The Post–endodontic Adhesive Interface: Theoretical Perspectives and Potential Flaws

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Abstract

Introduction: The aim of this review was to analyze the potential of successful bonds of endodontic posts to radicular dentin as well as the limitations of the post–endodontic adhesive interface. **Methods:** The MEDLINE/PubMed and Web of Science electronic databases were searched. The search was augmented by a manual search of the pertinent bibliographies. **Results:** The post–endodontic adhesive interface finds application in the endodontic cohesive units. Many techniques and materials exist to improve the bond between endodontic posts and resin-based materials as well as between resin-based materials and radicular dentin. Different techniques used for the adhesion of metallic and fiber-reinforced posts are discussed and critically analyzed. **Conclusions:** Although adhesive cementation of endodontic posts is popular, a long-term predictable bond may be compromised because of procedures related to the endodontic treatment and/or the adhesive cementation procedures. Microleakage and degradation phenomena may further jeopardize the post–endodontic adhesive interface. *(J Endod 2017;■:1–9)*

Key Words

Adhesion, endodontic dowel, endodontic post, radicular dentin, resin cement

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Significance

Although adhesive cementation of endodontic posts is popular, long-term predictable bonds may be compromised because of procedures related to the endodontic treatment and/or the adhesive cementation procedures. Microleakage and degradation phenomena may further jeopardize the post–endodontic adhesive interface.

Adhesive cementation of intraradicular posts has become a popular treatment modality. Traditionally, the purpose of the cement is to fill the gaps between the prepared post space and the post. The main retentive value of the post is provided by the geometric characteristics of the post and the properties of the cement (1, 2). However, the development of resin cements significantly expanded the role cements play. Resin cements exhibit a higher number of cycles to preliminary failure (3) and better retention (4–7), even if the post has a reduced length (8, 9). They also appear to be the most suitable for the cementation of fiber posts (6, 10, 11). Finally, there is some evidence that the use of resin cements may increase the fracture resistance of teeth restored with a cast post and core (12).

The post–endodontic adhesive interface is 1 of the interfaces that form the cohesive endodontic units or "monoblocks." The "cohesive endodontic unit" model is based on the idea that a strong bond could be achieved among radicular dentin, post, and foundation core material (13). Also, the different materials would have similar flexural properties (13). As a result, they function cohesively and not as a mechanically heterogeneous unit (14). The term "monoblock" is a misnomer because it refers to structures made from 1-piece materials, and as such it cannot describe a multi-interface adhesive system accurately. Monoblocks have been further classified into primary, secondary, and tertiary based on the number of the different existing interfaces (13). This model was first described with the adhesive cementation of fiber posts using resin cements and the bonding of foundation core composite resin materials to the post and the remaining dentin. However, adhesive cementation could also be achieved today using metallic posts (15). This review aims to discuss the potential of achieving a predictable bond between different post materials and dental substrates as well as the possible limitations that may lead to failure of the post–endodontic adhesive interface.

Literature Search Strategy

An online search of the literature was conducted using the MEDLINE/PubMed and Web of Science databases. The key words used to search the electronic databases were combinations of the following: "endodontic post" OR "endodontic dowel," "adhesion" OR "bonding," "resin cement" OR "composite resin," "dentin," "metals" OR "alloys," "surface treatment," and "monoblock." The search results were limited to articles published in English since 1980. Additionally, the following journals were manually searched to identify relevant articles: *Journal of Endodontics*, *Journal of Prosthetic Dentistry*, and *Journal of Prosthodontics*. Inclusion criteria for full-text review were that the selected articles should investigate or discuss the bonding of composite resin–based products to various types of endodontic post materials and dentin.

Results

After duplicate articles were removed, titles and abstracts were reviewed to select relevant articles. Because of the nature of the search, a variety of article types were included, such as systematic reviews, narrative reviews, and *in vitro* studies. No clinical studies were identified. A total of 66 articles were identified that were related to the aim of this review. Articles that provided additional relevant information but were not related to bonding of endodontic posts to radicular dentin were also included to provide a more complete review of the materials and techniques described, bringing the total number of articles to 118. The articles were subsequently organized into the following topics: bond to fiber-reinforced posts, bond to metallic posts, bonds to radicular dentin, and microleakage and degradation phenomena.

Discussion

Bond to Fiber-reinforced Posts

Fiber-reinforced posts consist of fibers (glass, carbon, quartz, or polyethylene) embedded in a polymer–epoxy resin matrix. The purpose of the fibers is to increase the tensile and fatigue strength of the post and to enhance its volumetric stability. The epoxy matrix is highly cross-linked, with a very high degree of polymerization conversion. Its purpose is to support and protect the fibers (16). The most common technical complication of endodontically treated teeth restored with fiber posts is post debonding (17, 18). Interpenetration between resins and the fiber post material is feasible in products with an intrapolymer network–polymer matrix (ie, everStick Post [GC America Inc, Alsip, IL]) (19). This is consistent with the absence of adhesive failures of post systems with an intrapolymer network–polymer matrix (20). The direction of the fibers can be longitudinal or vertical and is product dependent. Longitudinal fibers may allow for a better bond with the tooth, resin cement, and foundation core material (21). However, when the fibers are vertically oriented, the post generally has superior mechanical properties, increased stiffness, fatigue, and fracture resistance (22). The high degree of polymerization conversion of the resin matrix in fiber posts may result in a poor bond between resin cements and the post surface because of the lack of free functional groups (23). Adhesion to the fiber post surface is significantly inferior to dental substrates (24).

