

Restoring of endodontically treated tooth. Concepts and techniques

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المهدف من هذه المقالة هو تزويد طبيب الأسنان الممارس بالخطوط الرئيسية لترميم الأسنان المعالجة لياً والتي لها وضع خاص وذلك باستعراض شامل لعدد كبير من الدراسات الحيوية والمحورية والتي تغطي الجوانب التقنية والسريرية، وغطت هذه الدراسة عدداً كبيراً من جوانب الموضوع منها: هشاشة الأسنان المعالجة لياً، كذلك إعادة بناء السن بواسطة استخدام الأوتاد، استطبائات وأنواع الأوتاد، ثخانة هذه الأوتاد وطولها، شكلها وحشونة سطحها، طريقة تثبيتها والمواد المستخدمة لذلك، بالإضافة لاستعراض الدراسات المتعلقة بترميم الجزء الناحي من السن ومدى أهمية هذا الجزء المتبقي، من خلال تاج السن ثم تحضير قناة السن للوندد، بالإضافة للخطوط الرئيسية العامة لعلاج هذه الأسنان. أظهرت النتائج بأن الأوتاد لا تزيد من قوة السن المعالج لياً. إن المحافظة على بنية السن والمتزامن مع "تأثير الطوق أو الحلقة" يريد من علاج السن المعالج لياً. إن قوة اللادة المستخدمة في بناء القلب وطول الوند لهما تأثير مباشر على نجاح الأوتاد المستخدمة. إن استخدام الأوتاد المصنوعة في الأسنان الأمامية هي الأفضل في حين استخدام الأوتاد المعاصرة في الأرحاء الخلفية هي المفضلة. أما للتوضيح فيمكن استخدام أي من النوعين. تعتبر الأوتاد المخزنة والتي ثبت في حاج السن خطرة ولا ينصح باستخدامها. هنالك أنواع مختلفة من الاسمنت تغطي نتائج مرضية شريطة ان يكون الوند والقلب محكم الإعداد.

The purpose of this article was to provide the clinical guidelines in restoring endodontically-treated teeth (ETT). A comprehensive review of a considerable number of *in vitro* and *in vivo* studies that cover the technical and clinical aspects of these procedures was done. Topics covered included: the resulting brittleness of endodontically-treated teeth, the reinforcement of tooth structure by using a post system, the significance of remaining coronal tooth structure, coronal microleakage, indications of posts, post design, types of posts, post diameter, post length, surface roughness of posts, venting, canal preparation, luting agents, cementation methods, and general treatment guidelines. The review showed that posts do not reinforce a pulpless tooth and therefore the conservation of tooth structure and the incorporation of "ferrule effect" are vital to enhance the prognosis of ETT. The strength of core materials and the length of the post directly affect the clinical success of posts. Custom cast posts are potentially more conservative in anterior teeth whilst prefabricated posts are more conservative in molars. Premolars may be restored with either technique. Threaded posts that engage dentine are dangerous and generally not recommended. Various cements produce acceptable results provided the post and core are well executed.

Introduction

The restoration of endodontically treated teeth (ETT) has traditionally been known as an empirical practice without entirely predictable results.¹ A good percentage of clinicians have been carrying out their treatment plans based on past clinical experience without resorting to a specific treatment protocol.² However, recent technological advances in endodontics, periodontics and restorative dentistry have contributed to a shift in such practices paving the way for more predictable restorative results due to the gradual development of reliable treatment protocols.

