Aesthetic Posts and Cores for Metal-Free Restoration of Endodontically Treated Teeth

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Utilization of contemporary post and core systems has facilitated the aesthetic restoration of endodontically treated teeth. Light transmission and biocompatibility have been enhanced by the introduction of metal-free post systems. The periodontal and endodontic status, root length, and histological structure of the devitalized teeth must be considered in order to achieve successful restoration following endodontic treatment. This article presents various restorative criteria for the aesthetic placement and build-up of post and core materials, as well as the preservation of maximum coronal and root structure.

Key Words: post, core, endodontically, aesthetic, ferrule

Over the past two decades, innovative dental materials have been developed. Emphasis has primarily been placed on improvement of the mechanical and physical properties of aesthetic materials to enhance their performance. The restoration of endodontically treated teeth, however, can be challenging due to lack of tooth structure, tooth discoloration, and/or mechanical behavior. It is evident that numerous variables (e.g., root reinforcement, post design, ferrule effect) have contributed to misunderstandings and failures in the restoration of endodontically treated teeth. Nevertheless, aesthetic post and core systems have been developed to maximize light transmission and the optical effects of foundation on aesthetic restorations. The introduction of numerous post systems and lack of an established protocol have raised concern and may increase the potential of failure if proper indication and handling are not achieved.

Biological Aspects

Controversy exists regarding the histological structure of devitalized teeth. It has been stated that the moisture of the dentin-root complex may be different following endodontic treatment. The literature has affirmed that coronal dentin contains twice the number of tubules when compared to root dentin, and that deposition of peritubular dentin may diminish the moisture content during vital tooth aging. Since the resistance of pulpless teeth is primarily affected by the amount of remaining tooth structure, architectural modifications affect the mechanical properties (e.g., strength and stiffness) of dentin. Endodontic access can be responsible for a 5% stiffness reduction, while an MOD preparation can result in a 60% decrease due to the loss of the marginal ridge. In order

![Illustration demonstrates the influence of post placement on potential root fracture (arrow indicates occlusal forces).](image-url)

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to ensure long-term success, conservation of tooth structure during root canal reshaping and dentin removal for intraradicular anchorage is essential. The placement of a post and core does not reinforce tooth structure; intraradicular anchorage provides retention and resistance forms for coronal restoration.

A primary consideration for pulpless tooth restoration is that loss of vital pulp tissue would result in a decrease of proprioceptive response. There is some evidence that the pressure threshold is 57% higher in endodontically treated teeth when compared to vital teeth. This can result in less sensitivity to heavier occlusal contacts and subsequently increase potential of greater stresses on these teeth.

**Restorative Considerations**

Restoration of endodontically treated teeth involves additional aspects in comparison to vital teeth. During preliminary analysis of periapical radiographs, it is necessary to observe the root length and shape, periodontal and endodontic treatment status, and coronal tooth loss. While the preliminary analysis of root anatomy is generally obtained from periapical radiographs, supplemental views may be necessary to reveal the anatomic details (e.g., invaginations, curvatures, splits, multiple canals, tapers) of individual teeth. An understanding of root anatomy variation is therefore essential to prevent misdiagnosis and facilitate determination of the most appropriate shape of the post system.

The periodontal status should also be considered preoperatively. Since post placement can induce additional internal stresses during placement or function, 

![Figure 2. The length, width, bone support, and apical seal of a nonvital tooth preparation must be evaluated.](image)

![Figure 3. Case 1. Preoperative view of tooth #10(22) demonstrates compromised aesthetics.](image)

![Figure 4A. Preoperative radiograph indicates need for endodontic retreatment. 4B. Postoperative radiograph following endodontic retreatment.](image)

![Figure 5. Carbon-fiber post prior to cementation. Lack of coronal structure indicates placement of a post and core and an all-ceramic crown.](image)

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reretreatment is indicated. Insufficient root length for an adequate apical seal or intraradicular retention requires the clinician to reconsider post placement (Figure 2). In order to prevent microleakage and the potential of endodontic failure, the time interval between end treatment and post placement should be minimal.\textsuperscript{13,14}

