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An *In Vitro* Comparison of Different Cementation Strategies on the Pull-out Strength of a Glass Fiber Post

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Clinical Relevance

A three-step etch&rinse adhesive system, combined with a dual-cured resin cement and a simplified self-adhesive resin cement, appears to be a good strategy for fiber post cementation.

SUMMARY

Purpose: To evaluate the effect of different strategies for post cementation on the pullout bond strength of a double-tapered glass fiber post cemented into a root canal. Materials and Methods: The root canals of 70 single-rooted bovine teeth (16 mm-length) were prepared to 9 mm using the preparation drill of a double-tapered glass fiber post system (White Post DC, FGM). Each specimen was embedded in a plastic cylinder using acrylic resin up to 3 mm of the most coronal portion of the specimen and allocated into one of seven groups (n=10) based on strategies for cementation: Gr1–ScotchBond Multi Purpose plus (SBMP) + Relyx ARC resin cement; Gr2–Single Bond + Relyx ARC; Gr3–ED Primer + Panavia F resin cement; Gr4–SBMP + AllCem resin cement; Gr5–Relyx ARC; Gr6–Relyx Unicem resin cement; Gr7–Relyx Luting 2 glass ionomer cement. After cementation, the specimens were stored for seven days (in a humid environment at 37°C) and submitted to pullout bond strength testing (the inferior part of each specimen was fixed and the fiber post was pulled out). The data (Kgf) were submitted to statistical analysis (one-way ANOVA and post-hoc Tukey tests, α=.05). The tested specimens were analyzed under the microscope and SEM for fracture analysis. Results: The strategy for post cementation affected the pullout retentive strength (Kgf) (*p*<0.0001) significantly. Gr6 (37.7 ± 8[a]), Gr1 (37.4 ± 5.7[a]) and Gr4 (31.6 ± 6.6[ab]) presented the highest pullout bond strengths. Gr2 (12.2 ± 5.6[c]), Gr3 (6.5

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± 5.2[c]) and Gr7 (5.1 ± 2.8[c]) presented the lowest pullout bond strengths. Gr5 (24.2 ± 7.4[b]) was similar to Gr4 and inferior to Gr6 and Gr1. Conclusion: The use of a three-step etch-&-rinse adhesive system appears to be effective. The application of other adhesive systems (single-bottle etch-&-rinse and self-etch adhesive systems) did not present high pullout strength values. The simplified self-adhesive resin cement (without adhesive application) presented good retentive performance. Further studies should be conducted.

INTRODUCTION

The advent of enamel acid etching and dentin hybridization has allowed for more conservative restorative treatments and minimal intervention procedures.[1] Coronal reconstruction and root anchorage using root fiber posts associated with bonding agents allows for the preservation of maximum amounts of dental structure. Additionally, the risk of root fracture has been reduced by using root posts with improved mechanical properties (such as modulus of elasticity).[2-5]

Although clinical studies have demonstrated good results with teeth restored with carbon-, glass- and quartz-fiber reinforced resin posts (FRC) (success rate from 95% to 97%),[6-8] some failures were noticed, such as debonding of the cement-FRC-core set (loss of retention) with debonding of the composite core from the fiber post.[6-7]

Factors, such as chemical incompatibility between some adhesive systems and resin cements,[9] heterogeneous dentinal substrate,[10-11] uncertainty of hybridization in dentinal walls,[12] the shape and width of the root canal providing access to the surfaces to be bonded[13-14] and the shape and composition of the fiber post[15] may damage the post-root dentin bond and post retention. An increased factor of cavity design is an inherent factor that can impair the bond to root dentin,[16-17] since the higher cavity design increases the polymerization contraction stress of the resinous materials.[18-19] Thus, the use of a resin cement with low shrinkage for post cementation could improve the retention of fiber posts by improving the friction to root dentin walls.[20]

Goracci and others[20] evaluated the push-out bond strength between fiber post and root dentin in two cementation conditions—with or without the use of an adhesive system, while using a resin cement. Those authors observed that the push-out strength was not improved with use of an adhesive system when compared to cementation without adhesive agents. On the other hand, a recent study[21] showed that adhesive cementation can contribute to the improved push-out bond strengths of fiber posts to root dentin.

