Effect of the activation mode of post adhesive cementation on push-out bond strength to root canal dentin

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Objective: To evaluate the effect of the activation mode of adhesive cementation on push-out bond strength of fiber-reinforced resin posts to root canal dentin. **Method and Materials:** Forty mandibular premolars were endodontically treated and randomly divided into 4 equal groups. In groups G-1, G-2, and G-3, Single Bond (3M Espe) was applied and light polymerized for 20 seconds; in group G-4, Scotchbond Multi-Purpose Plus (3M Espe) was used as an autopolymerized adhesive. The dual-cure resin cement Rely X ARC (3M Espe) was light polymerized in G-2 and G-3 but not in G-1 and G-4. The translucent post Light-Post (Bisco) was used in G-3 and the opaque post Aestheti-Plus (Bisco) in the other groups. The roots were sectioned in 3 parts (cervical, middle, apical); each slice was submitted to the push-out test at a crosshead speed of 0.5 mm/min. Data were analyzed by analysis of variance and Tukey test (α = .05). **Results:** Light polymerization of both the adhesive and resin cement in G-2 led to significantly higher bond strength than in G-1, where only the adhesive was light polymerized. No difference was found between G-2 (opaque post) and G-3 (translucent post). The autopolymerized adhesive showed the highest bond strength in all root regions. The middle and apical post/root regions had similar bond strength, but it was significantly lower than that in the cervical region (P < .001). **Conclusion:** Bond strength to root dentin varied as a function of the activation mode of post adhesive cementation and post/root regions. *(Quintessence Int 2007;38:387–394)*

Key words: adhesive systems, fiber-reinforced resin post, push-out bond strength

The use of root canal posts is a routine clinical procedure, yet several concepts still are controversial. For many years, cast metal posts were believed to reinforce pulpless teeth,[1] but the present viewpoint is that they serve only as an anchor for the future restoration.[2,3] The development of fiber-reinforced resin posts with mechanical properties similar to dentin characteristics reduced the stress transmitted to the tooth and the risk for root fracture.[4,5]

Because information on adhesion to root canal dentin is limited, knowledge of the dentin structure and the efficacy of adhesive systems is fundamental for the success of

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bonding procedures inside the root canal. Mjor and Nordahl[6] observed in scanning electron microscopy (SEM) that the number of dentinal tubules in the middle of the root is lower than in the middle of the crown. Ferrari et al[7] also reported variation of tubule density among the root canal regions; and, after acid conditioning, the surface available for adhesion increased in 202% at the cervical region, 156% at the middle region, and 113% at the apical region. The diameter of the tubules also was modified after acid conditioning in the cervical, middle, and apical regions. When fiber posts were cemented, the hybrid layer was thicker at the cervical region, which suggests that bond strength is proportional to tubule density. The apical region also showed a thinner hybrid layer than the cervical and middle regions, probably because of the smaller area of tubules.

The mechanism of adhesive systems is based on removal or modification of the smear layer, demineralization of the surface dentin, and its permeation by a hydrophilic bifunctional monomer to form the hybrid layer.[8] In root canal dentin, adhesion may also be affected by root canal geometry, which is responsible for its high configuration factor (C-factor), ie, a high force of resin cement contraction opposite to the cavity walls competing with the bond strength of the adhesive area.[9,10] Furthermore, the use of irrigation solutions with sodium hypochlorite and endodontic cements with eugenol may interfere with the bond strength to dentin.[11,12]

Many combinations of different adhesive systems and resin cements can be used.[10] One-bottle adhesives have been indicated for adhesive procedures inside the root canal, but the resulting adhesion quality is uncertain because of the difficult light access to provide complete polymerization. Ferrari and Mannocci[13] showed that a one-bottle adhesive was efficient to form a hybrid layer in root canal dentin in vivo, but better qualities of hybrid layer and resin tags were achieved with autopolymerized adhesives.[14,15] Translucent posts, with the capacity to transmit light through their fibers, allow polymerization by the light source positioned at the canal entrance and by a second light polymerization through the post. However, it still is unclear if this double light polymerization improves the efficacy of adhesive procedures in root canal dentin.

This study evaluated the push-out bond strength to root canal dentin of fiber-reinforced resin posts cemented with Single Bond or Scotchbond Multi-Purpose Plus adhesives (3M Espe) and the dual resin cement Rely X ARC (3M Espe) polymerized by different modes. The a priori null hypotheses were: *(1)* There is no difference in bond strength between the light and self-polymerization of adhesives/resin cement for fiber post cementation; *(2)* the type of post, translucent or opaque, does not affect bond strength; and *(3)* there is no difference in bond strength among the post/root regions (cervical, middle, apical).

