Effect of Fiber Post Cementation Timing on the Bond Strength of Resin Cements in Epoxy Resin–Obturated Canals

This study evaluated the influence of timing after endodontic treatment and type of resin cement used on the bond strength of fiber posts to epoxy resin–obturated canals. A total of 80 bovine incisor roots were divided into four groups (n = 20). Glass fiber posts were cemented at two different times, immediately or 7 days after endodontic treatment, using either a dual-curing resin cement (RelyX ARC, 3M ESPE) or a self-adhesive resin cement (RelyX U200, 3M ESPE). Following post cementation, the samples were cross-sectioned into slices containing root dentin, cement, and fiber post at the cervical, mid, and apical root thirds. The push-out test was performed on a universal testing machine. Three-way analysis of variance for randomized blocks showed no significant effect within the triple interaction (P = .394) or between the double interactions cement-timing (P = .395), cement-root thirds (P = .996), and timing-root thirds (P = .331). The main factor cement revealed a significant effect, showing that regardless of the timing and root third, RelyX ARC provided significantly higher bond strength values than U200. Regardless of root third and timing, the dual-curing resin cement showed higher bond strength to root dentin when the canals were filled with epoxy resin–based cement. Int J Periodontics Restorative Dent 2018;38:711–717. doi: 10.11607/prd.2649

Intracanal fiber posts are used for the retention of coronal restorations of endodontically treated teeth that have suffered excessive loss of structure.1–3 This material exhibits a modulus of elasticity close to that of dentin,2,4 allows for cementation procedures to be carried out without tension to the root canal walls, reduces the risk of vertical root fractures, and distributes incident forces more evenly across the root dentin. These characteristics result in reduced fracture rates, and fractures that do occur are often less destructive than those caused by cast posts.2

The most appropriate time for cementation of glass fiber posts following endodontic treatment remains controversial. Considering that the endodontic sealer is not fully set when cementation is performed in the same session as the obturation,5 the bond strength of resin cements to root dentin may be affected. Delayed post cementation has been observed to provide higher bond strength values when calcium hydroxide6 or eugenol-based endodontic sealers7 were used. It is generally accepted that eugenol may adversely affect the bond strength of resin cements7 and that calcium hydroxide–based cements are difficult to remove from the canal, which might lead to bonding problems due to cement residue.8,9 Epoxy resin–based cements are

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therefore preferred as they exhibit such favorable properties as lower microleakage rates and periapical healing.\textsuperscript{10,11} Boone et al\textsuperscript{12} verified that cementation timing for cast metal posts was not affected by epoxy resin–based sealers; however, no studies have yet investigated the influence of glass fiber post cementation timing when epoxy resin–based endodontic sealer are used.

Furthermore, an effective coronal seal is needed to prevent further contamination of the root canal, which makes restoring the tooth in the same session as the obturation the ideal case scenario.\textsuperscript{13,14} The materials used for post cementation have different bonding strategies to the dentin.\textsuperscript{15} Dual-curing resin cements initiate setting by chemical and light activation and establish a bond to the tooth substrate via the adhesive systems.\textsuperscript{16} However, the numerous steps involved in the application technique for dual resin cements make them susceptible to handling errors and increase clinical time.\textsuperscript{17} Therefore, self-adhesive cements have been developed to eliminate the steps related to preparing the tooth substrate.\textsuperscript{17} This consists of a multifunctional matrix composed of phosphoric acid for demineralization that infiltrates the enamel and dentin simultaneously, resulting in micromechanical retention and providing adequate bond strength to the dentin.\textsuperscript{17,18}

Therefore, the most appropriate moment, in terms of bond strength, for cementation of glass fiber posts using dual-curing or self-adhesive resin cements following endodontic obturation with epoxy resin sealer should be investigated. The objective of this study was to evaluate the influence of timing after endodontic treatment and the type of resin cement on the bond strength of glass fiber posts to root dentin when the canals were filled with an epoxy resin–based sealer.

Materials and Methods

Experimental Design

The experimental units comprised 80 bovine incisors divided into four experimental groups (n = 20). Independent variables were the following: type of resin cement on two levels—dual-curing (Rely X ARC, 3M ESPE) and dual-curing self-adhesive (RelyX U200, 3M ESPE); cementation timing on two levels—immediately after endodontic treatment and 7 days after treatment; and root thirds on three levels—cervical, mid, and apical.

