Restoring Endodontically Treated Teeth Prior Fixed Prosthodontic Care

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It generally is agreed that the successful treatment of a badly broken down tooth with pulpal disease depends not only on good endodontic therapy, but also on good prosthetic reconstruction of the tooth after endodontic therapy is completed.

Endodontically treated teeth can be restored with a wide range of techniques of varying complexity.[1] Selecting the optimum restorative modality to compensate for the loss of coronal tooth structure is considered the key to restorative success.

This presentation will address a number of commonly asked questions about restoration of endodontically treated teeth:

- Is restoration of endodontically treated tooth necessary?
- When is the best timing to start tooth restoration?
- Is crowning of the endodontically treated tooth mandatory?
- What is the build-up (core) material of choice?
- When is a post necessary?
- Does a post strengthen the endodontically treated tooth?
- How long should the post be?
- What shape of post is the best to use?
- What is the best way to create the post space?
- What material should be used to cement the post?

Is restoration of endodontically treated tooth necessary?

A well-sealed coronal restoration is critical to endodontics success. Until an endodontically treated tooth is restored to full function, treatment is incomplete.

Unrestored endodontically treated teeth are structurally compromised! Caries, previous restorations, fractures, wear, erosion, and endodontic procedures combine to necessitate careful tooth reconstruction to ensure a favorable prognosis. The unrestored endodontically treated tooth is susceptible to fracture, which could lead to loss of the tooth. Endodontic access in combination with the earlier loss of one or both marginal ridges leave the tooth at serious risk of fracture (lowered its fracture resistance), even if it were reduced out of direct occlusal contact before endodontic treatment began.[2]

In addition, recent studies have confirmed that coronal leakage is a significant etiology in endodontic failure.[3] If an obturated canal is exposed to saliva, leakage will compromise the gutta-percha seal, and the tooth may require retreatment. Saliva and microorganisms from the mouth migrate rapidly alongside poorly adapted restorations and even root fillings which appear well condensed.[4] The periradicular tissues will become inflamed by such reinfection and microorganisms lying dormant after initial treatment will be reactivated.

It was thought that the dentin of endodontically treated teeth was significantly different than vital dentin.[5,6] However, more current research casts doubt on this assumption.[7,8]

When is the best timing to start tooth restoration?

Because modern endodontic therapy achieves a predictably high success rate, postponing restoration for extended periods of time to be certain of endodontic success is unnecessary and could place the tooth at risk.

Bishop and Biggs[9] reiterated the need for prompt restoration immediately following completion of endodontic therapy to protect the treated tooth from microbial contamination.[10,11] In addition, when immediate preparation (after endodontic filling) of the post space was compared to delayed preparation (after at least 24 hours), neither method proved to be consistently superior.[12]

Ideally, post space preparation is completed at the appointment when the root canal is filled.[2] At this time, the clinician is most familiar with the canal system and reference points. He is also able to prepare the post space with the rubber dam in place to minimize microbial entry, and can further condense the apical segment of the root filling after the coronal gutta percha has been removed.

When a tooth had a periradicular lesion, some practitioners commonly waited months for radiographic evidence of healing prior to restoration. If a final restoration cannot be placed within a few weeks of endodontic treatment, a strong, leak-resistant, protective, provisional restoration is indicated. A well-processed temporary crown or bridge, glass ionomer, or acid etched composite build-up may be considered for the minimum time possible, as can a properly fitted and cemented orthodontic band.

How to choose the final restoration? Is crowning of the endodontically treated tooth mandatory?

Multiple factors must be considered in choosing a final restoration. Essential considerations include the amount of remaining sound tooth structure, occlusal function, opposing dentition, and position of the tooth in the arch, as well as length, width and curvature of the root(s).

It is also important to understand that changes occur in the dentin of endodontically treated teeth; affect its function under stress. The weakness is primarily caused by loss of tooth structure due to caries, previous restorations, fractures, or endodontic access procedures. Therefore, the strongest tooth is the one in which the most sound dentin and enamel can be retained and used to rebuild the tooth.

Anterior teeth

Crowns placed on anterior teeth do not make teeth inherently stronger.[13,14] Laboratory testing demonstrated a comparable resistance to fracture between sound and ETT anterior teeth.[15] Anterior teeth with intact marginal ridges, cingulum, and incisal edges, the placement of a lingual or palatal dentin-bonded composite resin is the treatment of choice.

Placement of a crown on an anterior tooth is indicated when there is extensive coronal destruction or the need for occlusal change, or for esthetic reasons. In such situations, the mechanical and esthetic properties of all ceramic, metal-ceramic, or modified resin (e.g. Vectris-reinforced Targis) crowns offer advantages over large composites. [16]

Some anterior teeth may require complete coronal coverage along with posts and cores. This is common when large proximal restorations are present, caries has undermined the remaining marginal ridges, or the majority of the incisal edge has been lost due to trauma.

