Restoration of endodontically treated teeth: The seven keys to success
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Preservation of tooth integrity and strength is important for the long-term survival of endodontically treated teeth. Post space preparation requires reduction of the remaining supportive tooth structure. Restorative modalities following root canal therapy must provide sufficient strength for the prosthetic material and tooth structures. This article presents seven key factors that should be taken into consideration to ensure clinical success when restoring an endodontically treated tooth.

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Several factors play a role in the long-term survival of endodontically treated teeth and associated restorations. The key factors that affect tooth and restoration survival.

Fiber-reinforced resin posts should be used with caution until more long-term data are available
For many years, the standard method for restoring endodontically treated teeth has involved either a custom cast prefabricated metal post with a restorative material core. A nationwide survey of dentists in 1994 reported that used prefabricated posts, the most popular being the parallel-sided serrated metal post. It is likely that prefabricated post usage has increased substantially since that 1994 survey.

The high demand for esthetic restorations and all-ceramic crowns has led to the development of a variety of nonmetallic posts. In addition to the esthetic advantages of nonmetallic posts, laboratory tests of these posts offer favorable physical and mechanical properties and less root fracture compared to metal posts. Fiber-reinforced posts have produced a wide range of reported failure percentages, ranging from 0% (after a mean period of 2.3 years) to 11.4% (after two years). The most commonly reported complications are post loosening and root fracture (Fig. 1 and 2).
Given the wide range of reported failure percentages, it appears that more long-term clinical data are needed to determine the efficacy of fiber-reinforced posts.

Crowns should be placed on most endodontically treated posterior teeth to enhance their longevity. Clinicians have observed a difference between endodontically treated teeth and vital teeth. Endodontically treated teeth tend to break during extraction; in addition, pulpless molars without crowns can fracture.

Multiple studies have shown that endodontically treated teeth benefit from the placement of crowns. Aquilino and Caplan reported that endodontically treated teeth with crowns had a survival rate six times greater than that of teeth without crowns (evaluated 116 teeth that had failed and were extracted; the authors reported that endodontically treated teeth with crowns were lost after an average of 50 months, while endodontically treated teeth with crowns were lost after an average of 87 months.
According to several clinical studies, fixed partial dentures have increased clinical failure when they are supported by endodontically treated abutment teeth rather than vital abutment teeth.\textsuperscript{28,32-35} One study determined that crowns significantly improved treated posterior teeth but did not improve the success of anterior teeth, indicating that intact endodontically treat complete crown coverage unless they are weakened by large and/or multiple coronal restorations or they require color or form.\textsuperscript{36}

Conversely, Mannocci et al evaluated endodontically treated premolars that had been restored (both with and without complete coverage) by either a post or direct composite resin restorations and reported similar success rates for both.\textsuperscript{37} A similar retrospective cohort study by Nagasiri and Chitmongkolsuk indicated that endodontically treated molars that are intact (except for the access opening) could be restored successfully using composite resin restorations.\textsuperscript{38}

After considering the available data, the authors recognize the potential benefits of using composite resin to restc intact except for the access opening. However, since wear is an indicator of the forces that will be brought to bear data are needed to determine the long-term success of these teeth when varying degrees of occlusal wear are present. The authors recommend using crowns that encompass the cusps because they will help cusps that have been weakened by previous tooth structure removal to withstand the occlusal forces of everyday mastication.

Conversely, it may be possible to avoid placing crowns on some previously restored posterior teeth, such as maxillary first premolars with small, poorly developed lingual cusps that would not be subjected to the wedging effect from opposing cusps. With these first premolars, there is little chance that occlusal forces will separate the cusps, so the access opening can be restored without the need for a coronal coverage crown.\textsuperscript{39}

**Posts weaken endodontically treated teeth rather than enhance their clinical longevity**

Historically, the use of posts has been based on the concept that they reinforce teeth; however, nearly every laboratory study has reported that posts either fail to increase the fracture resistance of extracted endodontically treated teeth or that they decrease the resistance of the tooth when force is applied via a mechanical testing machine.\textsuperscript{40-50} Pontius and Hutter reported that maxillary incisors without posts resisted higher failure loads than those with posts and crowns.\textsuperscript{42} Gluskin et al found that mandibular incisors with posterior teeth with posts and cores.\textsuperscript{43} These studies showed no evidence that posts strengthen or reinforce teeth (Fig. 4).
Clinical studies also have failed to provide definitive support for the concept that posts strengthen endodontically treated teeth. Longitudinal radiographic study, Eckerbom et al evaluated the radiographs of 200 consecutively treated patients endodontic treatment and reported that teeth with posts had significantly more apical periodontitis. In a 2003 ar clinical studies, Goodacre et al noted fractures in 3% of teeth with posts, with no evidence that posts enhanced they have had little effect on the clinical success of fixed partial denture abutments but they have been reported to improve removably partial denture abutments compared to endodontically treated abutments that did not use posts.