The dependent variable was push-out bond strength of fiberglass posts. The failure mode was verified using a qualitative scoring system.

The treatments were randomly assigned to the experimental units, resulting in four experimental groups: group 1 (ARC/0) received glass fiber posts cemented with dual-curing resin cement immediately following root canal obturation; group 2 (ARC/7) received glass fiber posts cemented with the dual-curing resin cement after 7 days of endodontic treatment and 7 days after treatment; and group 3 received glass fiber posts cemented with self-adhesive resin cement immediately upon root canal obturation; and group 4 received glass fiber posts cemented with dual-curing self-adhesive resin cement 7 days after endodontic obturation. Table 1 describes the characteristics of the materials used in the experiment.

Teeth Selection, Crown Removal, and Root Embedding

A total of 80 bovine mandibular incisors were selected. They were stored in 0.1% buffered thymol solution and cleaned with periodontal curettes, pumice, and water.

The crowns were cut at a right angle to the long axis of the tooth at 17 mm from the root apex using a metallographic saw (Buehler), and the resulting surfaces were smoothed with 600-grain sandpaper. The roots were positioned in plastic tubes filled with dense condensation silicone (Zetaplus, Zhermack) to allow manual handling during endodontic treatment and post cementation to prevent the passage of light through to the root during adhesive curing.

Endodontic Treatment

Root canal preparation was performed using hand instruments (Dentsply), with 2.5% mL of 1% sodium hypochlorite irrigation (Milton solution, Biodynamics) used at every file change and ENDO-PTC Gel Lyte (Formula & Action) to clean, disinfect, and shape the canal to allow appropriate obturation sealing and the configuration of the apical stop prepared using a #60 file. The canal was dried
with absorbent paper points (Tanari) according to the canal taper. The teeth were obturated using gutta-percha (Odous) and epoxy resin-based sealer (AH Plus, Dentsply).

### Table 1 Characteristics of Materials Used

<table>
<thead>
<tr>
<th>Material (manufacturer and batch)</th>
<th>Composition</th>
<th>Application instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional adhesive system: Scotchbond Multi-Purpose (3M ESPE, batch NA03189/N368780)</td>
<td>Etchant: 37% phosphoric acid Primer: Aqueous solution of 2-hydroxyethyl-meta-methacrylate (HEMA), a copolymer of polyalkenoic acid Bond: bisphenol A diglycidyl dimethacrylate solution (Bis-GMA), 2-hydroxyethylmethacrylate (HEMA) and camphorquinone.</td>
<td>Etch with 37% phosphoric acid for 15 seconds and rinse with water for 20 seconds. Excess water was removed using absorbent paper. The primer was applied for 15 seconds followed by a light jet of air. The bond was applied and light cured for 20 seconds.</td>
</tr>
<tr>
<td>Silane (Angelus Londrina, batch 051113)</td>
<td>Ethanol solution of 3-Methacryloxypropyltrimetoxy hydrolyzed silane</td>
<td>The post was etched with 37% phosphoric acid for cleaning. Silane was then applied and left for 1 minute.</td>
</tr>
<tr>
<td>Glass fiber post Reforpost number 2 (Angelus Londrina, batch 28570)</td>
<td>Glass fiber and epoxy resin</td>
<td>–</td>
</tr>
<tr>
<td>Dual-curing resin cement Rely X ARC (3M ESPE, batch N476447)</td>
<td>Paste A: zirconia, silica, pigments, amine, bis-GMA, bisphenol-diethoxymethacrylate, TEGMA, silanized barium crystals Paste B: filler particles, benzoyl peroxide.</td>
<td>The conventional dual-curing resin cement was measured using its click system, and the two pastes were dispensed and mixed completely. The cement was placed into the root canal and hybridized, aided by a Centrix syringe.</td>
</tr>
<tr>
<td>Self-adhesive resin cement U200 (3M ESPE, batch 492547)</td>
<td>Paste A: UDMA, Bis-GMA, TEGDMA, HEMA, GDMA-P, and glass particles Paste B: UDMA, HEMA, water, photoinitiators, and glass particles</td>
<td>The conventional dual-curing resin cement was dispensed using its own click system, and the two pastes were mixed until homogenous. The cement was taken to the root canal and hybridized, aided by a Centrix syringe.</td>
</tr>
<tr>
<td>AH Plus (Dentsply, batch 110600075)</td>
<td>Paste A: bisphenol-A epoxy resin. Bisphenol F epoxy resin, calcium tungstate, zirconium oxide, silica, iron oxide pigments Paste B: dibenzylidiamine, amino adamantane, tricyclodecane diamine, calcium tungstate, zirconium oxide, silica, silicone oil</td>
<td>Mix equal parts in volume of paste A and paste B (1:1), using a metal spatula to obtain a homogeneous consistency. The cement was applied to the walls of the canal with the aid of a gutta percha point.</td>
</tr>
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</table>

