Push-out Bond Strength of Glass Fiber Posts Cemented in Weakened Roots with Different Luting Agents

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ABSTRACT

Aim: To evaluate the push-out bond strength (BS) of direct anatomic posts (DAPs) and conventional fiber posts (CFPs) cemented with different luting agents in different thirds of flared root canals.

Materials and methods: A total of 60 human single-rooted canine teeth were transversally sectioned 16 mm from the radicular apex. After endodontic treatment, canals were flared with diamond burs. Samples were divided into six groups according to post type and luting agent: DAP and RelyX U100 (RXU); DAP and RelyX ARC (RXA); DAP and RelyX Luting 2 (RXL); CFP and RXU; CFP and RXA; CFP and RXL. Roots were sectioned transversely into six 1-mm-thick slices. The push-out test was performed and failure modes were observed.

Results: The DAP groups (7.23 ± 2.05) showed highest BS values (p < 0.05) when compared with CFP (5.93 ± 1.76). RelyX U100 (8.17 ± 1.70) showed higher BS values (p < 0.05) than RXA (6.46 ± 1.38), and RXL (5.10 ± 1.65) showed the lowest values. Bond strength on the apical third was statistically lower (p < 0.05) than that on the other thirds of the root canals. There was a predominance of adhesive failure for all groups.

Conclusion: The DAPs improved retention in flared root canals, and RXU was the most effective luting agent. The apical third showed the lowest BS values.

Clinical significance: The relining procedure of fiber posts with composite and the proper selection of luting resin cement are important for increasing bonding effectiveness in flared root canals.

Keywords: Dentin, Fiber posts, Push-out bond strength, Resin composite cements, Self-adhesive resin cements.

INTRODUCTION

Dental clinicians frequently need to make decisions regarding which intraradicular retainers and filling cores to use to retain the final restorations in endodontically treated teeth with severe structural damage. This situation occurs due to caries, iatrogenic misadventures, overprepared teeth, fractures, open apices, or internal resorption. These flared root canals with thin dentin walls may require reinforcement and restoration using materials with a modulus of elasticity similar to that of dentin, resulting in biomimetic between the properties of post, luting cement, and dentin. Fiber posts have an elastic modulus that is similar to that of dentin and are believed to distribute stress more evenly in the tooth structure, making the root less susceptible to fracture. Fiber posts can be luted either conventionally or adhesively. Self-adhesive luted fiber posts in postendodontic restorations have resulted in high long-term survival rates.

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Despite the advantages presented above for using fiber posts, discrepancy between the diameters of post space in severely damaged endodontically treated teeth and posts can compromise the overall success of the restorative procedure, and prefabricated fiber posts do not fit well into flared canals. In such cases, if the post does not fit well, the layer of resin cement may be excessively thick, thus favoring the formation of voids and predisposing the post to debonding. The post increases its adaptation to the root walls and reduces the thickness of the resin cement. The improved contact between the post and the canal walls may also reduce dependence on the bonding for retention. It has been shown that cements with lower bonding potential, but having other favorable mechanical properties, may be useful in luting relined fiber posts.

Furthermore, retention of adhesively bonded conventional fiber posts (CFPs) to root walls is compromised by many factors, such as post type and post adaptation, type of adhesive and cementation system, heterogeneity of the substrate, and depth-of-cure in different root canal thirds.

The aim of this study was to assess the effect of fiber posts relined with resin composite, and cement type used for luting, on the push-out bond strength (BS) of fiber posts luted to the cervical, middle, and apical thirds of different root canal thirds.

The specimens were stored at 100% humidity for at least 72 hours to allow for the resin sealer to set. After the storage period, a 9-mm-deep post space was prepared in the root canal with Gates-Glidden drill #5. The roots were embedded in acrylic resin blocks in order to obtain parallelism between post space preparation and resin block. To obtain a standardized flared canal, the canal walls were enlarged using #4138 and #4137 high-speed diamond burs (KG Sorensen, São Paulo, Brazil) up to 9 mm from the root canal orifice.