METHOD AND MATERIALS

Forty sound human mandibular premolars, extracted for orthodontic or periodontal reasons, were selected according to similar external dimensions and internal anatomy. They were endodontically treated with lateral condensation of gutta-percha and sealed with a zinc oxide and eugenol-based cement (Odahcam, Herpo Produtos Dentários). The crowns were removed 1 mm above the cementoenamel junction (CEJ), and the roots were randomly assigned to 4 groups (n = 10 per group) according to post cementation procedures. The fiber-reinforced resin posts Aestheti-Plus (opaque) (Bisco) and Light-Post (translucent) (Bisco), with similar shape (No. 2, 1.8-mm-diameter, 1.2-mm-diameter at the apical third), were used.

The root canal was prepared using the sequence of mandrels from the post kits to a depth of 10 mm, under water cooling. All roots were embedded in silicone blocks to avoid the light access from the outer root walls and to facilitate manipulation during the post cementation procedures. The posts were conditioned, washed, and dried according to the manufacturer's instructions. One coat of the adhesive agent was applied on the posts and light polymerized with the Optilux light unit (Demetron Research), cali-

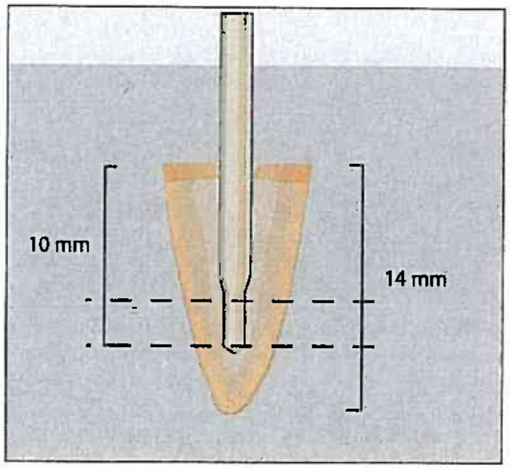

Fig 1 Positioning of the fiber-reinforced resin post inside the root canal.

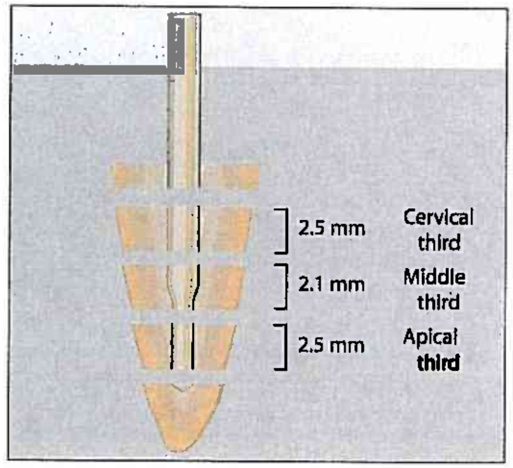

Fig 2 Sectioning of the post in 3 slices (cervical, middle, and apical) for the push-out bond strength test.

Table 1 Experimental groups, materials, and mode of polymerization

Group	Post	Adhesive system	Resin cement
G-1	Aestheti-Plus (opaque)	Single Bond (light polymerized)	Rely X ARC (self-polymerized)
G-2	Aestheti-Plus (opaque)	Single Bond (light polymerized)	Rely X ARC (light polymerized)
G-3	Light-Post (translucent)	Single Bond (light polymerized)	Rely X ARC (light polymerized)
G-4	Aestheti-Plus (opaque)	Scotchbond Multi-Purpose Plus (self-polymerized)	Rely X ARC (self-polymerized)

brated at 450 to 500 mW/cm^2. The root canals were washed with water spray and dried with suction and paper points before and after acid conditioning with 37% phosphoric acid (3M Espe) for 15 seconds.

For group G-1, the one-bottle adhesive Single Bond was applied inside the root canal with a disposable microbrush, excess material was removed after 20 seconds with paper points, and the adhesive was light polymerized for 20 seconds with the light source positioned at the canal entrance. The dual resin cement Rely X ARC, shade A3, was applied with a lentulo, and the Aestheti-Plus fiber post was inserted into the canal (Fig 1). The resin cement was polymerized only by chemical reaction. For group G-2, the procedures were the same as for group G-1, but the resin cement was light polymerized for 40 seconds with the light unit positioned at the entrance of the canal (manufacturer's recommendations). For group G-3, the translucent post Light-Post was used according to the procedures of G-2, which allowed transmission of the light through the post in this group. In group G-4 (control group), the 3-step adhesive Scotchbond Multi-Purpose Plus was used with no light polymerization, and post cementation followed the procedures in G-1 (Table 1).