Largo number 4 drills (Mani) to a depth of 9 mm, aided by rubber stoppers (Stop - injected). Gates Glidden and Largo drills were replaced every five preparations.

### Obturation Removal and Root Canal Preparation

At the predetermined experimental time frames, the experimental units had part of their obturation removed using Gates Glidden (Thomas) and Largo number 4 drills (Mani) to a depth of 9 mm, aided by rubber stoppers (Stop - injected). Gates Glidden and Largo drills were replaced every five preparations.

### Glass Fiber Post Preparation for Cementation

The posts were adapted to the root canals and verified to visually confirm the depth of preparation. The glass fiber posts (number 2, Angelus Londrina) for the four groups received the same treatment prior to cementation: cleaning and disinfection with 70% alcohol for 30 seconds. Posts were dried and painted with silane (Angelus Londrina).

### Cementation Protocol

The adhesive system and the conventional dual-curing and self-adhesive cements were used according to the manufacturers’
instructions, as described in Table 1. The cement was inserted using a Centrix syringe and a metal tip. The post was positioned and pressed into place for 10 seconds while the excess cement was removed using a microbrush (Vigodent). The tip of the light-curing unit device was placed at the cervical region of the root, at a 45-degree angle to the long axis. Light-curing was performed using a halogen light for 40 seconds on each aspect of the tooth with a minimum irradiance of 450 mW/cm², as verified by a radiometer (Newdent LTDA Equipment). The roots were stored in a moist bacteriologic incubator at 37°C for 7 days.

Sectioning of the Roots

The samples were removed from the condensation silicone putty and fixed onto a 5 × 5-cm acrylic plate with sticky wax parallel to the long axis of the root. The samples were cross-sectioned with a diamond disc mounted on a metallographic saw (Buehler), yielding slices approximately 0.7 mm in thickness in three different root regions (cervical, mid, and apical).

Push-Out Test

Sections of the samples were placed on a stainless steel base plate fixed to the testing machine (DL2000, FDMS). The metal base had an orifice measuring 3.0 mm in diameter in its central area, and the samples were positioned so that the part corresponding to the post remained over the orifice with the cervical aspect of the specimen in contact with the metal base. A metal shaft with an active tip measuring 1 mm in diameter attached to a load cell (50 kN) was then positioned over the central aspect of the post, and the push-out test was performed at a speed of 0.5 mm/min. The values were converted from KgF into MPa (MPa = KgF × 9.8/area). The area was calculated according to the diameter of the post and the thickness of the slice. Therefore, area = 2π × r × h, where π = 3.1416, r = radius of the post, and h = height of the root section.

Failure Mode

Following the push-out test, the specimens from each group were examined using a stereoscopic loupe to establish the pattern of failure observed, which was classified into the following types: type 1—bonding failure between the post and the cement; type 2—bonding failure between the dentin and the cement; type 3—mixed failure; and type 4—cohesive failure.

Statistical Analysis

The data was analyzed using Shapiro-Wilk and Levene tests to check normality and homogeneity of variance, respectively. The data was then transformed by the square root, which resulted in improved normality and homogeneity of variance. For the purpose of calculation, the transformed data were selected to undergo three-way analysis of variance (ANOVA) for randomized blocks. The breakdown of the interactions was analyzed via Tukey test. The significance level was 5%, using SPSS software for statistical calculation.

Results

The three-way ANOVA for randomized blocks showed no significant effect of the triple interaction (P = .394) or for the double interactions: cement-timing (P = .395), cement–root third (P = .996), and timing–root third (P = .331). The main factor (cement) revealed a significant effect, showing that regardless of the timing and root third, RelyX ARC provided bond strength values significantly higher than U200 (Table 2). The other main factors (timing, P = .777; root third,
P = .419) revealed no significant effect (Table 2).