Provision of proper endodontic treatment and subsequent coronal restoration to teeth that were once thought of as "hopeless" or "lost" contributes to maintaining the stability of the dental arches, as well as improving aesthetics.³ Furthermore, the use of ETT as abutments for fixed or removable prosthesis has provided successful clinical results over time.⁴

An 82% success rate in ETT restored with post 10 years postoperatively was reported⁵ with an average of 2.1% failure rate per year.⁶ Nanayakkara *etal.*⁷ reported the median survival rate to be 17.4 years. The fact that traditional endodontic therapy

has a reported success rate of up to 95%⁸ may be slightly misleading as this is not truly indicative of the end result of the treatment plan for a particular tooth. Rather, it is the final coronal restoration of ETT, carried out at a precise and appropriate time that determines the success or failure of completed treatment. In fact, workers have gone on to report that a primary cause of endodontic failure can be attributed to the failure in properly restoring an ETT, which may have failed due to the lack of an adequate restoration.⁹

Selecting the optimum restorative modality to compensate for the loss of coronal tooth structure is considered the key to restorative success. This selection process is often complicated by the many clinical techniques and post and core systems currently available.¹⁰ Prior to choosing a post and core system, the dentist must have a clear understanding of several variables regarding the post-tooth combination. These variables include the post length, diameter, shape or design, venting, surface roughness, in addition to the canal preparation, method of cementation and luting medium.

Despite the vast literature that had been published with regards to the restoration of

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endodontically treated teeth,¹¹ the organization and subsequent formulation of such information into a proper treatment protocol remains cumbersome for many clinicians. This article aims to provide a review of the aforementioned literature and then to highlight some of the significant guidelines for the restoration of ETT.

Brittleness of Endodontically Treated Teeth

The belief that ETT are brittle has been attributed to their reduced toughness due to desiccation or other physical changes in the dentine of pulpless teeth. However, despite the fact that ETT have reduced moisture content than vital teeth^{12,14} there is no experimental proof that ETT are weaker or more brittle than vital teeth.^{15,16} Laboratory testing demonstrated a comparable resistance to fracture between sound and ETT anterior teeth¹⁷ but that does not preclude occurrence of clinical fracture of ETT. Hence, attempts at strengthening such teeth by the use of metal posts have been carried out. However, 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.¹⁸

Reinforcement of Tooth Structure by Using a Post System

Despite the lack of data to support its success¹⁹, post placement in ETT is a common clinical procedure amongst restorative dentists. Most of the laboratory and stress analyses studies have actually determined that no significant reinforcement results.²⁰⁻²⁴ This might be explained by the hypothesis that, when the tooth is loaded, stresses are greatest at the facial and lingual surfaces of the root and an internal post, being only minimally stressed, does not help prevent fracture.^{17,23,25,26} Cemented posts may further limit or complicate endodontic retreatment options if they become necessary. Furthermore, if coronal destruction occurs, post removal may be necessary to provide adequate support for a future core, for these reasons, a metal post is not recommended in anterior teeth that do not require complete coverage restorations. This view is supported by a retrospective clinical study²⁷ that did not show any improvement in prognosis for ETT anterior teeth restored with a post. Therefore, when a complete coverage restoration is not required for aesthetics and/or functional reasons

(to serve as an abutment for fixed or removable partial dentures), a post is not indicated.²⁸

Significance of Remaining Coronal Tooth Structure

In most ETT, the amount of coronal tooth structure remaining is often limited as a result of trauma, caries, prior restoration and endodontic access procedures.^{19,29} This might reduce the fracture resistance of ETT. Endodontic access in combination with the earlier loss of one or both marginal ridges leave the tooth at serious risk of fracture, even if it was reduced out of direct occlusal contact before endodontic treatment began.¹⁸ The amount of remaining tooth structure is probably the single most important predictor of clinical success. If more than 2 mm of tooth structure remains, the post design probably has a limited role in the fracture resistance of the restored tooth.^{30,31} Furthermore, the strength of an endodontically treated tooth is reported to be directly related to the bulk of remaining dentine.^{19,31}

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 1-2 mm onto sound tooth structure.^{31,32}

Coronal Microleakage

In addition to the traditional endodontic failure causes which include poor apical seal and poor canal debredation and obturation,^{31,33,35} coronal microleakage is considered a major cause of endodontic failure.⁹ Saliva and microorganisms from the mouth migrate rapidly alongside poorly adapted restorations and even root fillings which appear well condensed. The periradicular tissues will become inflamed by such reinfection and microorganisms lying dormant after initial treatment may be reactivated. A well-sealed coronal restoration is therefore critical to endodontics success, and it is stressed that this applies as strongly to temporary restorations as it does to permanent ones. Posterior teeth can be temporized with cuspal coverage amalgam restorations, which will prove durable and well-sealing for many months or years, but the same cannot be said for anterior temporary post crowns, which should be in place for the minimum time possible.¹⁸

