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Post and core restoration of endodontically treated teeth

Marwan Abou-Rass, DDS, MDS, PhD

Department of Endodontics, University of Southern California, School of Dentistry, Los Angeles, California, USA

This review discusses the multifactorial nature of tooth strength and concludes that endodontic treatment alone does not weaken intact anterior teeth. Therefore, restoration of such teeth does require post placement or full-coverage restorations. Posterior teeth, however, require full-coverage protection. It appears that the full-crown restoration "covers up" some of the disadvantages or deficiencies of some post and core restorations. The literature supports the use of the amalgam coronal-radicular core or the post-retained amalgam core, as well as the composite post and core. The literature does not support use of the glass ionomer post and cores. As to which post system to select, the literature indicates that the parallel-sided, serrated Para-Post or Para-Post plus is a safe post when seated passively in the canal and cemented with zinc phosphate cements or composite resin cement, or when retained with amalgam. Dentin-retained, stress-producing posts such as the threaded posts should be avoided.

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The restoration of endodontically treated teeth is important to all the endodontic, restorative, and prosthodontic disciplines. Endodontic treatment is incomplete without proper protective restorative therapy. Many teeth are lost or damaged by faulty posting procedures or improper final restorations. The multiplicity of commercial products available for posting procedures has created confusion in many clinicians' minds as to the best method to use. Many of the traditional and empiric principles in post and core restorations have been challenged and replaced with new concepts. Recent research has dispelled many commonly held misconceptions regarding posting procedures. The literature supports the concepts that endodontic therapy does not weaken teeth, a dowel core does not strengthen the teeth, and the cast post is not the "ideal" post. This review explores current posting concepts and trends in the restorative management of endodontically treated teeth, including the current post and core methods.

Structural strength considerations

The resistance of a tooth to fracture is a multifactorial issue. Loss of the pulp should not be equated with loss of vitality or strength. Many teeth lose their pulps to calcification, atrophy, and necrosis but remain strong, do not fracture, and function normally for years until they become symptomatic and receive endodontic treatment. The pulpless tooth and endodontically treated tooth have received much undeserved negative evaluation from the public and the profession. Many dentists avoid the use of endodontically treated teeth in restorative and prosthetic treatment plans. Other practitioners believe that the endodontically treated tooth is less resistant to fracture and thus can be "strengthened" or "reinforced" with a post, or that it is better extracted and replaced with an implant! The structural strength and fracture resistance of a tooth are dependent on several factors (Table 1).

Many studies have shown that proper endodontic treatment does not weaken the maxillary anterior teeth [1–4]. The evidence indicates that there is no difference in impact resistance to fracture between endodontically treated teeth and untreated teeth. Additionally, evidence has shown that the insertion of a large post actually weakens the tooth [1–3]. Furthermore, posting does not make the tooth more resistant to fracture [5,6]. A recent study by McDonald *et al.* [7••] confirmed that with respect to fracture mechanics, there is no advantage to restoring endodontically treated teeth with posts.

Endodontic considerations

The quality of existing endodontic therapy must be assessed and assured prior to any restorative treatment.

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The traditional goals of restorative treatment of a well-fitted, biologically and anatomically designed and contoured restoration should be matched by, and supported on, a sound endodontic foundation. Endodontically treated teeth should have a well-condensed gutta-percha filling terminating 0.5 to 1 mm from the radiographic apex and be free from any serious procedural errors that could jeopardize the success and predictability or new restorative treatment.

Prior to any post placement procedure, the quality of gutta-percha filling should be clinically evaluated for proper extension and obturation. Radiographic evaluation alone, without clinical evaluation, of preexisting endodontic treatment should be avoided due to the limitations of the radiograph. Before a tooth is posted, all previous paste fillings, corroded silver points, and poor-quality gutta-percha fillings should be replaced with a sound gutta-percha filling: regardless of the patient's symptoms, endodontic retreatment of defective or questionable endodontic fillings prior to new restorative therapy is emerging as a standard of care in endodontic therapy.