An understanding of the root length, periodontal condition, and endodontic status aid in the determination of post length. Adequate post length provides enhanced distribution of stresses along the root; it must be considered that aesthetic post systems are passive and depend on adhesion for better retention. Short anatomical root or endodontic fillings will cause difficulty in the acquisition of proper intraradicular retention. The crown-to-root ratio must be evaluated during treatment planning and the selection of intraradicular retention. An unfavorable ratio can be modified with either crown lengthening or orthodontic extrusion procedures. While crown lengthening can also be used to improve the gingival zenith, post placement supported by sufficient alveolar bone can be difficult to obtain. Orthodontic extrusion is the preferred treatment option if adequate gingival contour is available, and the crown-to-root ratio will subsequently be enhanced.

Following analysis of these three factors, various restorative aspects must be considered. The total amount of coronal tooth loss influences the selection of a cast post or a post and core procedure. Contemporary adhesive and restorative materials provide many treatment options that facilitate more conservative preparations when compared to traditional metal-ceramic crowns. It is of primary importance to determine the type of coronal restoration prior to the selection of intraradicular anchorage because the amount of coronal tooth above the margin preparation (particularly the height of the remaining dentin) is of primary importance. Additional modifications to the treatment plan may result in the selection of a cast post rather than a prefabricated post and core material. Once the type of coronal restoration has been established, it is possible to determine the need for and type of intraradicular anchorage.\textsuperscript{15}

The importance of the ferrule effect has been well documented.\textsuperscript{5,6,8,16} A minimum of 1.5 mm of coronal structure should be present cephalic to the post in order to resist dynamic loading and reduce stress concentration at the post and core junction.\textsuperscript{16} When less structure is
available, leakage can occur in the post space. Direct post techniques associated with a composite resin core provide simplified handling and the potential for immediate preparation. Since composite resin has a low modulus of elasticity, absence of a ferrule is a risk factor in the anterior region, which is more subject to shear forces; patients with bruxism or clenching are also a contraindication. In posterior areas, however, evaluation of width and depth of the pulp chamber can indicate a direct technique as a result of shear strength resistance, even if composite resin is utilized as the core material.

There is clinical evidence that the angle of incidence of occlusal forces may be more influential than the amount of force itself; heavier forces parallel to the long axis are less damaging to the tooth than lighter, more inclined forces. This explains why more failures occur in anterior teeth restored with posts and cores when compared to other endodontically treated teeth.

Tooth location in the arch is the determinant of the type of preparation. Posterior areas are more prone to heavier occlusal contacts and require cuspal coverage for enhanced long-term results. Anterior teeth, however, often require only coronal restoration, without the need for full coverage. The type of reconstruction will influence the amount and type of forces exerted on retainers; a single crown or a fixed partial denture retainer require different mechanical features.

Post and Core Innovations
Various factors (e.g., caries, trauma, fillings, and endodontic access) will compromise the coronal structure of a tooth that requires restoration. Final preparation features

<table>
<thead>
<tr>
<th>Post System</th>
<th>Material</th>
<th>Shape</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aestheti-Plus Post</td>
<td>Quartz-Fiber</td>
<td>Parallel</td>
<td>Bisco</td>
</tr>
<tr>
<td>Aestheti-Post</td>
<td>Carbon-Fiber</td>
<td>Parallel</td>
<td>Bisco</td>
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<tr>
<td>C-Post</td>
<td>Carbon-Fiber</td>
<td>Parallel</td>
<td>Bisco</td>
</tr>
<tr>
<td>U.M. C-Post</td>
<td>Carbon-Fiber</td>
<td>Parallel</td>
<td>Bisco</td>
</tr>
<tr>
<td>Luscent Anchors</td>
<td>Glass-Fiber</td>
<td>Conical</td>
<td>Dentatus</td>
</tr>
<tr>
<td>Fiberkor Post System</td>
<td>Glass-Fiber</td>
<td>Conical</td>
<td>Jeneric/Pentron</td>
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<tr>
<td>Targis System</td>
<td>Glass-Fiber</td>
<td>Conical</td>
<td>Ivoclar Williams</td>
</tr>
<tr>
<td>CeraPost</td>
<td>Zirconia</td>
<td>Conical</td>
<td>Brasseler USA</td>
</tr>
<tr>
<td>CaimoPost</td>
<td>Zirconia</td>
<td>Conical</td>
<td>Ivoclar Vivadent</td>
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Figure 10. The glass-fiber post (Luscent Anchors, Dentatus USA, New York, NY) is tried-in on the tooth structure.