**Bonding Fiber Posts to Root Canals**

The roots were randomly assigned to the following two major experimental groups (n = 30) to test the effect of post type:

1. Direct anatomic post – 1.5 mm diameter glass fiber-reinforced epoxy post system (Reforpost; Angelus, Londrina, Brazil) relined with resin composite (Filtek P60, 3M ESPE, St Paul, Minnesota, USA) with 95% ethanol. A single layer of silane coupling agent (RelyX Ceramic Primer) was applied to the post surface. The Adper Single Bond 2 (ASB2) adhesive system (3M ESPE, St Paul, Minnesota, USA) was applied and light cured. The canal walls were lubricated with a hydrophilic gel; the fiber post was covered with the resin composite and inserted into the canal. The resin composite was light cured for 20 seconds, the relined fiber post was removed, and the resin composite was light cured for an additional 20 seconds. Copious rinsing removed the lubricant gel from the root canal and relined post.

2. Conventional fiber post – 1.5 mm diameter glass fiber post system (Reforpost). The posts were cleaned with 95% ethanol, and a single layer of silane coupling agent (RelyX Ceramic Primer) was applied to the post surface, followed by the adhesive system (ASB2), with further light curing.

For each post type, the specimens were further divided (n = 10) with respect to the luting agent used: a self-adhesive resin cement (RelyX U100, RXU, 3M ESPE); a resin cement (RelyX ARC, RXA, 3M ESPE); a resin-modified glass ionomer cement (RelyX Luting 2, RXL, 3M ESPE). The handling of cements and the dentin pre-treatment, where applicable, were performed in accordance with the manufacturers’ instructions and are summarized in Table 1.

**Materials and Methods**

**Teeth Selection and Preparation**

This study was approved by the local Research Ethics Committee (Project Registration 122/12). A total of 60 extracted human maxillary canine teeth with straight root canals were used. The crown of each tooth was removed to obtain a root height of 16 mm using a high-speed diamond saw (Isomet, Buehler, Lake Bluff, Illinois, USA). For the endodontic treatment, the working length was established 1 mm short of the apex, and a step-back preparation technique was used with stainless steel K-files sizes 25 to 55, and Gates-Glidden drills #2 to #4 (Dentsply TulsaDental, Tulsa, Oklahoma, USA). Each canal was irrigated with 2.5% sodium hypochlorite, dried with paper points, and obturated with gutta-percha cones by using the lateral condensation technique and Sealer-26 (Dentsply Ind. e Com. Ltda., Petrópolis, RJ, Brazil).
The Journal of Contemporary Dental Practice, February 2016;17(2):119-124

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Buehler Ltd., Lake Bluff, Illinois, USA). Two slices were obtained from each root third (i.e., apical, middle, and coronal) of the post space preparation. Push-out tests were conducted placing each slice in a universal testing machine (Instron 4411; Instron, Canton, Massachusetts, USA) with the apical surface facing the punch tip. A compressive load was applied to the root section via a 1-mm diameter cylindrical punch at a crosshead speed of 0.5 mm/min until failure. The punch tip was positioned so that it only contacted the post on loading. Bond strength (MPa) was calculated by dividing the maximum failure load (N) by the area (mm²) of the post-dentin interface.19

Failure Mode

After the push-out testing, specimens were analyzed by stereoscopic microscope (Olympus SZ 6045 TR Zoom Stereomicroscope; Olympus Optical Co, Tokyo, Japan) at 40× magnification to determine the failure mode. The type of failures were categorized as type I, adhesive between dentin and resin cement; type II, adhesive between resin cement and post; type III, cohesive within dentin; type IV, cohesive within cement; type V, cohesive within post; type VI, mixed failures. After debonding, representative specimens were mounted on aluminum stubs, gold sputter-coated, and observed by scanning electron microscopy (SEM) to illustrate failure modes.

Statistical Analysis

Data were analyzed using three-way analysis of variance and the Tukey test for post hoc comparisons (α = 0.05).

RESULTS

The statistical analysis revealed significant differences for post type (p < 0.0001), cement type (p < 0.0001), and root third (p < 0.0001) factors. On the contrary, there was no significant effect for any interaction between the factors (p > 0.05). The push-out BS was significantly higher for the DAP, and among luting agents RXU resulted in statistically greater BS than RXA, which was stronger than RXL (Table 2). For each post, the apical third (5.77 ± 2.07) resulted in statistically lower BSs than the cervical (6.98 ± 1.97) and middle (6.98 ± 1.78) thirds (Table 3). The cervical third and the middle third did not show statistically significant different BSs at p > 0.05. The results of failure types are presented in Table 4. Type I category was the most frequent failure mode for both post types (52% for DAP and 51% for CFP), followed by type VI failure (22% for DAP and 34% for CFP). For DAP groups, the type II failure mode was the third most
frequent failure type (16%), and the remaining 10% of failures were in categories 3, 4, or 5 (cohesive failures).