After storage in distilled water at 37°C for 7 days, the roots were sectioned perpendicular to their long axis in slices 2.2 to 2.5 mm thick using a diamond-wafering blade (South Bay Technology) in a low-speed saw (Isomet 1000, Buehler) under water cooling. Three slices were obtained: 1 slice from the cervical third of the post (approximately 1 mm below the CEJ), 1 from the middle third, and another from the apical third (Fig 2).

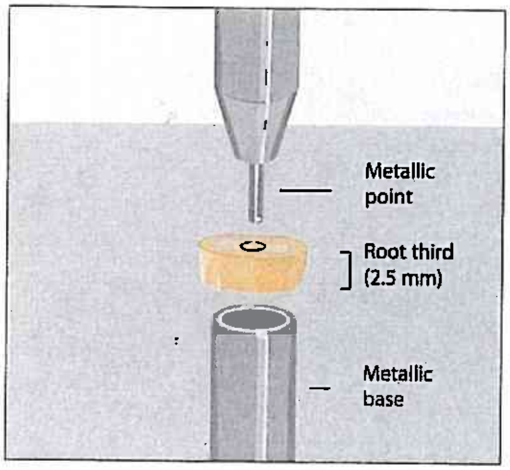

Fig 3a Positioning of the specimen for the push-out bond strength test.

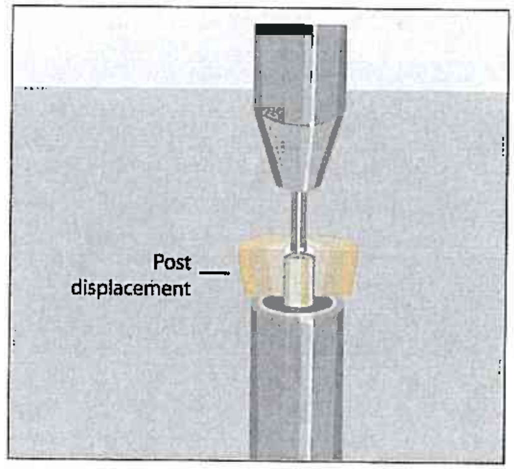

Fig 3b Displacement of the fiber-reinforced resin post from the root canal during the test.

For the push-out test, the specimens were mounted in a customized device (a stainless steel base with a 2.5-mm-diameter central orifice) fixed to the lower part of an Instron 4444 universal testing machine (Instron). The post cemented into the root canal was positioned exactly in the same direction as the central orifice. The coronal side of each root slice was positioned in contact with the base. The metallic test point (1.0-mm-diameter) was attached to the upper part of the universal machine and centralized in relation to the fiber-reinforced resin post (Figs 3a and 3b). No adhesive material was used to fix the dental slice to prevent contamination of the base at the tooth-post interface area, which could have influenced the results. The push-out strength test was performed at a crosshead speed of 0.5 mm/min until dislodgment of the post.

The adhesive surface area of each specimen was individually measured to calculate the bond strength value. The force necessary to dislodge the post was recorded in newtons. Bond strength values (megapascals) were calculated by dividing the force at which bond failure occurred by the bonded area of the post in square millimeters. The internal area of the adhesive interface was computed using the following equations:

1. For the cervical and apical third slices: $\pi \times h \times (2 \times R)$ (cylindrical shape)
2. For the middle third slices: $\pi \times h \times (R + r)$ (tapered shape)

where π = constant = 3.1416, h = height of the root slice, R = largest radius (radius of the thickest portion of the post = 0.9 mm), and r = smallest radius (radius of the thinnest portion of the post = 0.6 mm).

For statistical analysis, the independent variables were "cementation techniques" (experimental groups of post adhesive cementation) and "post/root regions" (cervical, middle, apical). Bond strength data (megapascals) were analyzed by 2-way analysis of variance (ANOVA) and Tukey test, at the significance level of .05.

RESULTS

Table 2 displays the bond strength values for the experimental groups (cementation techniques) in the 3 post/root regions. Significant variation was found among groups ($P < .001$) and post regions ($P < .001$), but there was no interaction between these 2 factors ($P = .227$). The lowest bond strength was recorded

Table 2 **Mean (SD) push-out bond strength (MPa) of the experimental groups at the 3 post regions**

	Apical	Middle	Cervical	Total
G-1	1.18 (1.84)	0.69 (1.45)	7.29 (5.79)	3.05 (4.63)
G-2	3.01 (3.61)	2.41 (3.41)	10.87 (3.67)	5.43 (5.21)
G-3	2.79 (4.73)	3.79 (1.52)	9.78 (2.10)	5.45 (4.34)
G-4	8.06 (3.17)	9.99 (4.40)	12.45 (2.94)	10.17 (3.89)
Total	3.76 (4.26)	4.22 (4.57)	10.09 (4.18)	6.03 (5.18)

See Table 1 for a description of the groups.