Table 1. Factors on which structural strength and fracture resistance of a tooth depend

Factor	Description
Anatomy	Tooth type, location, and position Number of roots Root length, width, and curvature Root defects
Occlusion	Occlusal type and loads Bruxism Parafunctional forces Masticatory habits and function
Pathology	Periodontal disease Osseous support Caries Fracture Resorption Pulp loss and calcification
Structure	Dentin composition Developmental defects Structural cracks
Restoration	Restoration type and design Post type and design
Endodontics	Proper preparation Overflaring Overinstrumentation Overcondensation Endodontic leakage

Whenever necessary, surgical endodontic therapy should augment nonsurgical therapy to finalize endodontic treatment and achieve the most optimal treatment results. Throughout the endodontic treatment, the clinician should be cognizant of the restorative aspects of the treatment. Large access openings destroy valuable tooth structure and excessive flaring or tapering of the root canal preparation at the cervical zone can weaken the tooth structure, leading to restorative dislodgement, fracture, or both (Fig. 1). The root canal preparation should preserve the integrity of the concave proximal surface by avoiding circumferential filing and excessive flaring of curved roots in posterior teeth. Excessive condensation pressure can cause microscopic structural cracks that may develop into fractures in time.

The post cavity preparation should have a minimum depth of 7 mm from the canal orifice and not exceed 1.0 to 1.5 mm in width. It is best prepared immediately after the gutta-percha filling, when the root length measurement, canal dimensions, and root morphology are most familiar to, and well remembered by, the clinician. Final restoration should be accomplished within 1 to 2 weeks after nonsurgical endodontics and 8 to 12 weeks after surgical endodontics.

Some dentists postpone restoration of endodontically treated teeth until the resolution of the patient's symptoms [8] or until some evidence of radiographic healing has occurred. In fact, delaying the restoration in expectation of lesion regression or resolution or in conjunction with the wait-and-see practice philosophy is risky because the tooth may be jeopardized by caries, fracture, periodontal disease, movement, and treatment failure. Additional discussion on the issue of endodontic considerations was previously published [9].

Restoration of intact anterior teeth

Laboratory investigations performed on intact, unrestored anterior teeth with endodontic therapy through a conservative lingual access indicate these teeth do not require post placement [1–3]. Furthermore, these studies found that such teeth become more susceptible to impact fracture or oblique compression fracture when a post has been placed [1–3,5,6]. Clinically, therefore, endodontically treated anterior teeth with otherwise intact clinical crowns are optimally restored with any of the modern composite resins without the placement of a post. Amalgam restorations of endodontically treated anterior teeth should be avoided for aesthetic considerations.

Restoration of teeth with insufficient coronal structure

Endodontic therapy is primarily performed on teeth with clinical crowns previously damaged by caries, previous restorative failure, or fractures. Such teeth require some form of structural augmentation, either to

Fig. 1. Top, Preoperative radiograph (*left panel*). Excessive flaring following endodontic retreatment (*second panel*). Tapered nonprecious cast post that led to vertical fracture (*third panel*). Tapered cast and prefabricated posts are easy to dislodge experimentally (*right panel* and *bottom left panel*). **Bottom**, Tapered post cavity preparation associated with prefabricated post dislodgement (*second panel*). Excessive canal flaring with mechanical drills can weaken the root structure and cause fracture, especially when short posts are used (*third panel* and *right panel*).

retain the coronal restoration or to restore the lost structure. A variety of methods have been investigated and compared in a search for the most retentive, resistant, and permanent post and core. The literature has focused on 1) comparing the prefabricated post with the cast post and 2) comparing core build-up materials such as amalgam alloys, composite resins, glass ionomer cements, and cast cores.

