

# Effect of Resin Cement System and Root Region on the Push-out Bond Strength of a Translucent Fiber Post

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## Clinical Relevance

The use of self-adhesive resin cements is an option for bonding fiber-reinforced composite posts to root canal dentin. Traditional resin cements apparently provide higher bond strengths than self-etch resin cements. Because of this, the bond strength of self-adhesive resin cements to root dentin should be evaluated.

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## SUMMARY

**Objectives:** This study evaluated the bond strength of luting systems for bonding glass fiber posts to root canal dentin. The hypothesis tested was that there are no differences in bond strength of glass fiber posts luted with different cement systems.

**Methods:** Forty bovine incisors were randomly assigned to five different resin cement groups (n=8). After endodontic treatment and crown removal, translucent glass fiber posts were bonded into the root canal using five different luting protocols (self-cured cement and etch-and-rinse adhesive system; dual-cured cement and etch-and-rinse adhesive system; self-cured cement and self-etch adhesive system; dual-cured cement and self-etch adhesive system; and dual-cured self-adhesive cement). Push-out bond strength was evaluated at three different radicular levels: cervical, middle,

and apical. The interface between resinous cement and the post was observed using a stereoscopic microscope.

**Results:** Analysis of variance showed a statistically significant difference among the cements ( $p < 0.05$ ) and the root canal thirds ( $p < 0.05$ ). The self-adhesive resinous cement had lower values of retention.

**Conclusions:** The resin cements used with etch-and-rinse and self-etch adhesive systems seem to be adequate for glass fiber post cementation.

## INTRODUCTION

Posts and cores are frequently used in endodontically treated teeth that have suffered excessive loss of coronal tooth structure.<sup>1,2</sup> The choice of materials used in these cases has changed from rigid materials, such as gold and zircon dioxide, to materials that have mechanical characteristics that more closely resemble dentin, such as fiber posts and composite resins.<sup>3,4</sup> Use of these materials diminishes the probability of root fracture, because these failures occur particularly in the post, allowing for tooth recovery.<sup>5</sup>

The bonding performance of resin cements is dependent on the quality of the hybrid layer.<sup>6-8</sup> Some factors such as dentin morphology, bonding system, and luting cement and its cure may interfere with hybrid layer formation along the root canal walls, affecting post retention.<sup>9,10</sup> This hybridization is critical in the apical third of the post space because of difficulty in establishing adhesion in this area.

Various luting agents have been proposed for bonding fiber-reinforced composite (FRC) posts to root canal dentin used with self-etching or etch-and-rinse adhesive systems.<sup>11,12</sup> In recent years, new resin cement formulas have been developed that have a self-adhesive capacity. These cements have the advantage of not requiring any dentin pretreatment.<sup>13</sup>

Thus, the aim of the current study was to evaluate the bond strength of luting systems for bonding glass fiber posts to root canal dentin. The null hypotheses tested were as follows: 1) there are no differences in bond strength among the different regions of a root canal, and 2) there are no differences in bond strength among different cement systems.

## METHODS AND MATERIALS

One-hundred forty freshly extracted bovine incisors with mature apices and without root curvature were utilized. A digital caliper was used to measure the

teeth at three root regions: cervical, middle, and apical, in both mesiodistal and buccolingual directions. Forty teeth with similar measurements were used.

For endodontic treatment, a step-back preparation technique was used with stainless steel K-files and #2 to #4 Gates-Glidden burs (Moyco Union Broach, York, PA, USA). All enlargement procedures were followed by irrigation with 1% sodium hypochlorite. Prepared root canals were then filled with gutta-percha cones using the lateral condensation technique and AH Plus resin sealer (Dentsply, York, PA, USA). Subsequently, the filled roots were stored in distilled water at 37°C for 48 hours.

After storage, root canals were prepared to ensure a standardized space for post insertion. The crowns were removed and the canal space of each root was enlarged with a #3 Gates-Glidden, providing access for a #3 post drill, using a low-speed handpiece, to a depth of 11 mm. During preparation of the canal, 5 mm of the endodontic filling was left at the apex of each canal. The roots were randomly divided into five experimental groups ( $n=8$ ). Double conicity translucent glass fiber posts (#3 White post DC, FGM, Joinville-SC-Brazil) and different resin cement systems were utilized in each group (Table 1).