Many techniques suggest modification or treatment of the post surface to increase the adhesion of resin cements. These techniques include, but are not limited to, the application of hydrofluoric acid (25), phosphoric acid (26), hydrogen peroxide (27–31), methylene chloride (29), potassium permanganate (28), silane (25, 27–29, 31–40), tribochemical coating systems (25, 39), and airborne-particle abrasion (26, 35, 36). Surface conditioning of fiber posts with silane, tribochemical coating, phosphoric acid, hydrofluoric acid, or potassium permanganate is not always effective (25, 26, 29, 32, 34, 37, 40). Silane could increase the bond strength, but a fiber post may have no free functional groups to react with silane (41). However, silane could be effective when it follows other post pretreatment techniques (25, 42). Hydrogen peroxide functions through dissolution of the epoxy resin matrix and appears to be more effective when compared with methylene chloride (29). Hydrogen peroxide is also more effective when applied to glass fiber posts when compared with quartz fiber posts (29). As far as air-particle abrasion is concerned, it could increase the retention of resin on the surface of fiber posts (36). Air-particle abrasion causes partial removal of the epoxy resin matrix that exposes the fibers, increases the available surface area, and increases the surface roughness of the fiber posts (35). Subsequently, resins could interact through micromechanical interlocking and slide friction (36). Whether this method increases post retention and bonding is controversial (26, 35, 36). Nevertheless, it is generally agreed that even though air-particle abrasion may increase bond strengths it may be an aggressive procedure that can alter the morphologic characteristics and the properties of the fiber posts (35, 36). Therefore, its application cannot be safely recommended for all fiber post systems. Thus, all the techniques previously described are highly material dependent, and there is no sound scientific basis for their predictable universal application on all fiber-reinforced posts.

Bond to Metallic Posts

Metallic posts, prefabricated or custom, can be fabricated from high noble alloys or various types of base metal alloys (nickel-chromium alloys, stainless steel, and titanium). A resin-based material could bond to a metal oxide layer through hydrophilic bonds. However, this bond is relatively weak and prone to hydrolysis (43). Techniques attempting to enhance the bond quality between metal surfaces and resin-based materials can be mainly divided into 2 categories: surface modification techniques and techniques involving the application of primers containing functional monomers.

Surface modification techniques include pyrochemical silica coating techniques (44), tribochemical coating systems (45), titanium dioxide coating systems (43), and spark erosion (46). These techniques create a silicified oxide layer on the metal surface that could lead to a predictable bond with resin-based materials. The tinplate technique could also be added in this category, increasing the bond strength of composite resins to noble alloys through the electrochemical deposition of a layer of tin (47). Generally, surface modification techniques could be used for both noble and base metal alloys (47). Their main disadvantage is that they are more complicated procedures and require special equipment. Also, they cannot be easily applied chairside.

Functional monomers contain groups of atoms or bonds that are responsible for a specific chemical reaction. These functional monomers have a chemical affinity to metals and concurrently copolymerize with the structural monomers of resin-based materials. Primers containing functional monomers can be further divided into primers for base metal alloys/titanium, primers for noble alloys, and universal primers. Base metal alloy primers include functional monomers that contain phosphate or carboxylic acid functional groups (48). Examples include 10-methacryloyloxydecyl dihydrogen phosphate and 4-methacryloyloxyethyl trimellitate anhydride, which create an ionic bond with resin-based products (48). The application of 10-methacryloyloxydecyl dihydrogen phosphate results in a better bond than 4-methacryloyloxyethyl trimellitate anhydride when applied on nickel-chromium alloys (49). It forms its most predictable bond with commercially pure titanium and titanium alloys (50–53). Noble metal alloy primers include functional monomers that contain thionic groups. An example is 6-(4-vinylbenzyl-n-propyl) amino 1,3,5-triazine-2,4-dithiol, dithione tautomer, which also creates an ionic bond (54). Finally, the universal primers consist of a combination of monomers, 1 for base metal alloys and 1 for noble alloys (55). Alternatively, they may consist of dual functional monomers, which contain both phosphate and thionic functional groups in a single molecule (56). An example is thiophosphate methacryloyloxyalkyl. The main advantage of the universal primers is that only 1 primer is necessary and can be applied to any kind of alloy. Examples of the metal primer products currently available are listed in Table 1.

Air-particle abrasion with aluminum oxide (Al_2O_3) particles is necessary for the primers to be effective. The principal mechanism is not clear, but it may act through an increase of the surface area (micromechanical retention), a decrease of surface tension (adhesion and wettability), and/or oxidization of base metal alloys (chemical bond) (49, 56, 57). However, air-particle abrasion may alter the character of the metal surface. Aluminum oxide particles may get trapped and partially cover the original alloy elements in the superficial layer