Amalgam post and cores

Amalgam alloy is often used in the restoration of endodontically treated teeth. It has been used as a coronal-radicular core alone, as introduced by Nayyar *et al.* [10], or as a pin-retained amalgam core, or as a core material in conjunction with a cemented prefabricated post. Amalgam as a material is superior to composite resins and glass ionomer cements because 1) it has reduced marginal leakage, 2) it has less polymerization contraction than composite, 3) it has better dimensional stability than composite and glass ionomer cements, 4) its marginal surface corrosion may act as a barrier to microleakage, 5) it has better compressive and tensile strength than composite, and 6) it has a better modulus of elasticity.

Fig. 2. Root perforation caused by extending the amalgam coronal radicular restoration into the root.

The amalgam post and core method was studied by Gelfand *et al.* [11], Plasmans *et al.* [12], and Mertz *et al.* [13]. These studies showed no differences in fracture resistance between the amalgam post-retained core and the coronal-radicular build-up method. Kern *et al.* [14], however, found higher mean fracture loads for post-retained amalgam build-ups than for amalgam coronal-radicular build-ups. They also found the amalgam post is even efficient as a final restoration or as a foundation for cast crown. Other studies showed no difference between the coronal-radicular core and the cast post and core when the teeth were restored with cast crown restorations [11,15].

In the amalgam coronal-radicular core method, the pulp chamber and any other areas of missing tooth structure are restored with amalgam. As to the method of extending the amalgam into the root canal space, Michelich *et al.* [16,17] and Kane *et al.* [18••] cautioned against extending the amalgam into the canal space

Fig. 3. Improper composite core restoration where the margins extend subgingivally.

because of the risk of perforation (Fig. 2). Extending the amalgam into the canal is suggested only when the pulp chamber height is less than 2 mm (teeth without clinical crowns). However, if there is a normal 4- to 6-mm pulp chamber height, there is no need to extend the amalgam into the canal.

Since the introduction of the amalgam coronal-radicular core by Nayyar *et al.* [10], many studies have proved its efficacy in terms of retention and resistance to fracture, thus justifying its use as a strong foundation for cast restorations of endodontically treated teeth. Although Kern *et al.* [14] found the post-retained amalgam to have higher mean fracture loads than the amalgam coronal-radicular restoration, this difference becomes insignificant once a proper cast crown is used. Pin-retained amalgam cores were found less retentive than the amalgam coronal-radicular core and should therefore be avoided [13]. The retention between the amalgam and the serrated prefabricated post can be critical. The strength of the retention was studied by Millstein and Nathanson [19••], who found that the composite and amalgam post and core materials required a substantially greater force to cause separation and fracture than did glass ionomer post and core materials. The mean separation and fracture forces were 220 lb for amalgam, 182 to 252 lb for composite, and 33 to 65 lb for glass ionomer cements.

Composite post and cores

The superior compressive strength, ease of handling, and rapid polymerization of composite resins has made them the most commonly used core and build-up materials today. The composite resin cements are used to cement the passively seated, prefabricated serrated post or in conjunction with pins or tooth structure undercuts. The critical factor in the use of composite post and core methods is that the coronal restoration margins should cover a minimum of 2 to 3 mm of solid tooth structure and should never terminate on