In all groups, the posts were cleaned with 37% phosphoric acid for 60 seconds, followed by water-rinsing and air-drying. One coat of adhesive (Scotch Bond Multi-Purpose, 3M, St Paul, MN, USA) was applied, when necessary (only in Groups 1 and 2). To simulate clinical conditions, a wax protection barrier was applied to the external surface of the roots to prevent the passage of light.

For Groups 1 and 2, the root canal dentin was etched with 37% phosphoric acid for 15 seconds and rinsed for 30 seconds with water. After excess water was removed from the root canal with paper points, one layer of the "primer" was applied and gently air-dried for five seconds. Subsequently, the "adhesive" was applied, dried with paper points to remove the excess, and light-cured for 20 seconds with a halogen light-curing unit (Optilux 501, Kerr Co, Orange, CA, USA), with an intensity of 600 mW/cm<sup>2</sup>. One coat of "adhesive" was also applied onto the entire post surface and light-cured for 20 seconds.

For cementation of the glass fiber posts, equal quantities of resin cement agents, base and catalyst, were mixed and applied onto the post surface and into the root canal with a periodontal probe. The post was then inserted and cemented into the root canal with light finger pressure, and excess material was

Table 1: Groups and Composition of Luting Agents and Manufacturers			
Group	Material	Composition	Manufacturer
G1	C&B Cement	Bisphenol A diglycidylmethacrylate ethoxylated, Bisphenol A dimethacrylate silica glass frit, Bisphenol A diglycidylmethacrylate, triethyleneglycoldimethacrylate	Bisco
G2	Rely-X ARC	Silane-treated ceramic, triethylene glycol dimethacrylate (TEGDMA), Bisphenol A diglycidyl ether methacrylate (BISGMA), silane-treated silica, functionalized dimethacrylate polymer	3M
G3	Multilink	Pastes of dimethacrylates, hydroxyethyl methacrylate (HEMA), inorganic fillers, ytterbium trifluoride initiators, stabilizers and pigments, dimethacrylates, HEMA, benzoylperoxide	Ivoclar Vivadent
G4	Panavia F 2.0	Hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated barium glass filler, catalysts, accelerators, pigments, others, sodium fluoride	Kuraray
G5	Rely-X U100	Glass powder, methacrylated phosphoric acid esters, triethylene glycol dimethacrylate (TEGDMA), silane-treated silica, sodium persulfate, glass powder, substituted dimethacrylate, silane-treated silica, sodium <i>p</i> -toluene sulfinate, calcium hydroxide	3M

immediately removed. For the self-cured cement (Group 1) (C&B, Bisco Inc, Schaumburg, IL, USA), seven minutes was allowed for complete polymerization. For the dual-cured cement (Group 2) (Rely-X ARC, 3M), light activation was performed through the cervical portion of the root for 40 seconds at the buccal and lingual surfaces, totaling 80 seconds of light exposure.

For Group 3, the luting procedure was carried out with self-cured material (Multilink, Ivoclar Vivadent AG, Schaan, Liechtenstein). This material was applied with the self-etching and self-curing Multi-link Primer. Multilink Primer liquids A and B were mixed and applied in the root canal for 15 seconds and dried with paper points. The cement base and the catalyst were then mixed in a 1:1 volume ratio, and the same cementation procedure as already described for Group 1 was performed for this group.

For dual-cured cement used with the self-etch bonding system (Group 4) (Panavia F2.0, Kuraray Co, Ltd, Tokyo, Japan), self-etching and self-curing Primers A and B were mixed and applied into the root canal for 30 seconds and dried with paper points. The cement base and the catalyst were then mixed in a 1:1 volume ratio, and the same cementation procedure as was already described for Group 2 was performed.

Finally, for the self-adhesive resin cement (Group 5) (RelyX U100, 3M), dentin pretreatment was not

necessary. The cementation procedure was carried out as previously mentioned for Group 2.

After cementation procedures were performed, specimens were stored in distilled water for 24 hours at 37°C. After the storage period, specimens were sectioned using an Isomet 1000 digital cutting machine (Buehler, Lake Bluff, IL, USA). The roots were divided into three parts, 1 mm from the cervical surface. Three 1-mm thick slabs, each separated by a 3-mm space, were obtained per root and identified as cervical, middle, and apical sections. The thickness of each root section was verified with a digital caliper (Digimess Direct, São Paulo, Brazil).

Immediately after the slabs were obtained, they were positioned on a push-out jig (1-mm diameter), which was placed on the universal testing machine (MTS 810 Material Test System, MTS, Eden Prairie, MN, USA) with a cell load of 50 kg at a crosshead speed of 0.5 mm/min until post dislodgment.