Clinical and laboratory data indicate that teeth are not strengthened by posts; rather, their purpose is to retain a core that will provide adequate support for the definitive crown or prosthesis. Unfortunately, this primary purpose has not been completely recognized. A 1995 survey showed that 24% of general dentists felt that posts strengthen teeth. A year earlier, Morgano et al reported that 62% of dentists over age 50 believed that a post reinforces the tooth, compared to only 41% of dentists under age 41. Thirty-nine percent of full-time faculty, and 56% of non-faculty practitioners felt that posts reinforce teeth. In a survey conducted in Sweden, Eckerbom et al found that 29% of general dental practitioners felt that a post reinforced the tooth, compared to 17% of board-certified prosthodontists.

Since posts do not appear to reinforce teeth, they should be used only when the core cannot be retained by any other means.

To ensure an adequate apical seal, 5 mm of gutta-percha should be retained. After an endodontically treated tooth is prepared for a post, the remaining gutta-percha at the apex is the only barrier against bacteria passing into the periapical area. Several studies showed that leakage increased when only 2–3 mm of gutta-percha was present; 4–5 mm of gutta-percha ensures an adequate seal. Although multiple studies indicate that 4 mm produces a precisely 4 mm is difficult and radiographic variations in angulation could lead to retention of less than 4 mm. With that in mind, 5 mm appears to be a safer minimal radiographic length.

The best method for preserving the apical seal during preparation of a post space is to use the working length determined during endodontic treatment; the same reference point used on the tooth during endodontic therapy should be used during post preparation. In addition, a canal preparation instrument with an appropriate diameter should be used with a rubber stopper placed around the instrument at the proper location to help ensure that an adequate amount of gutta-percha is retained apically.

Three methods have been advocated for removing gutta-percha when preparing a post space without disturbing thermal, and mechanical. According to the literature, both hot hand instruments and rotary instruments can adequately condensed gutta-percha, provided 5 mm is retained apically. Several studies have determined percha immediately after root canal treatment has no detrimental effect on the apical seal.

Short posts should be avoided. The appropriate length for a post should minimize the potential for damage to the tooth, optimize post retention, and ensure an adequate apical seal for the root canal restoration. Several guidelines for determining the length have been proposed.

While short posts have never been advocated, they have been observed frequently on radiographs (Fig. 5). A 19 McAndrew examined 327 posts and found that only 111 (34%) were as long as the incisocervical length of the crowns.
endodontically treated teeth, Ross determined that only 28 posts (14%) were equal to or greater than 66% of the root length. A radiographic study of 217 posts determined that 11 (5%) were 66–75% of the root length. Root fractures cause more frequently when short posts are used. According to Trabert et al, increasing the length of a post increases the resistance to root fracture.

Leary et al determined that posts that are equal to 75% of the root length offered the greatest rigidity and produced less root deflection. However, it can be difficult to utilize this apparently optimal post length. When a tooth has an average or below average root length and the post occupies two-thirds or more of the root length, it is not possible to retain 5 mm of gutta-percha at the apex. This length is determined by retaining 5 mm of apical gutta-percha and extending the post to that depth.

This post length guideline is appropriate for all teeth except for molars. Abou-Rass et al examined 150 extracted maxillary and mandibular molars and determined that molar post spaces should not be prepared more than 7 mm apical to the orifice of the roots (the distal root of mandibular molars and the palatal root of maxillary molars) because of the increased potential for root perforation. Secondary roots (that is, the facial roots of maxillary molars and mesial roots of mandibular molars) cannot accommodate 7 mm posts without excess root thinning and potential perforation.

The potential for root thinning, perforation, and root fracture increases with large-diameter posts

Increasing the diameter of a post weakens the remaining root. It has been determined that stresses in a root increase as the post diameter increases. Larger post diameters decrease the resistance to tooth fracture. Deutsch et al determined that using a post diameter of 1.2 mm or more) increased the potential for root fracture sixfold for every millimeter of decreased root diameter.