Current research indicates that when an enamel-bonded porcelain veneer is being placed on an endodontically treated tooth, there is no need for post. [17]

Because the maxillary lateral incisor and the mandibular incisors are smaller teeth, a post is commonly indicated before crown placement. In maxillary central incisor and canine teeth, however, the decision should be made after crown preparation. If the dentist believes there is adequate remaining tooth structure to provide adequate resistance to fracture, a bonded composite is placed in the access preparation. If, in the judgment of the dentist, there is insufficient remaining coronal tooth structure to resist the functional forces, a post is placed.[18]

Discolored endodontically treated teeth may be bleached to an aesthetically acceptable color to prevent the need for removing sound tooth structure to place a veneer or porcelain fused to metal crown. However, when bleaching is indicated, caution may be advised if the tooth has been traumatized, as case histories for these teeth reveal a predisposition to cervical resorption.

Posterior teeth

Posterior teeth present a different set of restorative needs due to their structure and the occlusal forces placed on them during function. Posterior teeth receive predominantly vertical rather than shear forces. Contemporary thought, in both research and clinical practice, supports the placement of a protective restoration with full cuspal coverage on these teeth.[13,19] This is easily accomplished with a crown or onlay when sufficient tooth structure remains. Full coverage restorations prevent the fractures that can result from occlusal forces separating cusp tips during function.

Unless a large percentage of coronal tooth structure is missing, posts are rarely required in endodontically treated molars.[18] More conservative methods of core retention can be used.

However, complete coronal coverage may not always be necessary in cases of posterior teeth opposing partial or complete dentures. In these cases, the forces of mastication and cuspal interdigitation may be significantly reduced, thus minimizing chance of fracture.

ETT as abutments for fixed or removable prosthesis

The use of ETT as abutments for fixed or removable prosthesis has provided successful clinical results over time.[20]

Single abutments supporting precision attachment removable partial dentures (RPDs), distal extension RPDs or cantilever fixed partial dentures (FPDs) that are endodontically treated or likely to become so in the future should be avoided. Careful assessment of the occlusal demands and other loads such as FPDs or RPDs must be made prior to restoration.

Why build-up broken down endodontically treated tooth prior Fixed Prosthodontic Care?

The purposes of a build up are:

- To provide the compromised crown of the tooth with resistance, retention, and geometric form for the final restoration.
- To fill the pulp chamber and replaces lost tooth structure prior to crown preparation.
- To removes unknown restoration.

Should all teeth receiving crowns be built-up to provide "ideal" tooth preparation anatomy? Not for every case. Box with parallel walls increase the retention of the cast crown.

Choices in Build-up Materials

The optimal build-up material will have adequate strength, be biocompatible, exhibit a high level of resistance to bacterial leakage, and be insoluble and dimensionally stable in the presence of oral fluids. Easy of placement, bond to tooth structure, and can be contoured and prepared immediately are ideal features of build-up materials. Bullard and others[21] showed that a coefficient of thermal expansion close to that of the tooth reduces leakage.

The currently available core (build-up) materials are: cast gold, amalgam, composite, glass ionomer, and Resin-modified Glass ionomer.

Cast Gold

Cast gold offers high strength. It doesn't absorb water and has a coefficient of thermal expansion (CTE) very close to that of dentin. Typical CTE for gold is 14×10^{-6}; the CTE of dentin is 10.6×10^{-6}.[16] Its resistance to leakage is derived from the luting agent.

Cast gold build-ups require a post for retention and a substantial degree of coronal destruction to be used. It is expensive and time consuming.

Where applicable, this is the build-up material of choice.

Silver Amalgam

Its strength has been confirmed in laboratory studies in both static and dynamic loading.[22-25] It is relatively stable in the presence of water. It offers a high-level resistance to leakage once it has been in place for a period of time due to the sealing effects of its corrosion products.[16] Initial leakage has been shown to be significantly lower with dispersed phase alloys than with spherical alloys.[26]

Its coefficient of thermal expansion is almost double that of dentin (about 22×10^{-6}, versus 10.6×10^{-6}).[16] The dark color of amalgam has the potential to lower the value of all-ceramic restoration. Additionally, it is not possible to bond to set amalgam. Its lower early strength requires 15-20 minute wait before core preparation, even when a fast-set spherical alloy is used. It is messy to prepare and can result in irreversible staining of the marginal gingiva during preparation.

Bonding of amalgams is an option, and has the potential to strengthen the tooth and reduce leakage. Christensen[27] recommends that bonding of amalgam restorations be routine; however, with root-treated teeth, sensitivity is not an issue and the additional strength obtained is apparently transient. Santos and Meiers[28] found no significant strengthening of teeth with amalgam bond after thermocycling, and Bonilla and White[29] found short-term increases in strength that disappeared after 500-day storage or load cycling. As apparently the bond of amalgam to dentin will ultimately degrade, there is concern about increased leakage after bond failure. The bonded surface of the amalgam may be more corrosion resistant than an unbonded amalgam, leading to the risk of increased leakage on a long-term basis.[30] Given the short-term nature of the bond, the additional time and cost to bond, and unanswered questions as to the effects on long-term leakage, amalgam bonding is contraindicated for build-ups.