Figure 11. Following post cementation, a rounded shoulder preparation is achieved. Tooth structure is preserved for the maxillary left lateral incisor.
must be added to these factors in order to determine the amount of retention and resistance forms and the subsequent need for a core (e.g., cast posts, prefabricated posts with core materials). Nevertheless, protocols for clinical situations with limited coronal structure and intraradicular retention remain unclear. Fortunately, new metal-free post systems have been developed to overcome the aesthetic limitations of traditional cast-metal and prefabricated metal posts. These fiber- and ceramic-based alternatives have significantly expanded the metal-free options available to contemporary clinicians (Table 1).

**Fiber Posts**

Fiber-reinforced composite materials have been used for various applications outside dentistry. Their physical properties (e.g., strength, absence of corrosion, easy repair) have facilitated their application in various industries, and their importance in the dental field has grown. Depending on type and direction of fiber, materials have specific properties; applications are related to these properties. Carbon-fiber posts became commercially available in 1990 (Composipost, RTD, St. Egreve, France) and have been marketed in the US since 1996. Carbon-fiber posts are composed of 64% longitudinal fibers and 36% epoxy resin matrix. Fatigue resistance is high (~1,440 MPa) and the lateral modulus of elasticity is similar to that of root dentin, which is advantageous due to the minimized transmission of trauma to the dental structure. Reversible failures associated with these posts may be attributed to such elasticity and they are simple to remove via endodontic retreatment. Disadvantages of these posts include a lack of radiopacity and poor adhesion to composite resin cores. While color is also a concern, coated posts (e.g., Aestheti-Posts, Bisco, Schaumberg, IL) are available to overcome this complication (Figures 3 through 8).

Glass- and quartz-fiber posts embedded in a filled resin matrix present another option (Figures 9 through 13). Composition of glass-fiber posts by weight is 42% glass fiber, 29% filler, and 18% resin. They can be conical or parallel, and present enhanced aesthetic results when compared to carbon-fiber posts. All systems include their own burs for intraradicular preparation in order to facilitate minimal placement of luting cement at the dentin-post interface.
Ceramic Posts

Introduced in 1993, ceramic posts presented a flexural strength value measured as high as 1,400 MPa and excellent aesthetics. It has been speculated that dentin height must have a minimum coronal remnant of 2 mm to 3 mm in order to receive this system and prevent post or root fracture. Root preparation is made with specific burs for such systems; posts should not fit tightly. Care must be taken to remove all root canal filling for increased dentin adhesion. If a moderate loss of coronal structure is evident, the core can be built up by the luting of orings to ceramic posts and subsequent placement of a minimal amount of composite resin (Figures 14 through 18).

In 1997, an indirect system was introduced to fabricate ceramic posts with the lost wax technique. This process allows customization of a prefabricated ceramic post (Figures 19 through 24), albeit with additional chairtime. Utilization of this technique prevents development of an interface between different materials at the coronal aspect, as ceramic and composite resin materials are more prone to failure. Following root canal preparation for a conventional cast post to adequate length, the post is introduced with acrylic resin and further removed with impression material for indirect core buildup. For loss of coronal structure only, the coronal aspect can be directly built up with acrylic resin without impression taking. The coronal aspect is fabricated of ceramic material (IPS Empress, Ivoclar, Amherst, NY); the apical end is rounded to minimize stress transmission. The overall radiographic appearance is enhanced by the material's radiopacity, although post removal is complicated if endodontic retreatment is necessary.