According to the literature, root fracture is the second most common cause of post and core failure. Multiple types of posts have been associated with the potential for root fracture: large-diameter posts, short posts, and threaded posts (Fig. 6). The Academy of General Dentistry recommended that post diameter should not exceed one-third of the root diameter and that post diameters be proportional to average root dimensions.
The post should be between 0.6–1.2 mm in diameter, depending on the tooth being restored. Only post preparation instruments that match the desired diameter of the post space should be used. When using a particular brand of post, make sure they are made by the same manufacturer.

Understanding dental anatomy, the configuration of the roots and their variations, and appropriate instrument angulations can help dentists to avoid root thinning and perforation. Instruments should be angled so that they follow the canal. Figure 7 is an example of a distal canal that was perforated because the instruments were at an improper angle when preparing the post space.

When posts are needed in premolars, it is best to place them in the palatal root of the maxillary premolar and in the straightest root of any mandibular premolar with multiple roots. Root taper, curvature, and depressions should be reviewed prior to post placement.

When posts are needed in molars, they should be placed in roots with the greatest dentin thickness. These roots
maxillary molars and the distal roots of mandibular molars) are known as the primary roots. However, it is important to remember that extending a post more than 7 mm apical to the root canal orifice in primary canals increases the risk of perforation. Mandibular molars and the facial roots of maxillary molars should be avoided, if possible. Dentists also should avoid pressure on the root surface toward the furcation, as this surface is thinner than the outer surface due to root curvature.

For all teeth, the apical 5 mm of the roots should be avoided because most root curvatures occur within 5 mm of this area increases the risk of excessive root thinning or perforation.

A cervical ferrule should engage tooth structure to prevent root fracture
Ferrules can be established by the core engaging tooth structure (known as the core ferrule) or by the overlying encompassing sound tooth structure (known as the crown ferrule). The data indicate that crown ferrules are more effective than core ferrules in increasing the tooth’s resistance to fracture. Although the data indicate the benefit of a crown ferrule, not all practitioners recognize its value; according to a survey by Morgano et al, 56% of general dentists, 67% of prosthodontists, and 73% of board-certified prosthodontists believed that core ferrules increased a tooth’s fracture resistance.

Different lengths and forms of the ferrule have been studied in the literature. The length and form are essential for the success of the ferrule effect. When possible, encompassing 2.0 mm of intact tooth structure around the entire circumference of the effective crown ferrule. Ferrule effectiveness is enhanced by grasping larger amounts of tooth structure. The amount engaged by the overlying crown appears to be more important than the length of the post in increasing a tooth’s resistance to fracture. Figure 8 presents a case in which the length of the post was appropriate; however, the lack of a ferrule caused the restoration to fail.

If cervical tooth structure is insufficient for developing a ferrule, surgical crown lengthening or orthodontic extrusion should be considered to expose more tooth structure. It may be prudent to extract a tooth and replace it with an implant and crown when crown lengthening would create an unacceptable esthetic environment or produce a furcation defect present that would not allow for the development of appropriate post length.

Summary
Due to the wide range of reported failure rates in available clinical studies, fiber-reinforced resin posts should be used with caution until more long-term clinical data become available. Crowns are not needed for intact or minimally restored anterior teeth unless substantial color or form changes cannot be accomplished by more conservative means. Crowns should be placed on most endodontically treated posterior teeth to enhance their long-term survival. Some data indicate that posterior teeth that are intact except for the access opening can be restored satisfactorily with composite resin rather than a crown; however, the long-term success of this more conservative treatment in the presence of heavy occlusal forces is unknown.

Posts weaken teeth and should be used only when the core cannot be adequately retained by any other means. Retained by preserving 5 mm of gutta-percha. Short posts should be avoided, as they increase the potential for root fracture. For molars, optimal post length is determined by retaining 5 mm of apical gutta-percha and extending the post.
posts should be placed only in the primary roots (palatal roots of maxillary molars and distal roots of mandibular teeth) to extend more than 7 mm apical to the orifice of the root canal due to the potential for root thinning or perforation.

To minimize root thinning and the potential for root fracture, the diameter of posts should not exceed one-third of preparation instrument diameter should be matched to root diameter. Since crown ferrules increase the resistance placed on endodontically treated teeth should encompass 2.0 mm of tooth structure apical to the core whenever possible.

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