Table 4: Description of failure types observed by stereoscopic microscope at 40× magnification

<table>
<thead>
<tr>
<th>Post type</th>
<th>Cement type</th>
<th>Type I (%)</th>
<th>Type II (%)</th>
<th>Type III (%)</th>
<th>Type IV (%)</th>
<th>Type V (%)</th>
<th>Type VI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAP</td>
<td>RelyX U100</td>
<td>41.7</td>
<td>0.0</td>
<td>1.7</td>
<td>0.0</td>
<td>18.3</td>
<td>38.3</td>
</tr>
<tr>
<td></td>
<td>RelyX ARC</td>
<td>75.0</td>
<td>8.3</td>
<td>0.0</td>
<td>1.7</td>
<td>17.0</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>RelyX Luting 2</td>
<td>40.0</td>
<td>40.0</td>
<td>0.0</td>
<td>5.0</td>
<td>0.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>52.2</td>
<td>16.1</td>
<td>0.6</td>
<td>2.2</td>
<td>6.7</td>
<td>22.2</td>
</tr>
<tr>
<td>CFP</td>
<td>RelyX U100</td>
<td>61.7</td>
<td>0.0</td>
<td>0.0</td>
<td>8.3</td>
<td>3.3</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>RelyX ARC</td>
<td>76.7</td>
<td>5.0</td>
<td>0.0</td>
<td>5.0</td>
<td>0.0</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>RelyX Luting 2</td>
<td>13.3</td>
<td>3.3</td>
<td>0.0</td>
<td>21.7</td>
<td>0.0</td>
<td>61.7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>50.6</td>
<td>2.8</td>
<td>0.0</td>
<td>11.6</td>
<td>1.1</td>
<td>33.9</td>
</tr>
<tr>
<td>General total</td>
<td></td>
<td>51.4</td>
<td>9.4</td>
<td>0.3</td>
<td>6.9</td>
<td>3.9</td>
<td>28.1</td>
</tr>
</tbody>
</table>

Failure types: type I: Adhesive between dentin and resin cement; type II: Adhesive between resin cement and post; type III: Cohesive within dentin; type IV: Cohesive within cement; type V: Cohesive within post; type VI: Mixed failures; DAP: Direct anatomic post; CFP: Conventional fiber post.

On the contrary, for CFP groups, the third most frequent failure mode was type IV (12%), and the remaining categories represented 3% of the failure modes detected. The most frequent failure modes observed are illustrated by SEM images in Figs 1A to D.

**DISCUSSION**

In the present study, the use of DAP and self-adhesive resin cement improved fiber post retention at all evaluated root canal thirds. Thus, the null hypothesis was rejected. The main purpose of relining a post with resin composite is to reduce the cement layer thickness. This technique can reduce the negative effects of a large volume of resin cement and it also promotes an effective improvement in the mechanical retention of fiber posts. Some studies reported that the main mechanism of retention of posts to the root canal is not adhesion, but frictional retention. Since friction occurs by contact, posts that promote a closer contact with dentine tend to have higher retention forces. The results of this study...
corroborate the above-mentioned findings, since they showed a significant increase in the push-out BS for DAPs regardless of the root region and cement type.

Post retention is also affected by the formation of blisters in the cement-adhesive layer\textsuperscript{13} that can act as flaw-initiating sites, interfering with the BS.\textsuperscript{10} Apparently, the application of sustained pressure during cementation reduces blister formation.\textsuperscript{24} Refined fiber posts present a more intimate contact with the root canal walls.\textsuperscript{5} Better post adaptation increases pressure at the dentin-cement interface, which can suppress blister formation, resulting in better contact between the cement/post set and dentin.\textsuperscript{1} This could explain the highest results of the DAP groups, since the best adaptation of these posts generates increased sustained pressure during cementation, providing an enhanced interaction between luting agent and dentin. Reducing the cement layer thickness also helps to minimize the effects of polymerization shrinkage, which can lead to loss of retention,\textsuperscript{22,25} since the development of polymerization stress increases as the volume of resin cement is increased.\textsuperscript{2,3}