Recently, a simplified approach for cementing root posts, inlays/onlays and fixed partial dentures has been marketed. No dentin-enamel pretreatment is indicated in this one-step technique. The organic matrix consists of multi-functional phosphoric acidic methacrylates, which contribute to adhesion to tooth tissue. The content of inorganic fillers is about 72 wt%. The fillers are of a basic nature and are able to undergo a cement reaction with the acidic groups of the functional monomers. Due to the cement reactions, the pH-value of the material increases from one to six during the setting reaction.[22] The dominant setting reaction starts with free radical polymerization, which can be initiated by both light or a redox system, such as with the reactions of dual curing composite materials. Additionally, phosphoric acidic methacrylates in the monomer mixture can react with the basic fillers and hydroxyapatite of tooth hard tissue. Water is released in this reaction, which accelerates the neutralization reaction.[22-24]

The current study evaluated the effect of different strategies for fiber post cementation on the pullout strength of a tapered glass fiber post luted into bovine roots. The null hypothesis evaluated was that the cementations strategies would allow for similar higher pullout strength.

METHODS AND MATERIALS

The coronal and cervical portions of 70 (N=70) single-rooted bovine teeth (mandibular incisors) were sectioned to standardize the size of the specimens at 16 mm. Thereafter, the coronal diameters of the canals were measured with a digital caliper (Starrett 727,

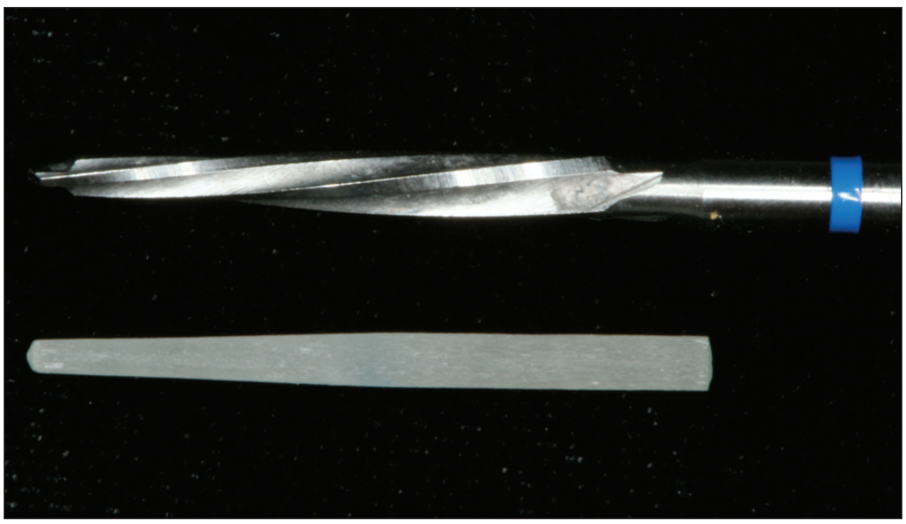


Figure 1: *White Post DC #2 and the respective drill, FGM.*

Table 1: *Testing Groups*

Group	Adhesive System	Luting Cement	Procedures
Gr1	3-steps etch-&-rinse, self-cure[1]	Relyx ARC, 3M ESPE*	a, b, c, d1, f, g
Gr2	Single-bottle etch&rinse, light-cure[2]	Relyx ARC, 3M ESPE*	a, b, c, d2, e, f, g
Gr3	Self-etching primer, self-cure[3]	Panavia F, Kuraray*	d3, f, g
Gr4	3-steps etch-&-rinse, self-cure[1]	AllCem resin cement, FGM*	a, b, c, d1, f, g
Gr5	------	Relyx ARC, 3M ESPE*	f, g
Gr6	------	Relyx Unicem, 3M ESPE‡	f1, g
Gr7	------	Relyx Luting 2, 3M ESPE‡‡	f, g

[1]*ScotchBond Multi Purpose Plus, 3M-ESPE*
[2]*Single Bond 2, 3M-ESPE*
[3]*ED Primer, Kuraray*

