:

As with the pre-fabricated post, the cast post and core is first decontaminated with alcohol, and then sandblasted lightly with a Micro-etcher (2.5-bar pressure - 36.3psi) for 3-5 seconds with 50-µm alumina oxide or using a silicate-coated alumina particle system (Cojet). (Figure 30) The post is then ultrasonically cleaned for 5 minutes followed by cleansing with alcohol to ensure a clean surface for adhesion before using a metal primer.

As for the case above, a 2% chlorhexidine gluconate solution is used to cleanse the chamber and canal space followed by drying with paper points. The canal space is then etched with 34% phosphoric acid tooth conditioning gel for 10 seconds, rinsed well and dried with a cotton point to keep the dentin slightly moist. Two coats of a dual-cured bonding agent are agitated onto the root dentin with a small micro brush; the excess is picked up with a dry micro brush or cotton point and the surface is air dried and light cured. As before, the manufacturer's recommendations must be followed.

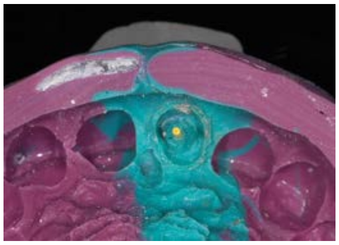


Figure 24. Master impression.

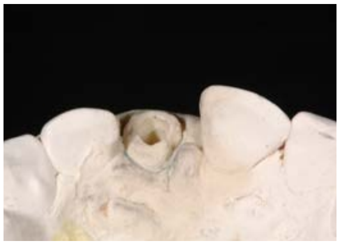


Figure 25. Master cast.

Figure 26. Gold post and core.

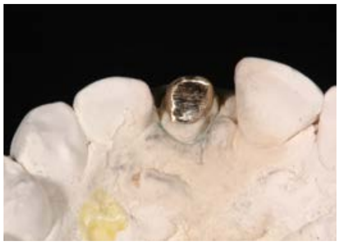


Figure 27. Master cast.

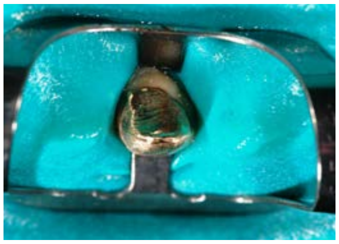


Figure 28. Cast gold.

Figure 29. Radiograph prior to post and core.

Figure 30. Radiograph with post and core.

Figure 31. After post and core placement.

d. Placement of the cast post and core restoration:

Placement of the cast post and core involves the following steps:

1. Inject dual-cured core build-up material into the prepared post space, using a small, fine tip to minimize void formation
   a. Insert the tip until it reaches the coronal part of the root canal filling
   b. While injecting the material, gradually move the tip coronally from the base of the post channel until the post space is filled to the brim
2. Immediately seat the cast post into the post space and move it up and down to remove any air bubbles
3. Remove excess composite material and after 30 seconds light-cure the periphery of the post thoroughly for 20 seconds.

Figures 29 and 30 show the pre- and post-operative radiographs. The tooth is now ready for the final impression and provisional restoration. (Figure 31)

Summary and Conclusions

Given the often contradictory nature of the literature in this area, it is important to keep abreast of new research and scientific findings and incorporate evidence-based recommendations into the clinical protocol. It is imperative that dental manufacturers utilize the current evidence and continue developing post and core systems to improve long-term clinical outcomes. Following a treatment plan flow sheet helps in the determination on the type of post and core restoration to be used. Following that determination, using a standardized protocol aids the clinican in the effective and efficient placement of post and core foundations.

