Evolving Technology In Endodontic Posts

Abstract: This article provides a brief overview of important, recent changes in the philosophy, materials, and technology that have impacted significantly on the art and science of endodontic post placement.

For many decades, posts have been a standard part of a dentist’s armamentarium for restoring endodontically treated teeth. As in most technologies, there has been a continuous search for the optimal material, design, and physical properties of the endodontic post. Changes in other dental fields and technologies have had a major impact on the dynamics of this search. For example, the growing interest and appreciation from both patients and professionals for all-ceramic and polymer-reinforced restorations (and the ability to reliably bond them in) have driven the development of esthetic post techniques. Likewise, recent changes in the field of endodontics impact the final shape of the instrumented root canal. Hand instrumentation with files and reamers, using step-back tapering, is gradually giving way to “top down” mechanical and sonic instrumentation systems. This has undoubtedly led to canals with an increased taper, which may have an effect on post selection and fit. While it remains too early to draw conclusions, even the introduction of microscopy into endodontics seems to drive some dentists towards bigger and less conservative access preparations. This may ultimately affect the way clinicians need to place posts and restore the tooth.

There are a number of major parameters that have driven the evolution of posts, from the cast metallic posts and preformed posts of the past, to the modern esthetic fiber post designs that are emerging as the preeminent standard.

Parameters for Post Improvements

Post Esthetics

During the years when the porcelain-fused-to-metal (PFM) crown, or the full-metal crown with subgingival margins, was the standard of care for a postendodontic restoration, post esthetics were not routinely considered an issue. In the face of limited options, cast post-and-cores fabricated from precious and nonprecious alloys were regarded as predictable and dependable, with an acceptable failure rate. Prefabricated metal posts offered some advantages over the cast post and were also very popular for many years. However, neither of these two techniques is ideal when used under one of the newer metal-free, light-conducting restorations, such as porcelain, ceramic or polymer glass inlays, onlays, crowns, and veneers. Metallic posts can create a significant esthetics issue as a result of “shine through” (Figures 1A and 1B), as...
well as the interference with natural light transmission through the tooth and the gingival complex.

Oxidation and corrosion byproducts of the metallic posts (Figure 2) are also known to diffuse into the root and can create irreversible discoloration and damage. One of the most common complaints from patients about traditional PFM crowns is their propensity towards causing a noticeable blue-gray discoloration to the marginal gingival surrounding the restoration. While it is true that there may be multiple causes for this phenomenon, at least part of the etiology is the lack of normal light transmission through the root and gingival soft tissue complex and the darkening of the root itself caused by a buildup of corrosion byproducts (Figure 3). Certain post materials play a significant role in this.

There are now several alternatives to the metal post that offer functional, as well as esthetic, benefits. These fall into several categories. One of the first viable alternatives was the carbon fiber post (C-POST™), made from unidirectional pretensed carbon fibers in an epoxy matrix. Developed and introduced in France (as the COMPOSIPOST) more than 10 years ago, it now has a solid clinical history. Though the original version of the carbon fiber post would not corrode like metal and offered exceptional functional benefits, it possessed a black (carbon) color and did not provide any significant esthetic advantages over a similarly sized prefabricated metal post. In each post type, the dark or black coloration can be partially masked if the post is embedded in a tooth-colored core material. However, improved versions of the carbon fiber post were offered with a white mineral coating/sheath surrounding a black carbon fiber core (AESTHETI-POST®). The white coating on the post would effectively eliminate the shine-through, but overall, most of the light transmission through the root and gingival complex was still diminished.

Fiber-reinforced posts consist of some type of mineral or glass fibers embedded in an epoxy or resin matrix. Unlike the earlier carbon fiber varieties, these posts offer significant esthetic advantages without sacrificing the functional benefits. Their overall coloration can usually be described as white, tooth colored, or translucent. Some are highly light-conducting (eg, LIGHT-POST® or Lucent™ Anchors®). Others are white or tooth-colored, but are fairly opaque. Examples of these include; FibreKor®

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*Figure 1A—A silver-colored, prefabricated metallic post is placed side by side with a tooth colored fiber post.*

*Figure 1B—Core buildups placed over the posts in Figure 1A clearly reflect the esthetic compromise with the metallic-colored post.*

*Figure 2—Corrosion byproducts can be clearly seen in the cross section of the root.*

*Figure 3—Elemental analysis of corrosion byproducts.*

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1 Bisco Dental Products, Schaumburg, IL 60193; (800) BIS-DENT

2 Dentatus USA Ltd, New York, NY 10016; (800) 323-3136
Post System, AESTHETI-PLUS, and the ParaPost Fiber White. Because of their tooth-like colorations, most of these posts will not "shine through" a light-conducting restoration.