On posterior teeth with enough pulp chamber depth to obviate the need for a post (2 to 4 mm), amalgam is the material of choice. Where a post is required to retain the build-up, amalgam is cheaper and faster than a cast gold core and often less destructive of tooth structure. Amalgam is the material of choice in a high stress situation.

Composite Resin

It is available in light-cured, autopolymerized, and dual-cured formulation, and it comes in tooth colors and contrast colors for posterior use.

Composite apparently offers adequate strength clinically, its ultimate strength being somewhat lower than that of amalgam. Laboratory studies have confirmed adequate fracture toughness and compressive strength in a static load test. However, composite has not perform successfully in dynamic load test that are preformed in a chewing machine (undergo a plastic deformity that may lead to core failure). Kovarik and others[22] showed significantly shorter fatigue life for composite build-up supported crowns than for those with amalgam build-ups.

It is easy to be manipulated, and strong initially that can be prepared immediately. The major advantage of composite is its ability to be bonded to tooth structure and then serve as a substrate to which a ceramic crown can be bonded.

Its resistance to leakage is almost totally dependent on the bonding agent, and the ability of dentin bonding agents to prevent leakage over the long term is unproven. Burrow and others[31] showed a degradation of dentin bond strength in vitro over three years almost to the level of an unbonded restoration. If this is typical clinically, then the long-term ability of dentin adhesives to reduce leakage cannot be relied on, which means composite build-ups must rely on mechanical retention as do amalgam build-ups.

The coefficient of thermal expansion for most modern self-polymerising composite build-up materials is significantly higher than that of tooth; examples include Ticore by EDS at 34×10^{-6}, and BisCore by Bisco at 25×10^{-6}.[16] In addition, composites show significant polymerization shrinkage.

Sakaguchi and others[32] showed 0.2% post gel contraction. This shrinkage results in stresses on the bonding systems that may contribute to long-term bond failure. Also, composite is not dimensionally stable in a wet environment.[33] As it absorbs water, the core expands and as the composite dries out, the core shrinks. The absorption of water with composites is a potential concern due to the generation of internal stresses, but it is difficult to assess the clinical significance of this concern.

While composites are fast and convenient to use, in most instances they are inferior to amalgam and gold. On anterior teeth where a crown is not required and enamel margins offer the promise of long-term resistance to leakage, composite is an excellent choice. With the poor long-term prognosis for dentin bonding agents and the corresponding risk of leakage, relying on composite build-up materials for leakage control seems risky and unpredictable. On posterior teeth where composite is used as a build-up material, maintaining at least 2 mm between crown margins and the build-up should reduce leakage.

Composite resin is the material of choice when there is remaining coronal tooth structure and where high strength is not required.

Glass Ionomer

Glass ionomer materials offer a low level of leakage,[21,34] a relatively weak dentin bond and a low level of mechanical strength (including silver-reenforced).[16] They easy of manipulation and offer the appeal of fluoride release to reduce decay potential, but there is minimal evidence that this has any clinical significance. Kovarik and others[22] fatigue-tested crowns with amalgam, composite and glass ionomer cores, and found that amalgam was significantly stronger than composite and that glass ionomer had inadequate strength as a core build-up.

Because of its weak mechanical properties, glass ionomer has little to offer as a build-up material and should be reserved for limited applications such as blocking out minor undercuts.

Resin-modified Glass ionomer

It is easy to manipulate; however, its physical properties lie between those of glass ionomer and composite. In high-stress situation, therefore, is not material of choice. It should be only used in posterior teeth in which more than 50% of the coronal tooth structure remains.

How to Retain the Build-up?

With the use of cast gold, a post is mandatory for retention. With amalgam or composite, the retentive options are pins, posts and mechanical undercuts such as offered by a pulp chamber.

The use of pins to retain build-ups carries the risk of microfracture and introduces stress into the adjacent dentin. Teeth that require pins or posts to retain build-ups have already suffered significant coronal destruction. Caputo[35] recommends a minimum of 1 mm of solid dentin to surround a pin, yet this thickness is rarely available to retain build-ups on root-treated teeth. Also, the use of retentive pins associated with risk of perforation, weakening of the core restoration and prohibiting proper core condensation.

The use of slots or dovetails cut into dentin to retain the amalgam has appeal but requires the destruction of more tooth structure. There is also a risk that these retentive devices will be removed or weakened during crown preparation.

The undercuts in pulp chambers can be used to retain build-ups; Nayyar and others[36] and Kane and others[37] have shown that pulp chamber depths of 2 to 4 mm offer adequate retention for an amalgam build-up without pins or posts.

Posts offer the ability to retain the build-up and, if carefully placed, remove little tooth structure. They are also removable for orthograde endodontic retreatment.

When to Place a Post

Posts have one purpose (one main indication) is to retain a build-up (core) that can be used to support the final restoration. The decision regarding post placement should be made based on the amount of coronal remaining tooth structure. Thus, if adequate retention for the core can be derived from the use of natural undercuts in the pulp chamber and canal entrances, a post is not indicated. Cast post and core can help to change axial inclination of crowns to improve alignment.