The retention in the apical third was significantly lower regardless of the type of fiber post used. This result can be attributed to the heterogeneity of the substrate\textsuperscript{16,18,19,26} and the difficulty in accessing the apical third.\textsuperscript{13} After post space preparation, residual gutta-percha, sealer, and excess moisture may remain in the apical third,\textsuperscript{7,27} which could lead to bond loss.\textsuperscript{28} In addition, reduction in the amount of light transmitted into the root canal as the depth increases\textsuperscript{17} may play a role.\textsuperscript{29} Pereira et al\textsuperscript{30} evaluated the elastic module, Vickers hardness, and push-out BS for RXA and RelyX Unicem in different root thirds and demonstrated that those properties decreased from coronal to apical region.

The self-adhesive resin cement RXU showed significantly better results than the conventional dual-cured resin cement RXA. The RXU cement presents a higher amount of inorganic fillers by wt\% than RXA.\textsuperscript{31} The increased amount of inorganic filler content reduces the resin matrix/filler ratio, which leads to less polymerization shrinkage and improved mechanical properties.\textsuperscript{15} In addition, the composition of the self-adhesive cement contains phosphoric acid methacrylate.\textsuperscript{1} The neutralization reaction of this acid during the polymerization process forms water and may also be responsible for this cement’s higher tolerance to moisture.\textsuperscript{13,30} The RXU interacts with the substrate micromechanically and chemically with hydroxyapatite.\textsuperscript{15,29} Furthermore, the self-adhesive resin cement appears to exhibit less shrinkage due to its viscoelastic properties, leading to a better contact of cement to root canal walls, which generates higher frictional retention.\textsuperscript{1}

RelyX ARC showed statistically lower results than self-adhesive cement. This cement depends on the prior application of an adhesive system. In this study, a total-etch simplified adhesive system was used. Previous studies have reported the incompatibility of these systems and dual-cure resin cements.\textsuperscript{11,15} This might occur due to the presence of acid resin monomers in the nonpolymerized adhesive residual layer, caused by oxygen inhibition, that react with the tertiary amine of the resin cement.\textsuperscript{26} This interaction does not allow for an adequate polymerization of the resin cement to occur and reduces the BS of the adhesive system.\textsuperscript{7,26}

In addition, these types of adhesive systems behave as semipermeable membranes due to the absence of a more hydrophobic resin layer.\textsuperscript{10,17} Thus, the transudation of dentinal fluid through these simplified adhesives has been observed, and can generate a negative interference in adequate polymerization of the resin cement.\textsuperscript{11,13} The presence of water at the adhesive interface reduces the contact area between cement and root canal walls,\textsuperscript{1} which could result in lower retention in the push-out test.

The lowest results, observed for the resin-modified glass ionomer cement, RXL, mostly for CFPs, may be related to its low cohesive strength because this cement exhibits inferior mechanical properties when compared with resin cements.\textsuperscript{16} The results can also be associated with the lack of a prior acid conditioning to modify or remove the smear layer within the canal prior to cementing, which may have interfered in the chemical bonding of the cement.\textsuperscript{10} Thus, the retention provided by RXL may be more related to frictional retention than bonding to dentin walls.\textsuperscript{14}

Evaluation of the failure modes showed that most of the failures for all the groups occurred between dentin and cement, which is in accordance with other studies,\textsuperscript{6,8,19,20,30} followed by mixed failures. This suggests that the weaker link was located at the dentin-cement interface.\textsuperscript{27} In DAP groups, the failures between post and cement represented the third most common type of failure, indicating a decrease of the bond between these two substrates. On the other hand, for the CFPs, cohesive failures in cement were also common, and can be explained by the large volume of cement generating stress concentration in these materials, making retention more dependent on the mechanical properties of the cement used.

**CONCLUSION**

It can be concluded that the DAPs improved retention in flared root canals and that RXU cement was the most effective luting agent. The apical third of the root canal showed the lowest BS values.
CLINICAL SIGNIFICANCE

The reline procedure of fiber posts with composite and the proper selection of luting resin cement are important for increasing bonding effectiveness in flared root canals.

REFERENCES