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CEQuiz

1. The first critical treatment planning question for the endodontically-treated tooth is whether there is enough __________.
a. enamel for etching
b. tooth structure to support the foundational core
c. interocclusal space
d. all of the above

2. The successful long-term retention of endodontically-treated teeth relies on satisfactory __________ treatment.
a. fluoride use
b. restorative
c. endodontic
d. b and c

3. In a recent systematic review it was concluded that the quality of the coronal restoration impacts the success of root canal treatment __________ the quality of the root canal filling.
a. less than
b. the same as
c. more than
d. none of the above

4. Ng et al. concluded that __________ could improve the survival of endodontically-treated teeth.
a. a crown restoration and not being a molar tooth
b. mesial and distal approximal contacts
c. not being used as an abutment
d. all of the above

5. __________ is one of the possible factors in tooth fracture after endodontic treatment.
a. access cavity preparation
b. instrumentation and irrigation
c. post space preparation
d. all of the above

6. __________ concluded that only a reduced periodontal prognosis and a loss of attachment significantly correlated with endodontic failure.
a. Spitzer et al
b. Meltzer et al
c. Setzer et al
d. none of the above

7. Ideally, endodontically-treated teeth must have __________ of tooth structure coronal to the alveolar crest.
a. 3 mm
b. 5 mm
c. 6 mm
d. 7 mm

8. Caries excavation can result in __________.
a. subgingival preparation
b. a violation of the biologic width
c. severe destruction of tooth structure
d. all of the above

9. If insufficient biologic width is present, __________ is an alternative treatment.
a. crown lengthening
b. orthodontic extrusion
c. occlusal realignment
d. a or b

10. __________ may not be an ideal candidate for endodontic treatment and an alternative treatment may be preferable.
a. An older male patient with nocturnal bruxism
b. A tooth with attachment loss and furcation involvement
c. A tooth with inadequate cervical tissue
d. all of the above

11. The ferrule effect __________.
a. was first proposed by Rosen
b. requires sufficient cervical tissue
c. is critical to the biomechanical behavior of the restored tooth
d. all of the above

12. The ferrule effect __________, but is only part of the equation for sucessful restoration.
a. reduces internal tooth stresses
b. has a protective effect against tooth fracture
c. braces the crown over the tooth structure
d. all of the above

13. The evidence suggests that an improved prognosis could be gained if healthy dentin circumferentially extends __________ coronal to the margin of the crown.
a. 1.0 to 2.5 mm
b. 1.5 to 2.5 mm
c. 1.0 to 2.0 mm
d. 1.5 to 2.0 mm

14. __________ may result in root fractures and therefore in the failure of endodontically-treated teeth.
a. Over-instrumentation of **root canals,**
b. Thin canal walls
c. The presence of noncircular canals
d. all of the above

15. After obturation is complete, sealing off the endodontic filling material is essential to prevent __________.
a. the rapid movement of bacteria from saliva to the apex
b. reinfection
c. the requirement for retreatment
d. all of the above

16. White or opaque glass ionomers or resin modified glass ionomers are preferred materials for interim restorations as they will endure during the temporization period and __________.
a. are easily visualized during removal from the tooth
b. are esthetic
c. help avoid removal of tooth structure while being removed
d. all of the above

CE QUIZ

17. __________ forces generated at various angles less than 90° are more destructive than vertical loads and can lead to greater failure of restorations.
    a. Lateral or oblique
    b. Lateral, horizontal or oblique
    c. Horizontal or oblique
    d. none of the above

18. One retrospective and observational study of 220 endodontically-treated molars without crowns, 89% of which were restored with composite resin, resulted in 101 teeth with identified failures and survival estimates at 1, 2, and 5 years of __________ respectively.
    a. 96%, 88% and 36 %
    b. 94%, 84% and 46 %
    c. 96%, 82% and 46 %
    d. 92%, 78% and 36 %

19. A tooth with two or more walls missing after caries excavation and endodontic obturation requires placement of __________ for retention of the core foundation and final coronal restoration.
    a. a dowel or post
    b. multiple dentin pins
    c. an etch-and-rinse adhesive system
    d. all of the above

20. Updated delivery systems, lower viscosity and control over placement and setting times simplify the adaptation of dual-cured composite resin core materials in the __________ for post placement.
    a. pulp chamber
    b. canal
    c. peri-radicular space
    d. a and b