Core Materials

When metal-ceramic restorations were the only option for anterior tooth replacement, intraradicular anchorage was generally achieved with cast-metal posts. This metallic underlying structure, however, often resulted in light reflection that had to be concealed coronally with an opaque core and/or restoration. Traditional materials used for the core buildup included amalgam, glass-ionomer cement reinforced with silver, hybrid glass ionomers, composites, and composite resins. Since various types of metal-free restorations are currently available for the anterior region, core buildup with metallic materials has become a contradiction. In spite of their ability to release fluoride and adhere to dentin, hybrid glass ionomers have low tensile and flexural strength, and are indicated when the core buildup is not subjected to tensile and shear forces (e.g., onlay preparations).

Although appropriate color, adhesion to the tooth structure, easy handling, and reduced chairtime have

<table>
<thead>
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<th>Indications for Cast Posts</th>
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<tr>
<td>Excessive loss of coronal structure</td>
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<tr>
<td>Predominant shear stresses</td>
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<tr>
<td>Fixed partial bridge retainers</td>
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<tr>
<td>Altered coronal preparation for crown insertion</td>
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<tr>
<td>Multiple intraradicular retainers</td>
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<tr>
<td>Elliptical or flared root canals</td>
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</tbody>
</table>

Figure 15. The zirconia post (CeraPost, Brasseler USA, Savannah, GA) is luted prior to placement of the core buildup material.

Figure 16. The core is incrementally built up with a hybrid composite resin (Z100, 3M Dental, St. Paul, MN).
being hazardous. Displacement may result in microleakage, recurrent caries, and endodontic failure.\textsuperscript{17} The mechanical properties of composite resins used for core buildups were improved with the addition of titanium and lanthanide particles. In spite of this development, the height of remnant and ferrule effect is essential when using composite resins as core materials.\textsuperscript{8,13,36} Composite resin systems developed for buildup are mostly self-curing, due to the potential risk of inappropriate polymerization in deeper areas.\textsuperscript{37}

Utilization of a pressed leucite-reinforced ceramic core material for zirconia posts is indicated when loss of coronal structure results in a residual composite resin above the tooth remnant; this prevents horizontal forces from affecting the composite resin buildups. Interaction between the post and core material must be considered, since post head form is important to core retention.\textsuperscript{38,39} Core materials can influence the stress transmission of posts; while greater cervical stresses are found with metallic cores, higher apical stresses are associated with the use of composite cores (Tables 2 and 3).\textsuperscript{15}

The amount and type of stresses on the core must be considered during system selection. Factors related to the coronal remnant (eg, tooth height, single or multiple retainers, parafunctional habits) can predict the type of stresses that the tooth will undergo and even contraindicate post and core placement. In similar fashion, the root form should be compatible with the selected system. Cast posts are the most effective option for flared or elliptical canals.

### Table 3

<table>
<thead>
<tr>
<th>Indications for Post and Core</th>
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<tr>
<td>Coronal remnant with 2-mm height or deep pulp chamber</td>
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<tr>
<td>Single crowns</td>
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<tr>
<td>A minimum of 1.5-mm ferrule apical to the core material</td>
</tr>
<tr>
<td>Molars with divergent roots and adequate coronal structure</td>
</tr>
<tr>
<td>Root canal form compatible with the post system selected</td>
</tr>
</tbody>
</table>

Increased the use of composite resin as core buildups, this material presents two characteristics that can result in core displacement and failure of restoration: 1) a low elastic modulus that causes permanent deformation under mechanical and thermal stress,\textsuperscript{33,34} and 2) absorption of moisture, which results in lack of dimensional stability. Failure can be either catastrophic (loss of coronal restoration) or noncatastrophic (displacement),\textsuperscript{21} both