Post placement requires the removal of additional tooth structure, and this will likely weaken the tooth further and create an area of stress concentration at the terminus of the post channel.[2] There is compelling evidence that they do not strengthen teeth[13,38-40] and a post is not necessary when substantial tooth structure is present after a tooth has been prepared. In actuality, placing a post can predispose a tooth to fracture. The use of certain post designs can predispose them to catastrophic failure, as shown by Sorensen and Engelman.[13]

In response to the discovery that posts do not strengthen teeth - they only serve to retain the core - research into design, shape, diameter, and length of posts now focuses on issues of retention.

NOTE: When endodontic therapy is performed through an existing cast restoration, filling the access cavity and restoring the occlusal surface is sufficient. Placement of a post through an existing crown does not enhance retention of the crown and, in fact, risks root perforation.

Cast vs. Prefabricated Post

Custom cast post

Custom cast post and core restorations have had a long history of successful use in restorative dentistry, especially when a coronal ferrule is provided. Its advantages include rigidity, better fit and more uniform thickness of cement

Laboratory studies have consistently demonstrated that the fracture resistance of teeth restored with a custom post is lower than that of many different prefabricated posts. Furthermore, prefabricated parallel posts have been proven to have greater clinical success than the custom cast post in several retrospective clinical studies. This, coupled with the added expenses and extra-appointment required to fabricate the custom cast post, makes its routine use questionable.

In general, custom cast post and core restorations are indicated in teeth with elliptical or excessively flared canals. It is also indicated where alignment of the proposed crown is significantly different from the inclination of the canal, which is often the case with anterior teeth. With most anterior, and some bicuspid teeth, there is also inadequate room for sufficient bulk of build-up material around the post to provide a solid unit. Thus for most anterior teeth and small bicuspid teeth requiring a post, the choice is a cast post core design.

When used, a cast post core should utilize a high-strength type IV gold alloy or a similar high-strength non-precious alloy.

Prefabricated post

In recent years, there has been a considerable increase in the number of post systems available. Preformed posts with an amalgam build-up are often more conservative of tooth structure than cast gold especially in posterior teeth. They are generally less expensive and quicker and easier to fabricate.

In general, prefabricated posts are indicated with small circular canals. The prefabricated post and core remains the most widely used system. Prefabricated posts with a direct build-up work very well in posterior teeth where there is room for sufficient bulk of build-up material. Canal angulation is infrequently a problem. Custom cast posts are indicated when a prefabricated post cannot be properly fitted

Post Size

Post length

Studies have shown that as the post length increases, so does retention.[41-43]

While longer posts demonstrate increased retention, their position in the root may lead to clinical problems. In thin or curved roots, long posts can cause perforations or fractures. In short roots, they may disrupt the apical seal.[44]

Many formulae for recommended lengths have been proposed. It is rational to prepare a post channel as long as it is consistent with anatomical limitations while maintaining 4 to 5 mm of apical gutta percha seal. Clinical success rates support post length equal to or greater than the crown length of the tooth. In a study of 1,273 teeth restored a minimum of one year, Sorensen and Martinoff[44] showed a 97% success rate for any post crown restoration in which the post length equalled or exceeded the crown length. Another recommendation was that the post length should be between one half and three quarters the length of the root.

Most endodontic texts and researchers advocate maintaining a 4-5 mm apical seal.[45,46] However, if a post is shorter than the coronal height of the clinical crown, the prognosis is considered unfavorable, because stress is distributed over a smaller surface area, thereby increasing the probability of radicular fracture. A Short root and tall clinical crown present the clinician with the dilemma of having to compromise the mechanics, apical seal or both. Under such circumstances, an apical seal of 3 mm is considered acceptable.[47]

Post diameter

Standlee and others[43] showed that post diameter was not a major factor in retention, and many researchers confirmed that increasing the post diameter significantly increases internal stress within the tooth and contributes minimal, if any, to the post retention.[40,48,49] Utilization of larger posts requires the removal of additional tooth structure and weakens the tooth,[50-52] increasing the risk of catastrophic failure and of having a tooth that is unrestorable. Also, experimental impact testing with cemented posts of different diameters[5] showed that teeth with thicker (1.8mm) posts fractured more easily than those with thinner (1.3mm) ones. In addition, the increased removal of tooth structure to accommodate a larger post can lead to perforation or predispose the root to fracture.

Posts have one purpose, to retain a build-up on a tooth. Based on this premise, posts function primarily in tension. A relatively small diameter post has ample strength in tension to retain any crown. The rather loose adaptation of a small diameter post in a canal does not reduce retention, as shown by Chan and others.[53]

Since the fracture resistance of a restored ETT decreases as the amount of dentine removed increases,[54] conservation of dentin is critical in post placement and dictates a post diameter that requires minimal canal instrumentation. Post diameter should not exceed one-third of root diameter.[47,55]

In choosing a post size, the practitioner must consider that root diameter decreases apically and that concavities in the root can be invisible radiographically. These anatomical factors can contribute to thin dentinal walls that are subject to fracture during the initial post cementation or during occlusion if the post is too wide.