**resin cements*
‡self-adhesive universal resin cement
‡‡Glass ionomer cement
a–etching of the root and crown dentin with phosphoric acid 37% for 30 seconds. The tip of syringe reached whole post space into root canal
b–washing with com 10 ml of distilled water a disposable syringe
c–removing of the excess water with #80 paper points
d1–application of multi-steps ScotchBond Multi Purpose plus adhesive system (Activador, Primer, and Catalyst, 3M ESPE), using micro-brushes (Cavi-Tip, Svenska Dental Instrument AB, Upplands Värby, Sweden)
d2–application of the one-step Single-Bond 2 adhesive system, using micro-brushes (Cavi-Tip)
d3–application of self-etching adhesive ED-Primer A + ED-Primer B
e–photo-activation for 40 seconds (XL 3000, 3M ESPE)
f–manipulation of the cement and application into the root canal with a Lentulo #40 spiral
f1–Aplicap Capsule was activated and moved in a mixing machine. The resin cement was applied into the root canal with a Lentulo #40 spiral
g–insertion of the fiber post into the root canal

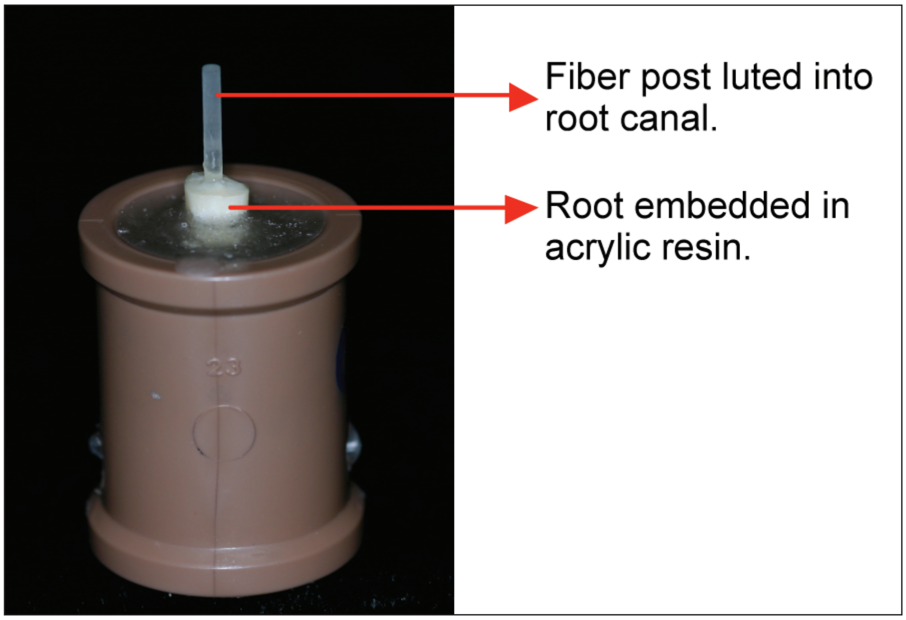


Figure 2: *Specimen obtained for testing.*

Starrett, Itu, Brazil) and specimens presenting diameters greater than the diameter of the post (1.8 mm) were discarded and replaced by other specimens that met this requirement. The canals were sequentially instrumented and irrigated with 0.5% sodium hypochlorite.

Root canals were prepared with the preparation bur of a tapered glass fiber-reinforced composite post system (White Post DC #2, FGM, Joinville, Brazil, Figure 1). Macro retentions were done with diamond burs at the apical third of each root, perpendicular to its long axis, promoting retention during the pullout test.

Upon completion of the preparation, each root was embedded into a PVC cylinder (h: 35 mm, diameter: 25 mm) filled with a chemically-cured acrylic resin (Dencrilay, Dencril, Caieiras, SP, Brazil) using the following steps: a) the preparation bur of the post system was placed inside the prepared root canal; b) the bur (with the root) was attached to an adapted surveyor, where the long axes of the bur, specimen and cylinder were parallel to each other and perpendicular to the ground; c) the acrylic resin was prepared and poured inside the cylinder up to 3 mm of the most coronal portion of the specimen.