Table 3 **Comparison of the variation of bond strength (MPa) as a function of the cementation technique (Tukey test)**

Comparisons 1 × 2	Mean 1	Mean 2	*P* value
G-1 × G-2	3.05	5.43	.045
G-1 × G-3	3.05	5.45	.042
G-1 × G-4	3.05	10.17	< .001
G-2 × G-3	5.43	5.45	.999
G-2 × G-4	5.43	10.17	< .001
G-3 × G-4	5.45	10.17	< .001

See Table 1 for a description of the groups

Table 4 **Comparison of the variation of bond strength (MPa) as a function of the post region (Tukey test)**

Comparisons 1 × 2	Mean 1	Mean 2	*P* value
Apical × middle	3.76	4.22	.825
Apical × cervical	3.76	10.09	< .001
Middle × cervical	4.22	10.09	< .001

when light-polymerized Single Bond was used, and the highest value was observed with the self-polymerized adhesive Scotchbond Multi-Purpose Plus (see Table 2). No improvement of bond strength was found with light polymerization of the resin cement through the translucent post (Table 3).

Bond strength was higher at the cervical post region for all groups, but no statistically significant difference was found between the middle and apical regions (Table 4).

DISCUSSION

This study showed that the self-polymerized adhesive had a higher bond strength to root canal dentin compared with the light-polymerized adhesive. The double light polymerization of Single Bond adhesive and Rely X ARC cement using the translucent Light-Post did not increase bond strength. Furthermore, bond strength was higher at the cervical post/root region than at the middle and apical thirds.

Previous studies tested adhesion efficacy to root canal dentin using traditional shear and tensile strength tests, SEM, and microtensile and push-out tests.[10,16,17] The push-out test uses smaller areas than the traditional shear test and allows the development of more uniform shear forces with no tensile component,[18] producing strains directed to the adhesive interface. Another advantage is that it is possible to measure bond strength in different root regions.

Adhesion to root canal dentin is a viable procedure,[7,9,13-16] but structural differences exist between coronal and radicular dentin,[6] particularly in the apical third of the root.[19] In our study, the highest bond strength was recorded in the cervical region, and no difference was found between the middle and apical thirds. Perdigão et al[20] evaluated the effect of luting systems and root region on the push-out bond strengths of a glass fiber–reinforced resin post and a zirconia post and found that means for the cervical region (6.2 MPa) were higher than those for the apical region (4.5 MPa), but the middle third was not different from the others. In SEM observations, others reported that the cervical region had better formation of hybrid layer and resin tags than the other regions.[7,14] Furthermore, the root regions do not respond equally to acid conditioning,[13,21] exhibiting a layer of resin infiltrated in the root dentin that is thinner than in the coronal dentin,[22] and, consequently, lower bond strength.[23]

These substrate-related factors may help to explain the low bond strength values recorded in our study compared to bond strength in coronal dentin. According to Diaz-Arnold et al,[9] besides the structural differences of root canal dentin, this substrate has another obstacle to adhesion—a high C-factor. Bouillaget et al[10] tested the effect of C-factor in intact and sectioned roots and found that microtensile bond strength was lower in intact roots (5.3 MPa) than in sectioned roots (23.2 MPa). This suggests that, although good adhesion can be achieved, the root canal geometry may have a fundamental role in the reduction of bond strength.

Light-Post and Aestheti-Plus posts are made of unidirectional quartz fibers embedded in an epoxy resin matrix. Both are passive posts with similar shape and composition, and they are indicated for adhesive cementation. Light-Post is translucent and allows light polymerization of the adhesive and resin cement inside the root canal. However, we found no difference of bond strength between the groups with Aestheti-Plus (5.43 MPa) and Light-Post (5.45 MPa), suggesting that the use of translucent posts did not increase bond strength to root canal dentin. Similarly, Mallmann et al[24] found no difference of bond strength between Aestheti-Post (7.47 MPa) and Light-Post (7.80 MPa) groups.