Post design and shape

Prefabricated post can be divided into 2 major groups: passive or active, and each one of them can be subdivided to parallel or tapered. The surface of the passive post can be serrated or smooth. Root width and curvature as well as flaring of the canal must be considered when determining post design.

Threaded posts are more retentive than serrated posts, which are more retentive than smooth-sided posts.

Parallel vs. tapered

Parallel post designs (such as the Parapost system) offer increased retention over tapered designs.[43,53] Torbjorner and others[56] reviewed almost 800 posts after four years, and parallel posts showed half the failure rate of custom-cast tapered posts. Weine[57] showed a 94% success rate with smooth-tapered posts over 10 years.

However, the preparation of a parallel-sided post channel and subsequent cementation of a square-sided parallel post may produce increased stress in a narrow and tapering root-end[58] that may predispose to root fracture. Systems that are beveled apically may therefore be preferred. But once again, the preservation of tooth tissue is important to the long-term integrity of the tooth and tissue should not be sacrificed in order to create a parallel-sided post channel if a well-adapted tapered post can be placed with less sacrifice of dentine. Additionally, with flared canals, the parallel-sided post does not closely approximate the canal wall in the cervical region of the root, and retention is subsequently compromised, rendering the post less stable.

Tapered posts such as the PD system have a good record of clinical success.[57] Concerns have often been raised over the generation of wedging stresses by tapered (including customised cast) posts, and the tendency to promote root fracture. However, such forces are not active in the same way as those generated by self-tapping screw systems, and it may be that many cases of root fracture associated with tapered posts reflect the type of cases in which such posts are often used, i.e. the wide, thin-walled tapered canal.[2] Again, the importance of providing a protective coronal ferrule can not be over-emphasized.

In summary, parallel-sided posts are preferred to tapered posts, but each case should be carefully considered on its merits and dentine should not be unnecessarily sacrificed to dogmatically satisfy the desire to place a moderately more retentive parallel post.[2]

Passive Metal vs. Active Posts

Active post designs rely on some form of mechanical engagement of cutting flutes into dentin to gain increased retention, thus producing stress concentration around the threads, which increase the risk of root fracture.[54] This is amplified if the post has a wedge-liked, tapered design. Studies show that passive parallel-sided posts are less likely to contribute to root fracture. Meta-analyses of the limited clinical evidence available suggests that the performance of threaded posts is inferior (regarding the longevity of restored ETT) to that of customised cast posts[59] rendering them not preferable.

In general, it has been reported that the active threaded post has the greatest retention, followed by the parallel post; the tapered post having the least retention.[54,60] Therefore, the post should be chosen, in part, by the amount of retention which the clinical situation requires. If the post length is adequate, and the canal configuration is normal, either the passive prefabricated post may be selected. However, if the length of post space available is minimal or the canal space is funnel-shaped, an active post may be required because of the difficulty in gaining adequate axial retention of the post.[44] Actually in such cases threaded posts are no longer considered to be the sole option. Indeed, resin-bonding agents have been increasingly employed with serrated and preferably sandblasted metal or fiber posts, thus reducing the potential for stress concentration and improving the possibility of developing a hermetic coronal seal.[61]

One active post design, the Flexi-Post by EDS, purports to provide the retention of an active post while avoiding the potential stress on the root of a conventional solid active post design. As pointed out by Manning and others,[62] for the Flexi-Post design, the change in diameter provided by the slot in the post is minimal. The post compresses to an ellipse whose greatest width is almost equal to the original diameter. Standlee and Caputo[63] showed Flexi-Posts generated significant stress levels comparable with other active post designs. While the additional retention of an active post has appeal, any active post design induces more stress into a root than a passive design.

In summary, Passive, small diameter, parallel post designs are predictable and simple to use and are the design of choice.

Post Head Design

Where a prefabricated post is used to retain a composite or amalgam build-up, the ability of the build-up material to attach itself to the post is important. Chang and Millstein[64] tested the retention of Paraposts and Unity posts by Whaledent, and the Flexi-post by EDS with two types of composite build-up as well as amalgam. They found that the amalgam core was significantly more retentive than either composite core. Their results show the importance of the retentive features built into a post head. When trimming prefabricated posts, it is essential that this feature be retained. Use of prefabricated posts without such features should be avoided.

Prefabricated Post material

There are various type and brands of prefabricated posts.

(1) Metal prefabricated posts:

They are typically made of stainless steel, nicked chromium alloy, or titanium alloy. They are very rigid and strong [98]. Stainless steel posts are stronger for any given size than titanium posts and they are more radiopaque. This radiopacity is an advantage making a post easir to identify clinically. The parapost system by Whaledent is currently the only passive, parallel, stainless steel prefabricated post series on the market available in small diameters. The system provides 0.9, 1, 1.14 and 1.25mm diameter posts in addition to larger diameters.