After preparation, the 70 specimens were allocated to seven groups (n=10), considering the strategies for post cementation (Table 1).

Before cementation, the silane-coupling agent (Prosil, FGM, Joenvile, Brazil) was applied onto the surfaces of each fiber post and allowed to dry for five minutes.

The posts were then cemented (Figure 2) and the specimens stored in water for seven days (37°C).

Pullout Test

A hole was prepared in the inferior third of the PVC cylinder for attachment to the inferior portion of a universal testing machine (Emic DL 1000). An adapted mandrel fixed to the upper part of the testing machine directly grabbed the coronal part of the fiber post. The pullout test was performed at a speed of 1 mm/minute (Figure 3).[25-26]

The obtained data (in Kgf) were submitted to one-way ANOVA and a post-hoc test (Tukey's) (α=.05).

All of the 70 tested specimens were observed under a measurement microscope (Mytutoio TM 505) (50x-300x) to evaluate the type of failure. Specimens with representative fractures were chosen for microscopic analysis. Each post selected for further evaluation was mounted on a metallic stub, sputter coated with gold (Denton Vacuum, DESK II) and observed under a scanning electron microscope (JSM-6360 SEM, JEOL) at different magnifications.

RESULTS

One-way ANOVA (Table 2) indicated that the pullout results were affected by the cementation strategies (p<0.001). Thus, the null hypothesis was rejected. The results of the pullout strength test (Kgf) are shown in the Figure 4. G1 and G6 were statistically similar and presented the highest values when compared to G2. G2 was similar to G3 and G7, both of which presented the lowest values. G5 presented medium values and G4 did not differ statistically from G1, G6 and G5.

Table 3 shows the types of fracture that occurred with the specimens analyzed under stereomicroscope. Figure 5 shows some representative micrographs from the pulled out posts.

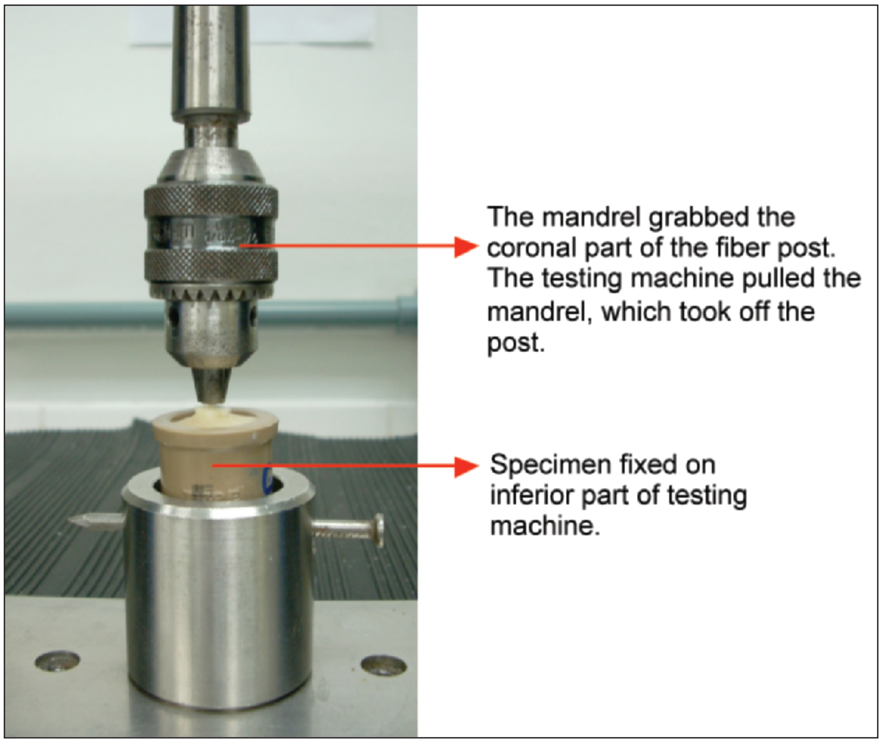


Figure 3: *Pullout strength test.*

Table 2: *Results of One-Way ANOVA Analysis*

Source	DF	SS	MS	F	*P**
Between	6	11994.5	1999.08	53.4	0.0000
Within	63	2358.6	37.44		
Total	69	14353.0			