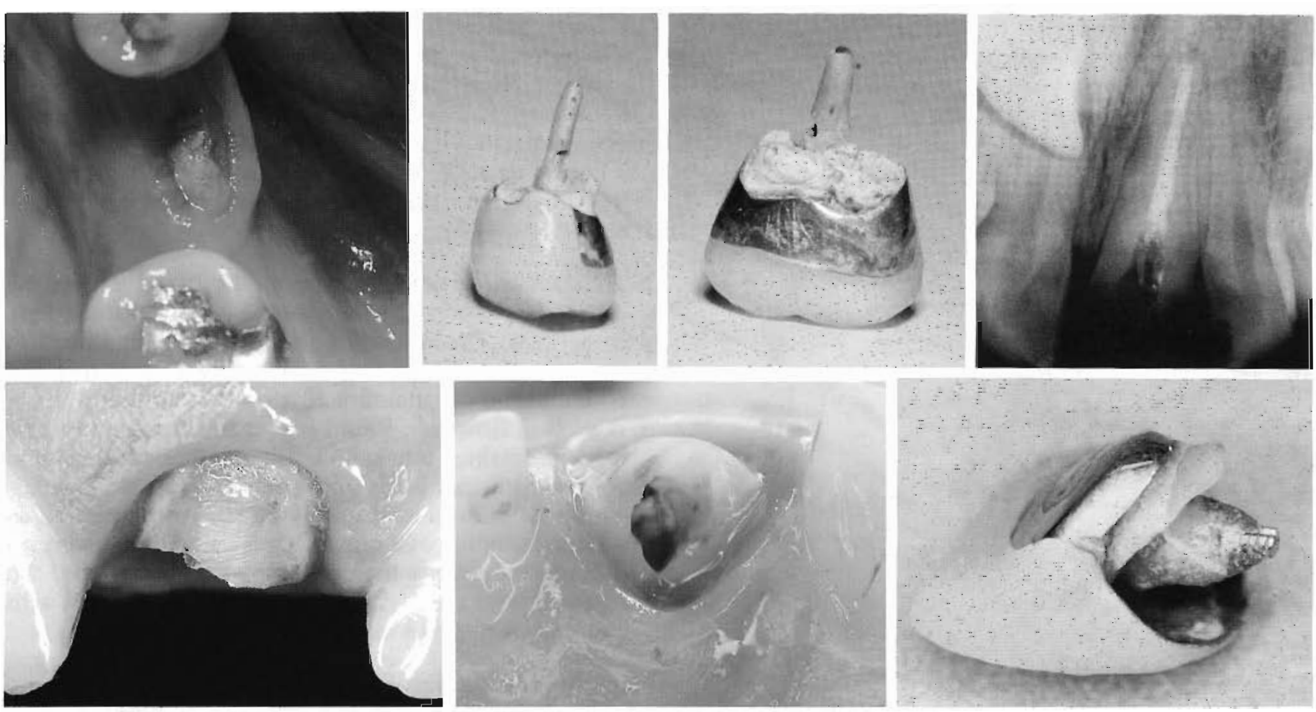

Fig. 4. Top, The placement of coronal restoration margins on the build-up material should be avoided. Such an error combined with short post length is an invitation to tooth fracture (*left, second,* and *third panels*). Short posts concentrate stresses at the cervical zone, leading to tooth and root fracture. Preoperative radiograph (*right panel*). **Bottom,** Labial view (*left panel*). Lingual view (*middle panel*). Tooth crown fracture (*right panel*).

the build-up materials (Fig. 3); otherwise, the coronal restoration will fail because of marginal leakage, loosening, or fracture of the build-up material itself (Fig. 4). The composite post and core have some disadvantages:

1) Composite shrinkage during polymerization may cause cuspal movements of up to 15 μm [20].

2) Composites have poor dimensional stability. Composites absorbs moisture, particularly in wet conditions. A direct correlation was found between the mass of absorbed water and linear expansion [21,22].

3) The thermal coefficient of expansion is two to 10 times the value of natural tooth structure. Values varied depending on the specific resin tested.

4) Composite cements interact with the eugenol used in most temporary cements, causing surface porosity [22].

5) The modulus of elasticity for composite resins is poor; thus, anterior composite cores are fragile and should be avoided.

6) Well-fitted provisional restorations are essential for controlling some of the disadvantages of composite core build-ups such as water absorption and leakage [23].

The composite post and core method is technique sensitive and should be performed with utmost attention to my specific 1982 and 1985 guidelines [24].

Glass ionomer post and cores

There is a definite trend against the use of glass ionomer cements in post-and-core restorations because of their weak tensile strength and their lowered resistance to fracture. The addition of silver alloy into the glass ionomer powder resulted in lower flexural strength and a lower modulus of elasticity compared to glass ionomer cement in which silver alloy was not added [25].