Depending on their light conduction properties, many fiber posts allow a near normal light transmission throughout the tooth and root. A second major benefit of high translucency is the ability to blend the post in with its surrounding core material (so called "chameleon effect"). This group of glass fiber-reinforced materials has become the main focus for post development in recent years. Their mechanical properties, excellent esthetics and clinical viability have been almost universally reported as favorable. The most commonly reported or perceived drawback to the esthetic fiber reinforced posts, have been their lack of radiopacity (particularly in the United States).

High-strength all-ceramic posts have also been successfully developed from materials such as zirconium oxide. Examples include the Cosmopost and Cerapost. As a result of their white or tooth-shaded coloration, they provide a limited esthetic benefit. However, these posts typically are relatively opaque when compared with the fiber-reinforced posts, and the bond the ceramic posts appear less predictable. Their elastic modulus is identical to that of stainless-steel posts (~200 GPa), and their in vitro effect on the root is similar.

**Reinforcing Capability/Stress Distribution (Elastic Modulus)**

When a tooth has received endodontic treatment, there is little dispute that in most cases it will be structurally weakened by the loss of dentin. This loss may be caused by endodontic access preparation, previous carious activity, or dental restorations. The strength of the remaining tooth structure is more directly related to the quality and quantity of dentin that remains after endodontic intervention than to whether or not it has a post. While it was once assumed that a post was required to reinforce a weakened, endodontically-treated tooth, more recent study has disproved this. Dentists now understand that a rigid, high-modulus post, such as metal or ceramic, may transfer functional stresses to the tooth and root structure (Figure 4) and actually increase the potential for root fracture.

When comparing various post materials and designs, the rigid metallic cast post-and-cores have been associated with irreversible clinical failures, such as vertical root fractures. Prefabricated metal posts offer some functional improvements, but are still associated with a high incidence of root fracture.
The principal reason for this is the development of focal stress points at the cervical area of the root and just below the terminus of the post in the root. Accumulation of metallic corrosion byproducts in the root has been shown to significantly weaken the dentin and the interface between the post and the canal. Given that a post does not internally reinforce an endodontically-treated tooth and that rigid and metallic posts are likely to cause a catastrophic failure, the improved post design is one that preserves precious tooth structure, is noncorrodind and has an elastic modulus, similar to the surrounding tooth structure (dentin). The newer fiber-reinforced posts address these parameters very well and are now available in a variety of sizes, shapes, and degrees of radiopacity. The impact of their shape and radiopacity will be discussed in further detail in the following sections. However, it is clear that their elastic modulus and strength are more mechanically compatible than their metal predecessors and may well be considered the most promising materials for post construction.

**Functional Harmony**

A tooth that is restored with a post-and-core and crown can be readily understood as a group of dissimilar materials that ultimately have to function as a single compound entity. Each of the individual materials will have a different set of physical properties. When two or more of these components have significantly different properties and are placed into contact with one another, the components and interfaces created will be subject to considerable clinical and functional demands. For example, it is known that when two components of significantly different elastic modulus form an interface, the component with the higher e-modulus will tend to transfer functional stresses to the component with lower e-modulus. This would logically lead to a breach in the integrity of the interface and ultimately to endodontic or restorative failure. It has been shown that when all of the reconstructive components have a very similar elastic modulus, there tends to be a more uniform stress distribution throughout the restored tooth with lowered interfacial stress and chance for failure. The developers of the...
original fiber post have described this condition as a monobloc (Figure 5).