(2) Fiber post

Several brands of fiber-reinforced epoxy resin posts are commercially available. These posts were originally reinforced with carbon fibers, which are black, that were a potential esthetic problem. Modifications to these fiber-reinforced posts include coating the post with quartz fibers to mask the black color. To improve the esthetic result, glass and quartz fiber reinforced dowel system were introduced. In these systems the carbon fibers were replaced with quartz fibers or glass fibers.

In vitro studies have indicated that these posts are not as strong as conventional post, and their strength degrades significantly in vitro after storage in water, thermocyding and cyclic loading.

Some investigators have suggested that these fiber-reinforced epoxy resin posts possess inherent flexibility that is similar to the flexibility of natural dentin, allowing the posts to behave similar to the radicular dentin, absorb stresses and prevent root fractures. Nevertheless an elastic modulus comparable to human dentin as measured in vitro does not ensure that the clinical behavior of the post will be similar to the clinical behavior of radicular dentine. The root is a hollow tube, and the post is a rod within this tube surrounded by a layer of composite resin luting agent. The radically different shape of root compared with the configuration of the post combined with the interposed composite resin luting agent suggest that the flexural characteristics of the post don't match that of the root.[99] Also, the suggestion that a young's modulus close to tooth is an advantage is questionable when the coronal restoration will be a rigid cast metal or ceramic crown. The increased flexibility in the coronal and radicular tooth structure resulting from these posts should cause increased, not decreased stress concentration at the crown margin. A flexible post can cause failure of the cement seal at the margin of the artificial crown, especially when the ferrule is minimal.

Fiber reinforced post is fairly easy to be removed[100] with an ultra sonic or rotary instrument[98].

(3) Zirconia Post:

These are all-ceramic post were originally designed for the use with composite core to improve the esthetic qualities of all-ceramic crowns, because it was assumed that a metal post and core would impede light transmission through the ceramic crown.

Zirconia dowels were made of from fine-grain dense tetragonal Zirconium polycrystals[101]. Ceramic materials are tough and have high compressive strengths, but because of their poor tensile strengths they may fracture when subjected to sheer stresses. To compensate for their brittle nature, these posts are made relatively wide, requiring substantial removal of radicular tooth structure. Retrieval of Zirconium post is very difficult[98].

Prior Post and Core Restoration

With previously filled root canals, the practitioner must determine the acceptability of the treated case prior to creating post space. A definitive final restoration should never be placed over an endodontic failure. Absolutely no adverse clinical signs or symptoms should be present. Radiographically, a dense, three-dimensional filling should extend as close as possible to the cementodentinal junction, without gross overextension or underfilling.

When a paste fill is present, retreatment of the canal is always recommended prior to post placement. If a silver cone is present and a post is necessary to accomplish the restorative treatment plan, it is always preferable to remove the silver cone and retreat the canal as opposed to removing the coronal portion of the silver cone with a bur. The latter approach has been shown to loosen the silver cone and often leads to root gouging or perforation. When treatment planning, if a practitioner is considering a thermoplasticized gutta-percha filling technique using a metal or plastic carrier, the plastic carrier is recommended when post space is required.

Post space Preparation

It is possible to disturb the apical seal during post-hole preparation. One of the goals of root canal treatment is to seal the root canal system in three dimensions. To achieve this, a minimum of four to five millimeters of root canal filling material must be retained as the apical seal.[45,67,68] Because of the complex anatomy of root apices, any less than four to five millimeters may lead to leakage.

Gutta percha removal and post channel preparation should not be undertaken in a single act with the aggressive end-cutting twist drills provided with proprietary post systems. To do so risks losing alignment and perforation of the root. Gutta percha should first be removed to the predetermined length using hot instruments or non-cutting tips burs (e.g. Gates Glidden or Peeso reamers) before the channel is shaped with measured twist drills appropriate to the post system selected.

Workers have investigated several methods of post space preparing and removal of gutta-percha and their effect on apical seal, these methods include the use of rotary instruments, heated instruments and solvents.[45,67,69-72] Mattison and others,[45] Camp and Todd,[67] and Suchina and Ludington[70] found little difference between mechanical removal with Gates-Glidden burs and removal with a hot plugger, while Haddix and others[69] found that removal with a warm plugger produced the least leakage.

Gates-Glidden burs offer a simple and predictable method for the removal of gutta-percha. Gates Glidden drills should be run at maximum speed with the slow-speed handpiece. Generating frictional heat that softens the gutta percha and eases its removal without disturbing the apical root filling.[69] Care must be taken when using rotary instruments to ensure the removal of gutta-percha only and the avoidance of routine enlargement of the canal space.

Powerful organic solvents (chloroform, halothane) should not be used in post channel preparation, since it is impossible to control their advance into the root canal where they can rapidly dissolve the gutta percha and sealer at a deeper level than anticipated.[2,47]

Once the coronal filling is removed and the space prepared, the remaining material in the canal should be gently but firmly vertically condensed.