The retentive strength of the post segment was expressed in MPa. Data were analyzed using analysis of variance (ANOVA) followed by the Tukey test at a 5% level of significance ( $p<0.05$ ) with GraphPad Prism 5 for Windows (GraphPad Software Inc, La Jolla, CA, USA) statistical software.

After push-out testing, the specimens were analyzed under stereoscopic microscopy to determine the failure mode<sup>14</sup>: type 1—adhesive between post and resin cement (no resin cement visible around the

Table 2: Means (Standard Deviation) of Push-out Bond Strength in MegaPascal (MPa)\*

Material	Region		
	Cervical	Middle	Apical
C&B Cement (G1)	9.5 (1.5) <sup>Aa</sup>	8.6 (2.7) <sup>Aa</sup>	7.7 (1.1) <sup>Aa</sup>
Rely-X ARC (G2)	11.8 (2.6) <sup>Aa</sup>	9.2(1.5) <sup>Aab</sup>	7.7 (1.6) <sup>Ab</sup>
Multilink (G3)	8.7 (2.0) <sup>Aa</sup>	8.3 (1.3) <sup>Aa</sup>	8.2 (0.8) <sup>Aa</sup>
Panavia F 2.0 (G4)	8.3 (0.7) <sup>Aab</sup>	10.2 (1.8) <sup>Aa</sup>	6.7 (1.3) <sup>Ab</sup>
Rely-X U100 (G5)	6.7 (1.2) <sup>Ba</sup>	6.6 (1.1) <sup>Ba</sup>	5.7 (2.7) <sup>Ba</sup>

\* Within each line, different lowercase letters mean statistically significant difference; within each column, different capital letters mean statistically significant difference ( $p < 0.05$ ).

post); type 2—mixed with resin cement covering 0 to 50% of the post surface; type 3—mixed with resin cement covering between 50% and 100% of the post surface; type 4—adhesive between resin cement and root canal (post enveloped by resin cement); and type 5—cohesive in dentin.

## RESULTS

Analysis of variance showed statistically significant differences among the cements ( $p < 0.05$ ) and the root region ( $p < 0.05$ ). Tukey test results are shown in Table 2.

No significant differences in bond strength were noted among groups G1 to G4. G5 (self-adhesive cement) showed statistically lower bond strength results. G2 (etch-and-rinse adhesive + dual-cured cement) demonstrated statistically lower bonding values in the apical region when compared with the cervical region. G4 (self-etching primer + dual-cured cement) had lower values in the apical third when compared with the middle third. G1 (etch-and-rinse adhesive + self-cured cement), G3 (self-etching primer + self-cured cement), and G5 (self-adhesive cement) had no significant differences along the root thirds.

The failure modes of the groups and root levels are presented in Table 3. No cohesive failure in dentin (type 5) was observed. A higher incidence of type 3 (53.3%) and type 4 failures (25%) was observed when compared with type 1 failure (6.7%). Type 2 failure was observed in 15% of cases.

Table 3: Failure Classification at Different Levels of the Root Canal

Group/Region	Type 1	Type 2	Type 3	Type 4	Type 5
G1					
Cervical	0	4	2	2	0
Middle	1	0	6	1	0
Apical	0	3	3	2	0
G2					
Cervical	0	1	4	3	0
Middle	1	1	4	2	0
Apical	0	4	2	2	0
G3					
Cervical	1	1	5	1	0
Middle	2	1	3	2	0
Apical	0	1	5	2	0
G4					
Cervical	1	0	7	0	0
Middle	0	1	6	1	0
Apical	1	0	5	2	0
G5					
Cervical	1	0	4	3	0
Middle	0	0	5	3	0
Apical	0	1	3	4	0
Total	8	18	64	30	0

## DISCUSSION

Shear bond strength depends on the degree and stability of interfacial micromechanical interlocking and chemical adhesion between the root canal dentin, the dentin bonding agent/resin-based luting

cement/silane coupling agent, and the fiber post.<sup>15</sup> Microtensile pull-out and push-out tests have been traditionally used to assess the retention of posts in the root canal.<sup>2</sup> The push-out test is based on shear stress at the interface between dentin and cement, as well as between post and cement.<sup>16</sup> In the present study, the push-out test was performed 24 hours after adhesive cementation procedures because bond strength can increase during this period.<sup>17</sup>