Indications of Posts

The chief function of a post is to retain the core. 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.^{18,36,37}

For ETT posterior teeth, some form of cuspal coverage should always be provided. A complete-coverage crown becomes mandatory in cases where there is extensive loss of coronal tooth structure or when the tooth is serving as an FPD or RPD abutment.¹⁹ In this case, retention and support are derived from within the canal due to the limited remaining coronal dentine once reduction for complete coverage restoration is completed. That, in addition to the loss of internal tooth structure to complete endodontic treatment renders the remaining walls thin and fragile, often requiring reduction in height.

Despite the aforementioned reports against the routine use of crowns for ETT, it is known that restored ETT using post have significantly greater longevity than do restored teeth without post, and that some ETT can perhaps be restored with more conservative modalities than the usual post and core covered with a complete crown.¹⁹

When complete coverage is not required for anterior teeth, several options can be thought of. A minimally damaged tooth (defined as a sound natural crown with a conservative access opening),² can be restored by an acid-etched resin composite or reinforced glass-ionomer restoration.⁴ Significantly damaged ETT teeth (undermined marginal ridges, loss of incisal edges, coronal fracture) may require full coverage.²

Although post systems are likely to provide satisfactory retention for the coronal restoration, the cost for such retention should be considered thus dentists should shift their attitudes towards factors that maximize resistance to tooth fracture²³ such as the preservation and protection of tooth tissue and the avoidance of stressing restoration components.

Post Design or Shape

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.^{38,39} Therefore, the post should be chosen, in part, by the amount of retention which the clinical situation requires. If the post length is adequate, usually considered to be 7 or 8 mm and

the canal configuration is normal, either the tapered or parallel prefabricated post may be selected. However, if the length of post space available is minimal or the canal space is funnel-shaped, an active threaded post may be required because of the difficulty in gaining adequate axial retention of the post.²⁵

Types of Posts

Custom cast post

Customized cast post and core restorations have had a long history of successful use in restorative dentistry, especially when a coronal ferrule is provided.^{31,40} They are especially versatile and can often be fabricated with minimal additional canal preparation. The shape of the canal dictates the type of post used.^{19,41} In general, customized cast post and core restorations are indicated in teeth with elliptical or excessively flared canals.¹⁹ However, laboratory studies⁴² 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.²⁷ This, coupled with the added expenses and extra-appointment required to fabricate the custom cast post, makes its routine use questionable.²⁵ In situation when multiple cores are being placed in the same region, the treatment of choice is to make an impression and fabricate custom cast post in the laboratory. Also, in situation whereby the crown angulation must be changed for esthetic reasons in relation to the root angulation, the cast post and core is considered the restoration of choice.

Prefabricated post

The prefabricated post and core remains the most widely used system.¹⁰ They can be divided into 4 major groups: passive tapered, active tapered, passive parallel and active parallel.^{43,45}

Passive parallel-sided posts, such as the Parapost system are more retentive than tapered posts.⁶ 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-end⁴⁶ that may predispose to root fracture but the

parallel post has long history of success. 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.

Active tapered posts such as the PD system have a good record of clinical success.⁴⁷ Concerns have often been raised over the generation of wedging stresses by tapered (including customized 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 canal¹⁸. Again, the importance of providing a protective coronal ferrule cannot be over-emphasized.