As described previously, the most important component material of the restored endodontically-treated tooth is the residual dentin. Since the modulus of dentin is obviously invariant, to achieve a monobloc, all other materials which interface with it should having a modulus as close as possible to that of the dentin itself. In this way, no one component is capable of overpowering any of the others. The components move, flex, and stress as one assembly—a monobloc.

Semiprecious and precious alloys used in custom cast posts and the base metals used in making preformed metallic posts have e-moduli that are significantly different (7 to 10 times higher) from dentin (Table 1). Likewise, the newer all ceramic posts are also much stiffer than dentin. Achieving a monobloc with any of these materials is impossible. Fiber-reinforced posts are all manufactured to have a very similar elastic modulus to that of dentin (15 GPa to 40 GPa). The high percentage of clinical success observed with them is a sound indication of the importance of achieving a monobloc.

**Table 1—Mechanical Properties**

<table>
<thead>
<tr>
<th>Product</th>
<th>Flexural Strength (GPa)</th>
<th>Tensile Strength* (MPa)</th>
<th>Flexural Modulus (GPa)</th>
<th>Elastic Modulus* (GPa)</th>
<th>Fiber Used</th>
<th>Percent of Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel</td>
<td>800</td>
<td>n/a</td>
<td>n/a</td>
<td>200</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Titanium Alloy</td>
<td>1000</td>
<td>n/a</td>
<td>n/a</td>
<td>110</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Gold Alloy</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>77</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Zirconium Oxide</td>
<td>820</td>
<td>n/a</td>
<td>n/a</td>
<td>200</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>C-Post**</td>
<td>1100</td>
<td>2900</td>
<td>120 to 140</td>
<td>17.8**</td>
<td>Carbon</td>
<td>64</td>
</tr>
<tr>
<td>ÆSTHETI-PLUS**</td>
<td>1400</td>
<td>2200</td>
<td>44</td>
<td>15</td>
<td>Quartz</td>
<td>62</td>
</tr>
<tr>
<td>D.T. LIGHT-POST®</td>
<td>1600</td>
<td>2050</td>
<td>46</td>
<td>15**</td>
<td>Quartz</td>
<td>60</td>
</tr>
<tr>
<td>FibreKor® Post</td>
<td>960</td>
<td>1200</td>
<td>13.5</td>
<td>n/a</td>
<td>Glass</td>
<td>42</td>
</tr>
<tr>
<td>ParaPost® White</td>
<td>990</td>
<td>1200</td>
<td>29.2</td>
<td>n/a</td>
<td>Glass</td>
<td>42</td>
</tr>
<tr>
<td>Snow Post® A</td>
<td>n/a</td>
<td>1229</td>
<td>n/a</td>
<td>45.1</td>
<td>Zirconium Oxide</td>
<td>65</td>
</tr>
</tbody>
</table>

*Data taken from manufacturer literature
**Tensile modulus at 30°
*Danville Materials, San Ramon, CA 94583; (800) 822-9294

As in most technologies, there has been a continuous search for the optimal material, design, and physical properties of the endodontic post.

Post Design

Post shape has been the subject of much study, experimentation, and disagreement. A post should: a) have a design that provides for good retention and resistance to dislodgement; b) apply stress evenly and minimally to the remaining tooth structure; c) require a conservative, minimally invasive preparation of remaining root and tooth structure; and d) have a good approximation to the root canal walls. It is also well accepted that the post design and placement must not compromise the apical seal of the root canal. Posts that end 3 mm to 5 mm short of the apex normally fulfill that requirement. The overall post designs are broadly classified as parallel, tapered, and anatomical. The parallel and tapered designs are normally available in prefabricated posts while the anatomical shape is traditionally only possible with a custom cast post. Custom cast posts have an excellent approximation to the root canal walls but, because of their rigidity, are the most likely to induce root fracture.18,21 Parallel-shaped posts have been gen-
composites have been successfully exploited by the aviation, automotive, and other industrial and engineering applications. When comparing some typical materials used in endodontic post fabrication, Table 1 clearly shows that the flexural strength of a fiber-reinforced post is significantly greater than stainless steel, and even titanium, while maintaining an elastic modulus nearly identical to dentin.