*p<.05

DISCUSSION

The good performance of adhesive systems when bonded to enamel and coronal dentin is well documented. However, some aspects related to intraradicular dentin remain uncertain, especially when adhesive systems are used for root post cementation, as some failures have been clinically observed.[7,27]

Adhesive resin cements are capable of achieving high regional bond strengths to exposed root dentin or crown dentin under ideal conditions (optimal cleaning and maximum resin flow for shrinkage stress relief).[28] Conversely, these criteria are difficult to realize when applied to post spaces (root canal) where highly unfavorable cavity configuration factors are present.[16-17,29] Bouillaguet and others[16] cemented fiber posts into intact root canals (high C-factor) and sectioned roots (low C-factor). They observed higher bond strengths in the low C-factor than in the high C-factor. This increase in bond strength was attributed to low stress generation in the adhesive systems during resin cement polymerization contraction due to the small configuration factors.

In the current study, the factor of cavity design was high, because the natural cavity of the root canal was employed. Thus, differences observed between groups in the current study were not only related to the C-factor but also to the ability of hybridization of the root dentin by the different adhesive systems and/or higher friction promoted between the luting cement and root canal walls.

The three-step etch&rinse self-cure adhesive system (G1 and G4) presented higher mean values when compared to the single-bottle light-cure (G2) and self-etching two-bottle (G3) adhesive systems. The three-step etch&rinse adhesive system probably yielded a better pattern of dentin hybridization, which increased the pullout strengths, because this system does not require light curing. On the other hand, the single-bottle total-etch adhesive system (G2) required light curing before cementation of the post, and light access into the root canal is problematical.[17,26,30-32]

The current findings agree with those observed in previous studies. The three-step etch-&-rinse adhesive system was used (ScotchBond MP) when compared to single-bottle etch&rinse (Single Bond) and self-etch primer (Tyrian SPE/One Step Plus) adhesive systems. Giachetti and others[30] found similar results. Mallmann and others[17] also showed that light-cured adhesives employed for post cementation presented lower microtensile bond strength than chemically-cured systems in the apical region of the root dentin due to difficult light access to the apical third, which is different from the middle and cervical thirds of root dentin.

Some studies have previously indicated a possible chemical incompatibility between adhesive systems with low pH and resinous materials.[33-38] The decreased microtensile bond strengths of chemically initiated polymerizing resin composites bonded to dentin have been noticed because of the acidity of the adhesive system, such as self-etching primers and some "etch and rinse" single-step adhesives. It is known that acidic resin monomers retard the polymerization of chemically and/or light initiated polymerizing resins that are initiated via peroxide-amine type binary redox catalysts. Interaction between acidic adhesive resin monomers and basic composite tertiary amines results in the consumption of the latter in acid-base reactions, depriving their capacity to generate free radicals in subsequent redox reactions.[38] In the current study, single-bottle etch&rinse and self-etching adhesive systems from Groups 2 and 3, respectively, exhibited low pH values and hence might have contributed to decreasing pull-out values.