In summary, parallel-sided posts are preferred to tapered posts due to its wedging effect on tooth structure, 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.¹⁸

Metal prefabricated posts made of precious and non-precious alloys may shine through all-ceramic restoration and thin gingival tissue in addition, they may cause discoloration due to corrosion products of non-precious metals.^{48,49} Various tooth colored post materials have been suggested to overcome this problem including zirconium coated carbon fiber posts, all-ceramic zirconium posts, prefabricated resin posts and direct resin composite reinforced with fibers.^{11,19,28}

Post Diameter

Although a group of investigators^{50,51} reported that increasing the post diameter increases retention, many researchers confirmed that increasing the post diameter significantly increases internal stress within the tooth and contributes minimal, if any, to the post retention.^{52,54} Keeping in mind that the fracture resistance of a restored ETT decreases as the

amount of dentine removed increases,³⁸ empirical evidence suggests that the diameter of the post should be as small as possible while retaining the necessary rigidity. The post diameter should not exceed one third of the cross-sectional diameter of the root and should fit with minimum alteration to the canal.^{19,28} Experimental impact testing with cemented posts of different diameters showed that teeth with thicker (1.8mm) posts fractured more easily than those with a thinner (1.3mm) ones.¹²

Post Length

Studies have shown that as the post length increases, so does retention.^{52,55,56} However, the relationship is not necessarily linear. A post that is too short will fail, whereas one that is too long may damage the seal of the root canal filling or risk post perforation if the apical third is curved or tapered.²⁵ Most endodontic texts and researchers advocate maintaining a 4-5 mm apical seal.^{57,59} 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 3-5 mm is considered acceptable.¹⁹

Surface Roughness

Surface roughening, such as air abrading or notching, of the post increases retention^{52,60,61} as does controlled grooving of the post and root canal.⁶² As agreed in the literature, the threaded post system offers the maximal mechanical retention. However, these systems offer active retention by engagement of elastic dentine, thus producing stress concentration around the threads, which increase the risk of root fracture.³⁸ This is of special importance when the posts are self-tapping, and is amplified if the post has a wedge-like, tapered design.

Meta-analyses of the limited clinical evidence available suggest that the performance of threaded posts is inferior (regarding the longevity of restored ETT) to that of customized cast posts⁴⁰ rendering them not preferable. In situations where enhanced retention is needed, 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.³¹

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.⁶³ 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.²⁸

Post Space Preparation

Bishop and Biggs⁶⁴ reiterated the need for prompt restoration immediately following completion of endodontic therapy to protect the treated tooth from microbial contamination.⁶⁵ 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.⁶⁶

Ideally, post space preparation is completed at the appointment when the root canal is filled.¹⁸ 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. 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 burs with non-cutting tips (e.g. Gates Glidden) or with hot instruments before the channel is shaped and enlarged progressively with measured twist drills.

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. Also, care must be taken to not cause any damage to the periodontal ligaments. Significant temperature increase on the root surface can be caused by rotary or hot instrument.⁶⁷

Luting agent

Cements for posts and post-and-core restorations have been investigated extensively.⁶⁸⁻⁷¹ These include zinc phosphate, polycarboxylate, glass-ionomer, filled and unfilled resin composites. Both zinc phosphate and glass-ionomer are commonly used because of their ease of use, coupled with their history of clinical success.⁷⁰ Some resin and glass-ionomer cement have demonstrated significantly higher retention in comparison to resin-modified glass-ionomer cements.⁷²

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 cements⁷³⁻⁷⁷ but another study did not confirm this finding.⁷¹ 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 which prevent adequate conditioning of the dentin and inhibits the set of the polymer.^{71,73}

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,^{74,75} 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 retention⁶⁸ or the fracture resistance of dentine.⁷⁶

Cement Placement

Several methods including placement of the cement with a lentulo spiral, a paper point, or an endodontic explorer were suggested. Investigations have shown that the lentulo spiral is the superior instrument for cement placement.⁷⁷⁻⁷⁹ 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 is slowly removed from the canal. After cement placement, the post is coated with the cement and is inserted.²⁸ The use of an organic solvent (Cavidry, Parkell) when zinc phosphate cement is used prior to post cementation increases its retention.⁸⁰ After cement placement, the post should be coated with the cement and placed in the canal.