Figure 1 illustrates the failure modes obtained for the samples after the push-out bond strength test and indicates that for all experimental conditions, adhesive failures between the cement and dentin (type 2) prevailed, accounting for 80% to 95% of the total.

**Discussion**

Root dentin undergoes changes in its mechanical properties and composition when subjected to endodontic treatment, and this is compounded over time. These changes are attributed to modifications in the organic matrix of the dentin by the action of sodium hypochlorite, dehydration of pulpless teeth, and the action of eugenol present in root filling materials. The selection of 1% sodium hypochlorite as an irrigant for this study was based on its broad-spectrum antimicrobial action and its ability to denature toxins and dissolve organic tissue. The epoxy resin–based sealer was chosen for its sealing ability and good biologic response, and especially because no studies were found evaluating the influence of time lapsed after obturation prior to cementation of fiber posts with resin cements when this sealer was used.

Regarding the bonding of resin materials to root dentin, the factors that can interfere with post retention along the root canal are length, shape, diameter, and surface treatment. Dentin surface preparation boosts post retention by increasing the surface area for interlocking between the cement and the dentin. Considering that the laboratory procedures were standardized, the similar bond strength values along the different root thirds (cervical, mid, and apical) found in this study were attributed to the uniformity of the laboratory steps, the snug juxtaposition of the post to the root canal walls favoring frictional retention, and finally the use of dual-curing resin cements, which feature not only physical but also chemical setting. Furthermore, the use of a Centrix syringe allows for greater uniformity in the process of inserting the resin cement (apex to crown), reducing the occurrence of air bubbles. The same performance was observed by Zicari et al and Pereira et al. The results of this study demonstrated that waiting time prior to cementation of the fiber post after endodontic treatment had no effect on the bond strength to root dentin when cemented soon after obturation or 7 days later. Mesquita et al observed higher bond strength values for glass fiber posts bonded after 7 days of obturation for both the dual-curing and self-adhesive cement. They used a calcium hydroxide-based root canal sealer, which is more hydrophilic and soluble and may interfere with the bonding mechanisms of hydrophobic resin cements when fiber post cementation is performed in the same session as the endodontic obturation, given that the sealer would not yet have reached its final set. The epoxy resin–based cement (AH Plus) used in this study is hydrophobic and contains a bisphenol monomer similar to that present in resin cements, therefore it did not interfere with bonding between the cement and the dentin.
In the present study, the self-adhesive resin cement (RelyX U200, 3M ESPE) showed lower bond strength values compared to the dual-curing resin cement (RelyX ARC, 3M ESPE), regardless of cementation timing. This finding may be associated with the lack of substrate pretreatment when using self-adhesive cements, which may result in lesser chemomechanical bond with the dentin and a reduced number of resin tags. The same result was observed by Mumcu et al., who attributed the higher bond strength values observed for dual-curing cements to the formation of micromechanical retention within the hybrid layer. On the other hand, some studies have reported high bond strength values using self-adhesive cements, which was explained by the formation of a strong micromechanical and chemical interaction with the hydroxyapatite due to dentin demineralization and consequent infiltration of acid monomers.

The variation in the results obtained between the resin cements also may partly be explained by factors that affect glass fiber post retention. The critical steps are the process of light curing and the high C factor of the post space, which increases tension on the bond interface. Another factor may be inadequate removal of root canal filling material, which will impair the adhesion of fiber posts to root dentin. The use of a clinical operative microscope for root canal preparation could allow complete removal of the filling material and consequently favor the longevity of the bond between glass fiber post and root dentin.

In the present study, the most common failure mode occurred between the cement and the root dentin, as observed by Mumcu et al., Zicari et al., and Pereira et al., justified by the fact that the resin interface is still a critical factor for intracanal post retention. Furthermore, cohesive failure in dentin was only observed when using the dual-curing cement, which can be explained by its higher bond strength values.

Therefore, when using an epoxy resin–based sealer, glass fiber post cementation with resin cements can be performed in the same clinical session as the root canal obturation, which may lead to an effective coronal seal and prevent further contamination of the root canal.

Conclusions

Regardless of root third and glass fiber post cementation timing, the dual-curing resin cement showed higher bond strength to root dentin when the canals were filled with epoxy resin–based cement.

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