Duret and colleagues\(^9\) reported on a comparative analysis of metal ParaPosts\(^6\) and C-POSTS\(^7\) (COMPOSIPOST) conducted at the University of California, Los Angeles (UCLA) in 1992. This work demonstrated yet another weakness of metallic posts. When exposed to intermittent fatigue cycle tests, metal ParaPosts\(^6\) would eventually lose significant amounts of their initial strength (Figure 8), and most would progress to permanent deformation or fracture. In comparison, the C-POSTS\(^7\) showed insignificant evidence of fatigue or fracture (Figure 9) while transferring significantly less stress to the tooth.

There are now a number of different brands of fiber-reinforced posts available on the market. While all of them appear to be safer than metal posts, in terms of e-modulus and stress transfer, variations in their strength and fatigue resistance appear to be roughly correlated to the differences in the type, quality, and volume of fibers being used (Figures 10 through 13).

**Cementation/Retention**

The principle purpose of a post is to replace the missing coronal tooth structure sufficiently to provide the required retention and resistance form for the final restoration (the crown). The retention of the metal post can be influenced by a number of key factors, including shape, post surface area, and type of cement used. Cemented parallel posts have been considered to be adequately retentive, but often necessitate over-preparation of the root canal to accommodate the post shape, especially at the apical terminus. Tapered designs were introduced to more closely approximate posts to the natural and instrumented canal shape leading to less preparation of the root canal. To increase retention of cemented, tapered posts, manufacturers began adding screw threads, grooves, and other surface modifications designed mainly to increase

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**Strength and Fatigue Resistance**

When the carbon fiber post was first introduced to the US market, many dentists were skeptical of the claims that a fiber-reinforced composite post could actually be as strong or even stronger than a metal post of comparable diameter. However, the differences between isotropic metals and anisotropic fiber-reinforced
surface area and thereby improve macro-mechanical retention. Though this was successful in improving the overall retention rates, a tapered post, which is mechanically or functionally driven into the root, also increases the risk of actively wedging the canal walls and increasing the potential for root fracture. The retention of the metal post can be influenced by a number of key factors, including shape, post surface area, and type of cement used.

Other manufacturers sandblasted the surface of the posts to improve micro-mechanical retention.

Much of this risk was eliminated when it became possible to bond in the post rather than cement it. With a bonded post, it is unnecessary for retention to come mainly from its design or surface features. With proper hybridization, adhesive bonding also creates a stable seal of the dentin/post interface; and it becomes possible to use a passive tapered post design without fear of losing retention.

Analysis by fractography (Figure 14), where the post is intentionally stressed to fracture, illustrates how the seamless attachment of the cement to the post is stronger than the post itself.

Retrieval/Re-treatment

It has been estimated that as many as 15% of endodontically treated teeth may eventually require re-treatment or re-access to the root canal (written communication, Dr. S. Sakkal, Professor of Endodontics, University of Montreal, October, 2001). Therefore, a post should reduce the likelihood of the need for re-treatment and offer the clinician a reasonable route to post removal and re-treatment if it becomes necessary. With cemented metallic posts or ceramic posts, the only practical option to regain access to a root canal is to loosen the cement seal and retrieve or remove the post in one piece. At best, this is a risky and difficult procedure that frequently resulted in the loss of additional tooth structure to expose the post adequately for recovery attempts. Often the safe removal proved impossible or removal attempts would lead to.
root fractures or other significant damage that would compromise the long-term prognosis or even necessitate tooth removal.

One of the major clinical advantages of fiber-reinforced posts is the ability to remove them expeditiously\textsuperscript{31,32} and without trauma. This now makes re-treatment of a failing root canal a practical and predictable procedure. Fiber posts are not retrieved or removed in one piece like a cast or prefabricated post. Instead, they are removed from the canal by drilling down directly through them. Manufacturers of the fiber-reinforced posts claim they are removable, by essentially the same mechanism, “hollowing the post out from the center.” In the case of the pretensed, unidirectional fiber posts, the drills/augers used in the removal technique are literally guided to remain in the canal (Figure 15) by following the post itself as a “path of least resistance.” One manufacturer even offers a specialized retrieval/removal kit, containing three drills designated for the job by research at University of Montreal.\textsuperscript{32}