21. In a recent randomized clinical trial comparing the use of glass fiber and metal screw posts, the researchers concluded that glass fiber posts are superior to metal screw posts, with the authors acknowledging that there was __________.
    a. statistical uncertainty in the trial
    b. statistical certainty in the trial
    c. unequivocal evidence based on the trial
    d. none of the above

22. Theoretically, matching physical properties of the post to the root dentin, such as __________ the could help reduce stresses and potential fractures of endodontically-treated and restored teeth.
    a. modulus of elasticity
    b. coefficient of thermal expansion
    c. compressive strength
    d. all of the above

23.The height and thickness of the remaining dentin after tooth preparation must be determined and the __________ taken into account when considering which post to use.
    a. number and location of dentin walls remaining
    b. direction of forces based on the tooth location
    c. direction of forces based on the occlusal scheme
    d. all of the above

24. A minimum of 4–6 mm of apical gutta-percha should be retained and the post and core restoration should be placed immediately to avoid __________.
    a. cross-infection
    b. contamination
    c. periodontal disease
    d. all of the above

25. The use of parallel, serrated or roughened posts that are adhesively cemented has been reported to result in __________ than threaded tapered posts.
    a. greater fracture resistance
    b. lower fracture resistance
    c. greater definition
    d. a and c

26. In situations where a smooth fiber post is used, airborne particle abrasion or sandblasting with 50-μm aluminum oxide at 2.8 bar (0.28 MPa) pressure for 5 seconds has been shown to remove the outer layer of resin, exposing the glass fiber available for chemical interaction and increasing the surface area of the post for better __________ to the cement.
    a. chemical retention
    b. micromechanical retention
    c. modulus of elasticity
    d. all of the above

27. The difference in the bonding performance of adhesives and adhesive luting cements in intra-coronal cavities versus post spaces may be explained by the differences in the __________.
    a. A-factor
    b. B-factor
    c. C-factor
    d. D-factor

28. Based on a number of studies, it has been reported that resin-based luting cements __________, compared with conventional and glass-ionomer cements.
    a. have higher bond strengths
    b. help strengthen the endodontically-treated tooth
    c. significantly increase post retention
    d. all of the above

29. It is important to utilize the correct adhesive system, and most one bottle etch-and-rinse or self-etch adhesives are compatible with light-cured composites only, and a __________ adhesive bonding agent system should be utilized for dual-cured luting cements and dual-cured composite core materials.
    a. universal
    b. tri-cured
    c. dual-cured
    d. a and c

30. Fiber posts are composed of unidirectional fibers of carbon, quartz or glass embedded in a resin matrix that __________.
    a. offer strength
    b. have the ability to adhere to the cement
    c. require the use of zinc phosphate cement
    d. a and b

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Howard E. Strassler, DMD

Introduction

The patient in this case had received a diagnosis and treatment plan for severe periodontal disease, but had not yet acted on it. He presented with his mandibular left lateral incisor in his hand. He had 'self-extracted' the tooth while eating the evening before. The site was satisfactory and a decision was made to fabricate a natural tooth pontic by joining it to the adjacent teeth with an adhesive composite and fiber reinforcement ribbon, and to splint the periodontally mobile teeth.

Procedure

Step 1: The length of the natural tooth pontic was determined by measuring the vertical distance from the incisal edge of the lateral incisor to the extraction site. Additional length was added so that the natural tooth pontic would be touching the gingival tissue when the site healed.

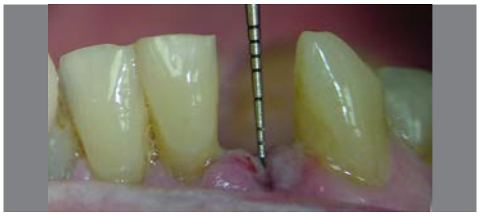

Figure 1: Measuring the length required for the natural tooth pontic with a periodontal probe

Step 2: The root was then sectioned from the crown at this final length with a tungsten carbide bur and then formed using a flame-shaped finishing bur. Following this, the root canal opening was filled with composite resin (TPH3, DENTSPLY Caulk), and the gingival aspect of the natural pontic smoothed and rounded.