The glass ionomer post and core is definitely contraindicated when used as a core build-up material in anterior teeth because of the fracture potential when compared with a cast post and core [26]. The glass ionomer cement core can easily separate from the post [19••]. Glass ionomer cement with silver powder can cause a serious discoloration problem when used on anterior teeth [27].

Cast post and cores

Although cast-post restorations were once believed to be the ideal restoration for endodontically treated teeth, their use is declining because of the cost, chairside time consumption, and most importantly because clinicians can save the valuable tooth structure usually removed to fulfill the requirements necessary for a cast post. Tapered cast-post restorations dislodge easily when compared with composite or amalgam-post cores and often act as a wedge causing the root to fracture. The use of semiprecious metals or nickel-beryllium should be avoided because of possible toxicity or carcinogenic and allergic responses [27]. The nonprecious metal post cores are difficult to fabricate, fit, and finish. They often require considerable adjustment to be fitted thus compromising the original intent of close cast-post adaptation to the canal. The method of casting cores to stainless steel prefabricated posts can alter the metallic structure of the stainless steel posts making them less resistant to corrosion [28••] and is contraindicated.

The possibility of casting gold cores to prefabricated titanium posts was studied. Such procedures require high temperatures (1000 to 1300°C), and although they may not influence the hardness and the tensile strength of the titanium, the processes make the titanium very brittle [29].

Post and pin cores

In addition to the four basic post-and-core methods discussed in this review, there are a variety of clinical studies or methods that modify or combine the ba-

Fig. 5. Top and **bottom**, Restoration with a ferrule effect is mandatory for abutment teeth without clinical crowns.

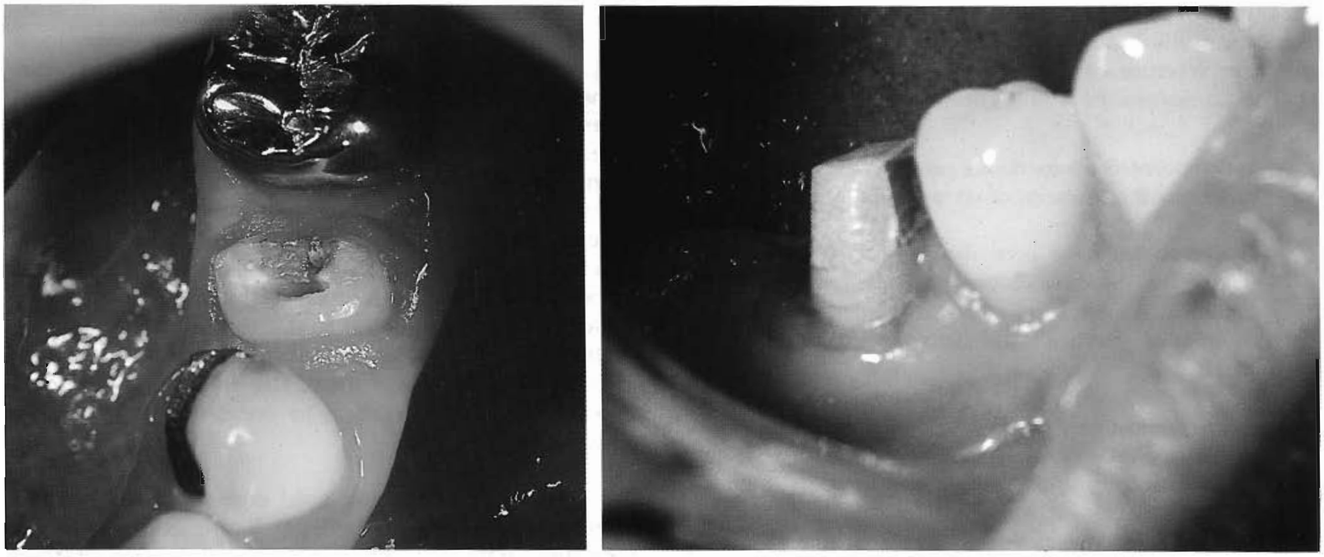

Fig. 6. Left and **right**, For teeth with no clinical crown or on teeth that have lost two or more surfaces, 2 to 3 mm of natural solid tooth structure is necessary to receive the margins of the coronal restoration regardless of the post and core method used.