Cementing media for posts

All posts, whether cast or prefabricated, are cemented inside the root canal. The cementing medium enhances retention, aids in stress distribution, and, ideally, seals microgaps between the tooth and the post.

Cements for posts and core restorations have been investigated extensively.[73-76] These include zinc phosphate, polycarboxylate, glass ionomer, filled and unfilled resin composites. Historically, zinc phosphate was the cement of choice, yielding higher retentive values than polycarboxylate or standard resin cements. Both zinc phosphate and glass ionomer have similar properties and are commonly used because of their ease of use, coupled with their history of clinical success.[75]

Zinc phosphate, and resin modified glass ionomer cements such as vitremer luting, offer adequate retention and resistance to leakage and simplify post removal. Pure glass ionomer cements should work as well but are sensitive to moisture or the lack of it in a canal when setting. The use of resin cements should be reserved for cases outside of these criteria where adequate post length and retention are not available.

In recent years, interest in the use of both filled and unfilled resins has increased. Some clinical studies have shown a significant increase in post retention with resin cements [77,78] but another study has not confirmed this finding.[76] Some studies have advocated the use of low viscosity resin cement in combination with removal of the smear layer from the canal walls. This permits a movement of the resin into the exposed, patent dentinal tubules. This process yields an increase in post retention when compared to zinc phosphate. From the perspective of the ability to retrieve the post in the case of fracture or for orthograde endodontic retreatment, the use of resin cement is contraindicated. In addition, the ability of resin cements to provide long-term resistance to coronal leakage is dependent not only on the longevity of the dentin bond but also on the bond to the post. Both are unproven. There is little or no evidence that the increased retention offered by these cements is a factor in clinical success where adequate post length can be obtained. In fact, Standlee and Caputo[79] warn that too much retention may predispose a tooth to fracture.

There are, however, two problems with the use of resin composite cements. First, resin cement is technique-sensitive because of its short working time. Second, it is difficult to remove all of the gutta-percha and eugenol-containing cement from the prepared canal without excessive removal of tooth structure, by irrigation with ethanol or etching with 37% phosphoric acid.[76,80] When using zinc oxide eugenol sealers, traces of which may prevent adequate conditioning of the dentin and interfere with the polymerization of restorative resins or cements. It may be prudent to rinse the pulp chamber with alcohol, as it rapidly sequesters excess eugenol and is not known to threaten the integrity of gutta percha root fillings.[80]

However, it must always be borne in mind that, despite improved retention in some laboratory studies, especially if the post has a poor fit within the canal,[81,82] none of the cements can overcome the inadequacies of a poorly designed post, and, ultimately, the choice of luting agent seems to have little effect on post retention[73] or the fracture resistance of dentine.[83]

With regard to cements, the practitioner must keep in mind that coronal leakage is a major factor in endodontic failure. All contemporary cements are susceptible to dissolution in the presence of saliva. Therefore, the importance of close marginal adaptation of crown to tooth for protection of the cementing medium cannot be over emphasized.

Venting

A means for cement to escape must always be provided to reduce the intraradicular hydrostatic pressure created during cementation of the post, this factor is of profound importance especially with the custom cast post.[84] Virtually most prefabricated posts have a venting mechanism incorporated in their design, A vent may be incorporated in the custom cast post with a bur prior to cementation or it may be incorporated in the wax pattern before.[55]

Method of cementation

These methods include placement of the cement with the post, and/or cement placement with a lentulo spiral, a paper point, or an endodontic explorer. Investigations of these methods[85-87] have shown that the lentulo spiral is the superior instrument for cement placement. Another method for cement placement is using a needle tube, taking care to insert the tip of the tube all the way to the bottom of the canal space and provided that cement extrudes from the tip as it slowly is removed from the canal. After cement placement, the post is coated with the cement and is inserted.[55] The use of an organic solvent (Cavidry, Parkell) when zinc phosphate cement is used prior to post cementation increases its retention.[88]