Step 3: To increase the bulk of composite resin at the connector area between the pontic and abutment teeth, and to create room for a double thickness of the reinforcement fiber ribbon (Ribbond-THM), a channel with a width of 3-4 mm was cut in the lingual surface of the natural pontic (Figure 2). The lock-stitch weave of this ribbon provides multidirectional reinforcement when embedded within composite, creating a laminated structure that increases flexural strength and is resistant to fracture.

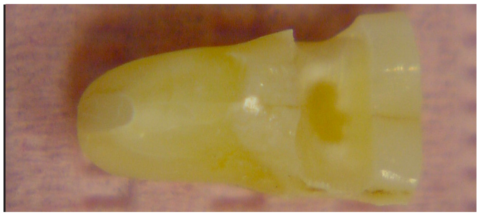

Figure 2. Tooth pontic with channel prepared on lingual surface

Step 4: A dental dam was placed, without a hole punched at the missing lateral incisor site. After cleaning the adjacent teeth, a thin diamond bur was used to barrel into the facial interproximal aspects of their facial surfaces – this was performed to minimize the thickness of the splint for aesthetics. Class III preparations were also made on the mesiolingual surfaces of the left canine and left central incisor, to create space for a double piece of fiber reinforcement ribbon that would further reinforce the bridge connectors once the pontic was placed (Figure 3).

Step 5: To determine the length of fiber ribbon to be used, a piece of dental floss was placed on the facial surface from distal of #23 to distal of #26 and cut. For the second piece of ribbon, a small piece of floss was placed on the facial surface from the mesial of #22 to mesial of #24 and also cut. The fiber ribbon was then cut into two pieces to match these lengths, impregnated with resin adhesive, put aside and covered to protect it from light. The natural tooth pontic was then etched with a phosphoric acid etchant for 15 seconds, rinsed with water and dried. Adhesive was painted on the etched surfaces and into the prepared channel on the lingual surface. The pontic was then put aside until it was time to bond it into place.

Step 6: Teeth #22-27 were then etched for 30 seconds with a 32% phosphoric acid gel on the facial and lingual surfaces, rinsed and dried. Resin adhesive was applied to the teeth adjacent to the pontic, and composite resin (TPH3) placed only on the facial surface. The pontic was placed into position with cotton pliers (Figure 3), excess composite removed, and the pontic was stabilized by light-curing the facial surfaces for 20 seconds.

Figure 3. Pontic positioned with cotton pliers after etching, placement of adhesive and composite resin placed on facial before light curing

Step 7: To minimize the presence of excess composite in the gingival embrasure spaces, a heavy-viscosity polyvinylsiloxane impression material was syringed into these areas (Figure 4) prior to further placement of composite. It is important that the impression material is placed after tooth etching, rinsing, and drying to avoid trapping moisture.

Figure 4. Blockout of gingival embrasures

Step 8: Resin adhesive was painted on the etched surfaces (Figure 5), and composite resin applied to the facial interproximal surfaces of the teeth involved in the splint, then shaped and light-cured.

Step 9: Composite resin was applied to the lingual surfaces, including the channel in the pontic and the Class III preparations. The shorter length of ribbon was placed

Figure 5. Adhesive painted on all etched surfaces, composite applied to facial aspect to create for tooth stabilization for final 180 wrap of teeth with bonding

on the lingual aspect into the Class III preparations and the lingual channel in the pontic. The longer fiber ribbon was then placed from tooth #22-#27, embedded into the composite (Figure 6) and adapted to the lingual surfaces of the teeth. Excess composite was removed and the composite light-cured. After removal of the PVS blockout material, the composite was finished and polished.

Figure 6. Fiber ribbon embedded into the composite resin

The completed splint-bridge was both aesthetic and functional, stabilizing the mobile teeth and replacing the lost incisor with an aesthetic natural tooth pontic. (Figure 7)

Figure 7. Final immediate fixed partial denture with natural tooth pontic

References

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