sic methods. Orkin and Louw [30] studied the use of TMS pins as supplementary antirotational devices in conjunction with the composite post-and-core method on anterior maxillary teeth and found greater resistance to dislodgement than that in teeth treated with composite post and cores without pins. Furthermore, the authors found that two pins were better than one for this purpose. Unfortunately, the use of pins in endodontically treated teeth is quite risky if there is insufficient root surface or if the pins are misplaced. The pins may also produce additional stresses resulting in increased root fracture and perforations. Whether or not the pins are used in conjunction with composite or amalgam, they offer poor retention and resistance to fracture [13,14].

Carbon fiber–reinforced carbon posts

A new nonmetallic composite prefabricated post was studied by King and Setchell [31]. This material has a transverse strength and modulus of elasticity similar to those of bone. In these posts, conditions of short-term or local overload stresses resulted in the cracking of only some fibers and not in the failure of the whole structure. In their study, King and Setchell found no difference in resistance to fracture between the carbon fiber–reinforced carbon post and the cast post and core or the composite post and core they studied.

Coronal coverage

While it is "customary" to restore an endodontically treated tooth with a full crown, there are no prospective studies on the subject. In a retrospective survey, Sorensen and Martinoff [32] analyzed the restorative success of endodontically treated teeth and found that full-coverage restoration or post placement did not influence the restorative success rate of maxillary and mandibular anterior endodontically treated teeth. However, bicuspids and molars showed significant restorative failure rates when not restored with coronal coverage, and it was shown that such restoration was critical regardless whether a post was used or not.

The ferrule effect (Fig. 5) is a traditional concept developed to protect the remaining root structure by increasing the resistance to wedging forces. The design and extensions of the ferrule were studied by Sorensen and Engelman [33••], who concluded that 1.4

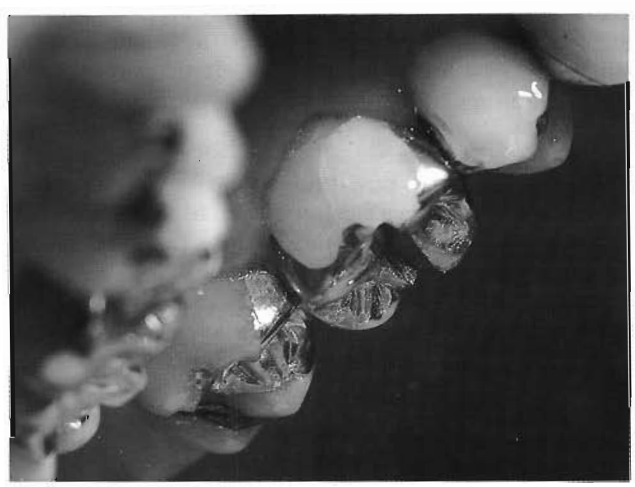

Fig. 7. Partial coronal coverage on endodontically treated teeth is risky, as it may lead to the fracturing of remaining tooth structure.