**Radiopacity**

The issue of the “radiopacity” of posts is an interesting one. Historically, US dentists seem to have a strong preference for using a radiopaque post. However, there are obvious clinical advantages to not having a totally radiopaque post. A high radiopacity compromises the ability to detect recurrent decay, root fractures, internal resorption and other pathology commonly associated with root canals and posts. On the other hand, a radiolucent post is not ideal either. It also may compromise detection of recurrent decay and may make it difficult for future dentists (and third party payers) to detect the presence of a post at all. So the ideal post would be one that is sufficiently radiopaque or perhaps radio-apparent to be easily detected without compromising diagnostic abilities.

The materials used in fabricating metallic cast posts and preformed metallic posts are inherently radiopaque, while those used in the production of the nonmetallic posts are normally radiolucent. However, several of the fiber post manufacturers have found ways to overcome this natural limitation.

The first carbon fiber-reinforced posts were introduced in (France) in 1990 and were radiolucent. Because of their clinical and commercial success, as well as the preferences of US dentists, they were later offered in a radiopaque version. This modified post combined the desirable physical properties of the original carbon fiber post, but now with a high radiopacity. However, it was still black—leaving the optical and esthetic shortcomings discussed earlier.

As demand for esthetic posts grew, numerous fiber-reinforced posts have become available. However, as pointed out previously, most are best described as radiolucent. One strategy to deal with this has been to seat the posts with cement, which has been formulated to offer ultra high radiopacity in very thin film thick-
ness (Hi-X™). This improves diagnostic abilities by clearly defining the outline of the post within the canal space (Figure 16). The very latest generation of fiber-reinforced posts is translucent and radiopaque (Figure 17).

**Light-Transmission**

As previously mentioned, the light transmission of posts now plays an increasingly important role in the final esthetic result when restoring an endodontically-treated tooth.

**One of the major clinical advantages of fiber-reinforced posts is the ability to remove them expeditiously and without trauma.**

However, in the age of the adhesively-bonded post, this has also become a key property with an influence on the overall retention of the post-and-core, hermetic seal of the canal and ultimately to the final structural integrity of the restored tooth.

Until the early 1990s, posts were usually “cemented” in place with self-setting materials, such as zinc oxyphosphate, polycarboxylate, or glass ionomers. Light transmission was not required, and aside from the esthetic benefits, served no real advantage with those products. The retention obtained with these traditional cements is largely macro-mechanical in nature and all are relatively soluble in oral fluids. Though they provided clinically reasonable longevity, the cement interface between post and tooth can begin to leak and fail. This, in turn, can lead to endodontic failure, infection, dislodgement of the post, or even a fracture of the post or tooth.

To counteract these issues, the recommended clinical protocol for placing esthetic and fiber posts is to bond them in. Because of the depth and narrow configuration of most root canals, the use of purely light-cured adhesives or light-cured composite cements is contraindicated. Self-cured dentin-bonding adhesives and luting composites can be used without light transmission, but offer extremely limited working time and make the clinical procedure very technique sensitive. A common clinical problem experienced with self-setting bonding materials is the inability to completely seat the post in the treated root canal as a result of a rapid or premature reaction between the adhesive and cementation system. So the best choice for bonding in fiber posts now appears to be a “dual cured” adhesive and luting composite system.

This gives the clinician sufficient working time to place the adhesive and luting composite layers and fully seat the post without interference. But to achieve the full curing potential and ideal polymerization conversion ratios with a dual cured product requires at least some light activation. In this capacity, a translucent light-conducting fiber-reinforced post acts much like fiberoptic light guide, which carries the light deep into the root canal (Figure 18) and improves the quality and cure of the hybrid layer. Tests with radiometers have demonstrated that this technique provides adequate light-curing energy to polymerize adhesive and stabilize dual-cure cement inside the tooth. This technique also saves steps and chairtime.

**Biocompatibility**

In any restorative or therapeutic modality, one of the cornerstone requirements is safety and biocompatibility. Post-and-core materials are no different. When comparing the various materials previously and currently available for post construction, six main groups can be formed, including: precious, semiprecious and base metal alloys, carbon fiber, glass fiber and all-ceramic materials.