The first null hypothesis, that there is no retention strength difference among the different regions, has to be rejected. Current results demonstrate that RelyX ARC (dual-cured cement) showed lower values in the apical third when compared with the cervical region. This could possibly be explained by limited light access to this region, leading to defective polymerization of the material.<sup>18</sup> Previous studies have shown that the use of translucent glass fiber posts may minimize this problem.<sup>19,20</sup> However, an increase in the ability to transmit light was insignificant for obtaining an appropriate degree of conversion of the cement, particularly in the apical region.<sup>1,20</sup>

Evidence indicates that a low degree of conversion does not necessarily reduce post retention.<sup>21</sup> The C-factor (ratio of bonded to unbonded surface areas of cavities) is critical when higher than 5.<sup>22</sup> In a root canal, the C-factor is always critical.<sup>23,24</sup> Depending on the diameter and length of the canal, the C-factor can range from 20 to 100<sup>25</sup> and may even exceed 200,<sup>23</sup> representing an unfavorable clinical situation. Shrinkage stresses in the confined space of the intact root canal can exceed cement-dentin bond strength, causing debonding.<sup>23</sup> In the canal apical levels, a lower degree of conversion may be an advantage, as it provides lower shrinkage stress, thereby reducing the C-factor impact.<sup>26</sup> This can explain the similar results with dual-cured (Rely-X ARC and Panavia) and self-cured (C&B Cement and Multilink) cements, which previously revealed low shrinkage stress.<sup>23</sup>

Other factors, such as moisture control in the apical region,<sup>27</sup> the presence of residual gutta-percha, and incomplete dentin hybridization,<sup>28</sup> may result in deficient sealing of the resin cement-dentin interface in the apical third. Values obtained in the apical region with the etch-and-rinse adhesive, especially when the Rely-X ARC luting agent is employed, might be due to the fact that this adhesive requires more complex procedures, and that moisture control in the apical third is compromised.

The self-adhesive cement (Rely-X U100) showed lower bond strength than the other cements. Possi-

ble deficient hybridization of dentin along the root canal walls may explain the lower results for self-adhesive cement in all thirds. Thus, the second null hypothesis, that different cements systems have no effects on the retention of glass fiber posts in root dentin, was also rejected.

Rely-X U100 has limited etching potential when compared with etch-and-rinse and self-etching adhesive systems.<sup>11,29</sup> This could possibly be explained by the methacrylated phosphoric esters present in this cement, which are not as effective as phosphoric acid in dissolving the thick smear layer in the root canal walls during post space preparation.<sup>16,29</sup> Additionally, this cement exhibits a low degree of conversion, even after light curing.<sup>30</sup>

Simplified adhesive systems (etch-and-rinse two-step and one-step self-etch) are incompatible with self-cured and dual-cured resin cements. This occurs by the presence of acid resin monomers in the nonpolymerized adhesive residual layer caused by oxygen inhibition, which react with the tertiary amine of the resin cement.<sup>7,8</sup> Moreover, these adhesives promote a permeable hybrid layer, allowing water diffusion from the dentin and forming water droplets along the adhesive resin-cement interface.<sup>31</sup> For this reason, a three-step etch-and-rinse adhesive system was used in this current study.

One-step self-etch adhesives were used for Multilink and Panavia resin cements because they belong to these luting systems. Nevertheless, results with these cements did not differ statistically from those seen in Groups 1 and 2. For the Panavia resin cement, this may be explained by the fact that cement tertiary amines are consumed by simplified adhesive residual acid monomers. The results for Multilink cement were similar to other non-self-adhesive cements. This can be explained by the chemical curing system that reduces shrinkage stress and consequently decreases adhesive layer injuries.<sup>23</sup>

Some studies have reported that the main retention mechanism of posts in root canals is not adhesive but frictional.<sup>16,17</sup> In the present work, excellent post adaptation to the canal walls in all regions of the root was obtained. This post adaptation, besides improving the frictional mechanism, reduces the resin cement coating, which contributes to minimizing the effects of polymerization shrinkage.

## CONCLUSION

The use of resin cements to bond glass fiber posts is an attractive clinical concept. Results of this present study indicate that etch-and-rinse and self-etch

adhesive systems, when combined with resin cements, are good options for bonding glass fiber posts. Self-adhesive resin cements exhibited the lowest bond strengths to dentin. Moreover, the lowest bond strength was found in the apical third of the root canal spaces.

#### Conflict of Interest Declaration

The Authors of this manuscript certify that they have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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