### Cementation

Since intraradicular anchorage is indicated for retention and resistance of coronal reconstruction, a lack of intraradicular retention will result in failure of treatment. Considering that the aforementioned aesthetic posts are passive, the post should ideally fit the root canal. Selection of the proper system should include consideration of form, which could result in enhanced post retention irrespective of the luting agent. Flared canals could compromise the use of some prefabricated posts. Luting agents employed for intraradicular cementation should be dual- or self-cured with a low viscosity to minimize film thickness. These luting agents should also be equipped with adequate mechanical properties, fluoride release, and radiopacity for use with nonradiopaque systems.
Zinc-phosphate, glass-ionomer, and resin cements can be used for post cementation. Solubility and lack of adhesion are disadvantages of zinc phosphate, particularly if one considers that these posts are not active. The ability to adhere to dentin and the resin composition of fiber-based posts have made the use of resin cements more prevalent. Higher mechanical properties and reduced microleakage have also been related to resin luting cements. While dentin-cement-post interfaces vary according to the combinations used, carbon-fiber posts appear to have fewer gaps and greater continuity at this level.

The literature supports that microcracks depend on the core material and type of luting agent used beneath all-ceramic crowns. Resin-modified glass ionomers and compomers allow microcrack formation up to one year following cementation as a result of hygroscopic expansion of the core materials or luting agents. Additional long-term evaluations are required to establish more predictable results.

**Discussion**

The proliferation of metal-free restorative materials forced clinicians to consider the importance of compatible post and core systems as foundations for these new aesthetic materials, particularly in anterior regions where light transmission is of prime importance. Concern about the biocompatibility of dental materials (eg, amalgam) and the potential hazardous effect of corrosion products has similarly resulted in the discussion of metallic alternatives. Chemical stability is a desirable property of nonmetallic materials, as the relationship between corrosive products and root fracture has been noted.

Due to the structural concerns related to the restoration of endodontically treated teeth, the search for properties similar to those of dentin began to prevent stress transmission along the root structure. Intraradicular restorative materials should include a shape that corresponds to the lost structure, physical and/or mechanical properties similar to structures to be replaced, higher shear strength to compensate for the loss of tooth structure, and a composition compatible to adhesion for better interface with dentin. In order to facilitate placement of the thinnest layer of luting cement, the shape of a post should be similar to the intraradicular space. While conical posts tend to distribute forces by creating a wedging effect,
cylindrical posts direct forces to the long axis of the root. In order to preserve dentin apically, some posts have a double cylindrical shape.

Metallic posts have a higher modulus of elasticity, which is responsible for functional stresses, root fractures, and/or restoration failure. Fiberreinforced materials have mechanical features closer to dentin. These materials are anisotropic and demonstrate varying mechanical behaviors depending on the incidence of force. They are also less damaging than metallic and zirconia posts.21,22

Post and core buildup materials should be compatible. Placement of materials with different mechanical properties (eg, composite resins and ceramics) should be considered a potential risk factor to restoration. Similar materials will create better interfaces, less stress between materials and, consequently, less microleakage and potential for failure. Focusing on more effective core materials and evaluation of the possible long-term effects of using various materials from the intraradicular position through the coronal aspect of the restoration will result in safer procedures for endodontically treated teeth. Composite resins have a low modulus of elasticity, which results in permanent plastic deformation following loading and catastrophic failure. The ferrule effect and amount of coronal structure are thus essential when teeth are restored with contemporary post and core systems. Milot and Stein have stated that when most of the tooth structure is preserved, post selection has little or no effect on resistance to root fracture.8

**Conclusion**

While numerous post and core systems have improved the aesthetic potential of all-ceramic restorations, it is essential for the underlying framework and crown restorations to have compatible colors. In vitro post and core studies cannot effectively simulate clinical conditions, and these models must establish the type of preparation design, restorative material, and functional stress treatment.

It is important to consider that adherence to clinical protocols improves results with the new post and core systems. The preservation of maximum coronal and root structure, mechanically compatible posts, and fewer interfaces with occlusal equilibration will facilitate the prevention of treatment failure during restorative procedures. Intraradicular retention is, therefore, an integral part of
treatment planning and it is essential to consider the necessity of treatment and the type of system that will provide long-term, predictable success.

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