While all of these main groups are considered to be generally safe for most people, metals
are well known to have a much higher potential for causing allergic reactions and other adverse biologic effects.

Using metal alloys with high noble content or titanium can minimize, but not eliminate these. Historically, custom cast post-and-cores are most often fabricated from precious or semi-precious alloys, while prefabricated metal posts are most often fabricated from stainless steel, titanium, or gold plated base metals. Direct metal allergies or reactions to one of the metal components in these posts have been reported for all of these materials, but are especially high for the base metals. Recently, it has also been shown that the oxidation/corrosion byproducts of metallic posts can accumulate in the dentin surrounding the post and lead to a structural weakening of the root. This may over time contribute to loss of integrity of the endodontic seal, post loss or failure or even root fracture.1

Carbon fiber and quartz/glass fiber posts are manufactured from materials that have a lower allergenic potential and are generally considered to be more biocompatible. In fact, glasses are considered to be among the most biocompatible materials known. The materials are also not subject to corrosion breakdown. Therefore, from the standpoint of biocompatibility, the ideal posts should be fabricated from nonmetallic materials.

**Conclusion**

The growing interest in esthetic dental restorations and adhesion dentistry has driven both manufacturers and dentists to create some innovative new post materials and techniques for restoring the endodontically treated tooth. Although metal posts were used extensively for many years, their popularity is currently declining. With more than 10 years of proven clinical success, there is now widespread interest in the use of nonmetallic post materials and techniques. Over the last decade, in vitro and in vivo testing has demonstrated that some fiber-reinforced endodontic posts can dramatically reduce the incidence of root fracture, tissue discoloration, and allergic reaction. If endodontic re-treatment is necessary, most fiber posts can be removed from a root canal with ease and predictability, when necessary, without compromising their only true function—core retention.
Today's marketplace offers the dentist many choices in size, radiopacity, and designs to fit the needs of the specific tooth and clinical application. The use of a highly translucent post not only can serve to enhance esthetics in the final restoration, but can also be useful as an instrument in the light-curing process.

Disclosure
The authors of this article received grant/research support from Bisco, Inc and RD.

References
Quiz 1

1. Fiber reinforced post coloration can usually be described as:
   a. white.
   b. tooth colored.
   c. translucent.
   d. all of the above

2. High strength all ceramic posts:
   a. are relatively opaque.
   b. the bond appears less predictable.
   c. have an esthetic modulus identical to stainless-steel posts.
   d. all of the above

3. Dentists now understand that a rigid, high-modulus post such as metal or ceramic may serve to:
   a. anchor castings with a galvonic reaction.
   b. increase the likelihood of an autoimmune disease.
   c. effectively transfer functional stresses.
   d. ineffectively transfer functional stresses.

4. The most important component material of the restored endodontically-treated tooth is:
   a. carbon fiber post.
   b. residual dentin.
   c. stainless-steel post.
   d. ceramic post.

5. Semiprecious and precious alloys used in custom cast posts and the base materials used in making performed metallic posts have e-moduli which are what from dentin:
   a. 7 to 10 times higher.
   b. 1 to 2 times higher.
   c. 1 to 2 times lower.
   d. 7 to 10 times lower.

6. The anatomical shape is traditionally only possible with a:
   a. ceramic post.
   b. stainless-steel post.
   c. screw post.
   d. custom-cast post.

7. Fiber posts are removed from the canal by:
   a. drilling down directly through them.
   b. retrieving in one piece.
   c. dissolving in weak citric acid.
   d. dissolving with diluted method-ethyl ketone (MEK).

8. The ideal post would be one that is:
   a. radiolucent.
   b. radio-apparent.
   c. radiopaque.
   d. radiopaque at the apex only.

9. The best choice for bonding in fiber posts now appears to be:
   a. self-cured.
   b. light-cured.
   c. dual-cured.
   d. zinc phosphate.

10. What are considered to be amongst the most biocompatible materials known?
    a. steel
    b. nickel
    c. amalgam
    d. glasses

Please see tester form between pages 72 and 73.