Treatment Guidelines

Minimal loss of coronal tissues is achieved as follows:

- A composite resin, bonded as soon as possible after endodontic treatment has the added advantage of securing an early hermetic seal against coronal microleakage.
- Gutta percha is cleared from the canal using Gates Glidden drills or hot instruments¹⁸ or reamer supplied with ready-made post kits.
- 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.^{18,19}
- When using zinc oxide eugenol sealers, traces of which may 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.⁷³
- Premolars and molars with minimal access cavities and no other coronal tissue loss can be restored with amalgam or composite combination combined with a resin bonding system which serves to enhance the marginal seal. Careful removal of root filling material with hot instruments or Gates Glidden drills as previously stated ensures that the restorative material extends 2-3 mm into the canal entrance.^{18,19}

Moderate loss of tooth tissue occurs in a number of clinical situations:

- When tissue loss is more severe, a post (either cast or prefabricated) is required. Gutta percha is first removed from the canal, ideally leaving 4-5 mm of the root filling material apically. The initial path is made with hot instruments or Gates Glidden drills (size 2 and 3) running 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.⁸¹
- Having created the initial path, twist drills appropriate to the post system selected are then used to enlarge and shape the channel. Care must be taken not to remove excessive

amount of dentine to accommodate a preformed parallel post in a flared canal a tapered or custom-made cast post is preferred in this situation.

- Features can be built in to provide a protective ferrule when using metal castings. In addition, they can be customized to minimize the need for dentine removal. However, their chief disadvantage is the need for temporization with a temporary post crown that is unlikely to provide a hermetic coronal seal during the time that is required to fabricate the post.³⁴ Thus, it may be preferable to use a prefabricated post and a composite core and restore the tooth immediately.^{34,82} In this situation, an immediate and permanent coronal seal is provided. This should be balanced in heavy-loading situations, considering the length of the core and the post-core interface.^{18,19} Extending the crown margins onto the sound tooth tissue by developing a ferrule should minimize the physical demands on the composite core - and this may be subgingival or may involve a crown-lengthening procedure or forced eruption to obtain supragingival margins.
- Posterior tooth that have lost one or both marginal ridges in addition to tooth loss for endodontic access require cuspal coverage. Amalgam and composite cores can be retained without the need for posts, but if a post is deemed necessary, it should always be placed in the straightest and most bulky root - usually the distal in lower molars and the palatal in upper molars. Premolar roots should be judged individually based on their merits. Even if a post is placed, root-filling materials should always be removed from the entrances of other canals to provide additional retention for the core and resistance to rotational torque.^{18,19}
- Adhesive retained plastic restorations are unreliable as long-term internal splints. When there is no plan to fully cover a weakened posterior tooth due to financial reasons, or when the root-treatment is on probation, then physical cuspal coverage and protection must be provided by the core material. Cusps lying adjacent to lost marginal ridges are reduced in height by 3mm and overlaid with dentine bonded amalgam or composite resin. These restorations can provide a cost-effective and durable service for many years.³⁶

Conclusions

1. Conservation of tooth structure improved the prognosis of ETT.
2. Posts do not reinforce a pulpless tooth.
3. Ferrule effect was critical it should come from the completed crown not from the cast core.
4. The clinical success of posts was directly related to their lengths; so 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.
5. When little coronal tooth structure remains and direct core is placed, strength of the core material was critical. Ranking of core materials according to their strength in descending order is amalgam, composite and glass-ionomer cement.
6. Custom cast posts are potentially more conservative of tooth structure particularly in anterior teeth because the post is made to fit the available tooth structure.
7. Prefabricated posts require preparation of the tooth to fit the post, so these are often less conservative especially when using parallel-sided posts for teeth with small tapered roots.
8. Because cast posts require a path of insertion which require more cutting in posterior teeth, a prefabricated post is usually more conservative in molars. Molars often perform satisfactorily with direct cores retained by engaging pulpal and portion of the canals and retention of the core can be augmented by placement of one or more prefabricated post.
9. Premolars may be restored with either custom cast posts or prefabricated post (s).
10. Threaded posts that engage dentin could be dangerous and generally not recommended.
11. Various cements are likely to produce acceptable results so long as the post and core are well executed.

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