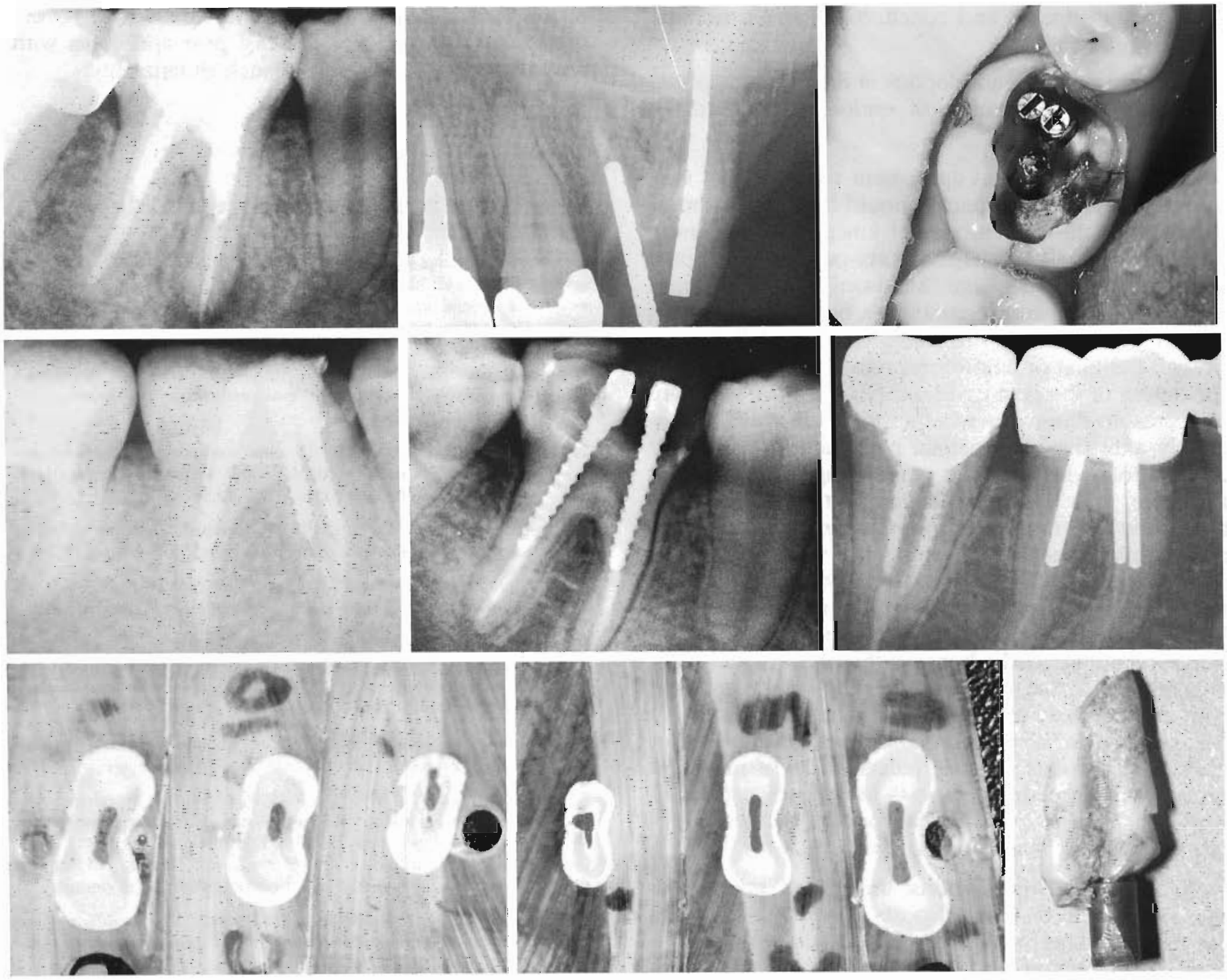

Fig. 8. Top and **second row**, The placement of a post in the mesial roots of mandibular molars and in the buccal roots of maxillary molars is risky, as it may lead to the interproximal perforation of the root (*left, middle,* and *right panels*). **Third row**, Cross-sections of the mesial root of mandibular molar. Observe the interproximal concavity (*left panel* and *middle panel*). The most common site for post perforation is the interproximal concavity of maxillary premolars and mandibular molar roots (*right panel*).

mm of coronal dentin above the shoulder significantly increased the failure threshold. Loney *et al.* [34•] found that 1.3 mm of ferrule effect led to greater stress concentration throughout in the experimental model. The study results, therefore, were not supportive of the concept of the ferrule. Further research is needed in this area.