To evaluate the effect of light polymerization of resin cement on bond strength, we compared group G-1, where only the adhesive was light polymerized at the canal entrance, with group G-2, where both the adhesive and resin cement were light polymerized. Group G-1 showed significantly lower bond strength (3.05 MPa) than G-2 (5.43 MPa). Similar results were reported by Witzel et al[25] using these same adhesives and cement in bovine teeth. Thus, light polymerization of resin cement seems to improve its polymerization and adhesion to root canal dentin.

We found that Scotchbond Multi-Purpose Plus had superior adhesion for all root regions, but the cervical third was not statistically different from the Single Bond groups. Vichi et al[15] compared the same adhesives and observed that the 3-step system had a higher percentage of hybrid layer and better morphology of resin tags than the 1-bottle adhesive, except for the cervical region where no difference was detected. This pattern also was reported for other materials, such as the chemically polymerized adhesive Excite DC (Ivoclar Vivodent) and the light-polymerized adhesives Excite (Ivoclar Vivadent) and One Step (Bisco).[7,14]

Scotchbond Multi-Purpose Plus showed good adhesion in all root regions, but the values were balanced among the 3 parts. For Single Bond, good adhesion was found in the cervical region, where the light access is direct, but bond strength in the middle and apical regions was very low, independent of using the translucent post. The possible causes of low bond strength for Single Bond in the middle and apical regions may be attributed to *(1)* absence of light penetration in deeper regions of the root canal; *(2)* presence of residual eugenol from the endodontic cement, which may have inhibited complete polymerization of the resin composite; and *(3)* a combination of these 2 factors.

Mallmann et al[24] observed similar bond strength among root regions using the same materials we studied, but their specimens had no endodontic treatment, and ours were sealed with eugenol-based cement. This topic is controversial, because some studies indicate that root canal irrigation with alcohol or dentin conditioning with phosphoric acid removes the residual eugenol and restores retention,[26,27] while others found negative results.[11,12,28] Kurtz et al[29] found no effect of eugenol-containing sealer on push-out bond strength of adhesive systems to root canal dentin.

Mayer et al[11] also observed significant reduction of tensile bond strength in roots sealed with eugenol-based endodontic cement when a 1-bottle adhesive was used, but the performance of a 3-step adhesive was not affected. This suggests that eugenol may have a selective effect on adhesives or adhesive procedures and may explain the differences between the behavior of Single Bond and Scotchbond Multi-Purpose Plus in our study. In Single Bond groups, the light-polymerized adhesive seems to be more sensitive to substrate alterations, such as presence of residual eugenol, especially in deeper regions inaccessible to the polymerization light. In these areas, polymerization is slower and depends on the chemical activation of the cement. However, in G-4 the catalyst of Scotchbond Multi-Purpose Plus adhesive may have reduced the polymerization time inside the root canal and provided a higher monomer conversion rate.

One limitation of this study is the fact that we tested the cementation activation mode in an immediate bond strength test, in contrast with studies that used artificial aging simulating a clinical condition. Artificial aging by long-term water storage and thermal or mechanical cycling is an attempt to simulate the oral environment that potentially increases material degradation and shortens the clinical life of the material. However, previous push-out studies have shown that fatigue testing by dynamic cycling has not affected the cement layer in prefabricated posts cemented with resin cement.[30,31] On the other hand, the flexure strength of fiber-reinforced resin posts decreased approximately 11% to 24% after thermal cycling.[32] It is possible that artificial aging would have some deleterious effect on bond strength of our experimental groups, and this should be addressed in the future.

Adhesive procedures are technically sensitive, and the root canal environment is subjected to a number of variables that may directly affect bond strength. The use of light-polymerized adhesives for root canal cementation is not a consensus. Although some good results have been reported in the literature, our data indicate caution for its indication, particularly when the teeth were endodontically treated with eugenol-based cement. Light is indicated for polymerization of some adhesives and resin cements, but it was not sufficient to completely polymerize the adhesive/cement in the middle and apical root thirds. Further studies are warranted to determine the efficacy of light-polymerized adhesives and resin cements for root canal cementation under other conditions, such as teeth endodontically treated with eugenol-free cements, other adhesive materials and posts, longer light exposures, high output light of the curing unit (eg, argon laser), and extensive loss of root canal dentin requiring intraradicular reinforcement.

CONCLUSION

The results of this study suggest that bond strength to root dentin varies as a function of the activation mode of post adhesive cementation and post/root regions:

1. The 3-step self-polymerized adhesive Scotchbond Multi-Purpose Plus demonstrated the highest bond strength.
2. The use of the translucent post Light-Post, did not affect the bond strength to root canal dentin compared with the opaque Aestheti-Plus post.
3. The cervical post/root region showed the highest bond strength for all adhesive systems.

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