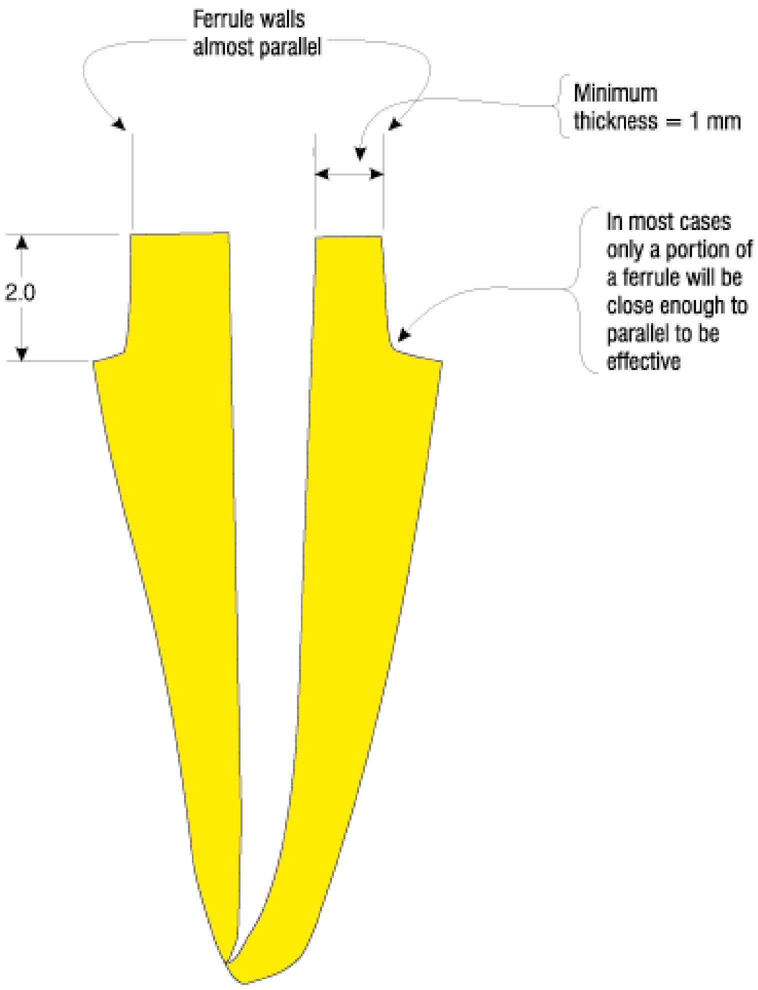
Ferrule Design

A ferrule is a band of metal that is thought to help bind the remaining tooth structure together preventing root fracture during function, as it completely encircles the tooth, extending the axial wall of the crown at least 1-2 mm onto sound tooth structure gingival to the core.[61,89-91] No matter how well the core materials are bonded to the tooth structure, the potential for leakage exists if the materials are left exposed to the oral environment. In addition to improved sealing, crown cementation on tooth margins gingival to the core significantly enhances stability and increases retention. Resistance to root fracture and core fracture are also improved.

Considerable focus has been placed on the potential for coronal leakage to cause the failure of otherwise acceptable endodontic treatment. Torabinejad and others,[92] Swanson and Madison,[93,94] and Khayat and others[4] showed that leakage will occur corono-apically along the obturated canal if the coronal access is not effectively sealed. In a retrospective study, Ray and Trope[95] have shown that the long-term success of a restoration depends more on the quality of the final restoration than on the quality of the endodontics. The importance of the quality of the final restoration and its ability to minimize leakage cannot be overstated. An in vitro study by Freeman and others[96] compared leakage under post-retained composite cores and cast gold post cores and the number of cycles until a strain gage detected movement between the artificial crown and the root. Movement between crown and root was measured very early in the experiment, on average after only a few hundred cycles. In the experimental design, tooth preparation "extended 1 mm apical to the core-tooth interface, thereby providing a 1 mm ferrule on tooth structure."[96] In reality, when the teeth were sectioned and the margins examined, there was little or no ferrule present. The cross-sections effectively showed a chamfered or bevelled margin that was far from parallel. Both Barkhordar[97] and Sorensen[89] have shown the importance of at least 1 mm of almost parallel wall preparation. The study by Freeman and others[96] highlights the misconceptions as to what constitutes a ferrule. Given the realities of intraoral tooth preparation, a minimum of 2 mm of preparation length on solid tooth is recommended to ensure an adequate length of parallel wall to achieve an effective ferrule (**Fig. 1**).

When these objectives cannot be readily achieved due to deep caries or tooth fractures, periodontal crown lengthening is indicated. In the case of the severely compromised endodontically treated tooth, crown lengthening ensures not only a properly restored tooth, but also allows for a sound biologic attachment of periodontal tissues two to three millimeters apical to the crown.

Fig. 1 Ferrule criteria and dimensions



Occlusal Equilibration

On a final note, one of the overall clinical goals of endodontic treatment is to retain teeth in a symptom-free functional condition. Often overlooked is the need to ensure proper occlusal equilibration during and following endodontic and restorative treatment. Recently endodontically treated teeth tend to be sensitive, even to minor occlusal irregularities, due to lingering inflammation of the periapical tissues. Careful attention to occlusion can routinely provide the patient with a comfortable and functional restored tooth.

Discussion

The restoration of anterior teeth needs better criteria on which to base restorative decisions. Even knowing when to place a crown on an anterior tooth is very hard to determine. The issue of leakage with endodontically treated teeth is of concern: how much leakage is too much? Does the degradation of dentin bonding agents over time present a concern for clinically significant leakage under build-ups or along posts?

It is impossible to guarantee success in every case. However, predictably successful endodontic therapy cannot be achieved without properly designing and executing restorations with careful consideration of potential periodontal complications. When prosthetic and periodontal considerations are addressed concurrently with endodontic treatment, patients leave the office with the best possible prognosis for teeth that would otherwise have been lost.

The information in this article is meant to aid dentists in the restoration of endodontically treated teeth. Practitioners must always use their best professional judgment, taking into account the needs of each individual patient when choosing a restorative plan.

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