In conclusion, teeth with no clinical crown or those that have lost two or more surfaces should be restored with complete coronal coverage that terminates on 2 to 3 mm of solid tooth structure thus providing a minimum of 1.5 to 2.5 mm of collar and ferrule (Fig. 6). The crown margins should be placed on sound tooth structure, *ie*, beyond any build-up material. The type of final cast-crown restoration is of paramount importance in the restoration of endodontically treated teeth and is of greater significance to the ultimate success than the type of post core used (Fig. 7).

Trends and conclusions

There is no universal post-and-core method that is optimal for all teeth. The individual anatomic, biologic, and clinical conditions for each case should all be considered in determining the type of post and core needed.

Natural tooth structure is more resistant to fracture than are any of the artificial core materials. There has been a definite "overkill" in the restoration of endodontically treated teeth in the past via unnecessary coronal coverage, posting, or both.

The literature trends and conclusions can be summarized as follows:

1. Good-quality endodontics is an essential prerequisite in the restoration of endodontically treated teeth.

2. There is universal agreement that the post cavity preparation "post space" should be a minimum of 7 mm from the cementodental junction. A minimum of 3 mm of well-condensed gutta-percha is essential to prevent apical leakage. Mattison *et al.* [35] found that the post cavity preparation is best prepared with a rotary drill such as the Gates Glidden drill instead of with the heat or chloroform removal method. As to the timing of the post cavity preparation, the literature indicates no difference whether it is performed immediately after the gutta-percha placement, or a day or a week following the root canal filling [36]. Clinically, therefore, it is better to do the post cavity preparation at the time of the endodontic filling while the root measurement and canal anatomy are still readily available to the clinician. Finally, the post cavity preparation should be nontapered in order to reduce the possibility of dislodgement. A retentive post cavity preparation is recommended whenever the prefabricated post is cemented in the canal, specifically with composite post-and-core or amalgam post-and-core methods [9]. The post should be placed mainly in the distal roots of mandibular molars and the palatal roots of maxillary molars. The placement of posts in the mesial roots of mandibular molars and buccal roots of maxillary molars is risky and should be avoided (Fig. 8).

3. There is a trend against the use of self-threading, screw-type or tapered posts. The threaded posts are highly stress producing devices and often fracture roots. Another stress-producing post system currently used is the Flexi-Post (Essential Dental Systems, New York, NY), which was studied by Burns *et al.* [37••], who found the post to produce asymmetric patterns of stress distribution, stress concentrations at each thread, and considerable stress at the shoulder area and the coronal aspects of the post. Tapered posts were found to produce significantly more fractures involving greater tooth structure apically and lingually [38••].

4. The steel or titanium prefabricated parallel-sided, serrated posts commercially available as Para-Post and Para-Post Plus systems (Whaledent, Int., New York, NY) are the most frequently used in comparative research studies and have been the most commonly used in clinical practice since the 1970s [39]. These posts are passively seated and cemented and have not been associated with stresses [38••,40]. A recent study [41] found no difference between the Para-Post and Para-Post Plus in dislodgement, regardless of the core build-up material.

5. The presence and quality of full coronal coverage is more critical than the type of post and core used.

6. Composite post and cores, glass ionomer post and cores or amalgam post and cores should not be used on endodontically treated anterior teeth with severe tooth structure loss. Parallel cast post and cores with type III gold are indicated in such situations.

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Marwan Abou-Rass, DDS, MDS, PhD, Department of Endodontics, University of Southern California, School of Dentistry, University Park MC-0641, Los Angeles, CA 90089-0641, USA.

mar@abourass.com
PAADI.org