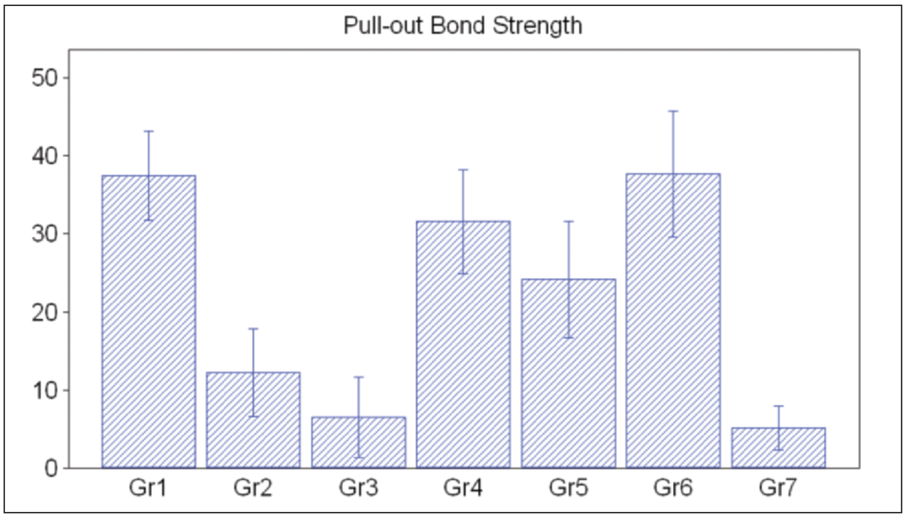
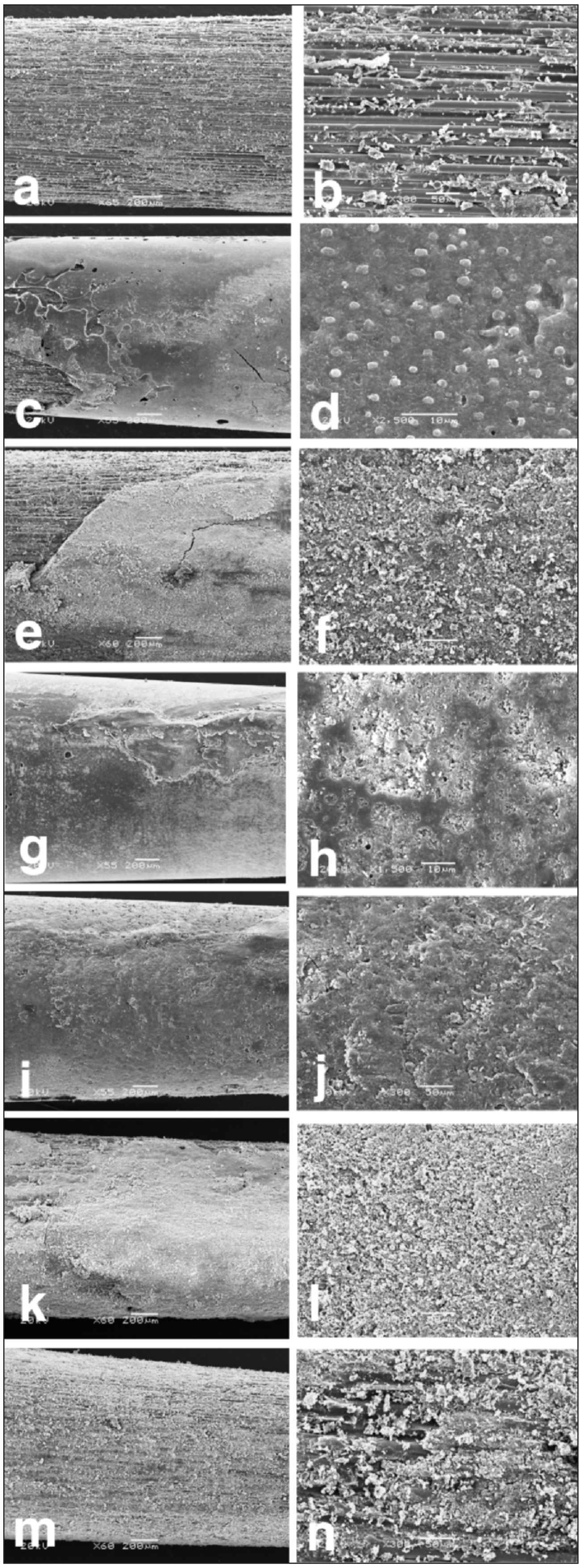


Figure 4: *Pullout bond strength results (Kgf) (**Gr1**: 37.4 ± 5.6[a]; **Gr2**: 12.2 ± 5.5[c]; **Gr3**: 6.5 ± 5.1[c]; **Gr4**: 31.5 ± 6.6[f]; **Gr5**: 24.1 ± 7.4[b]; **Gr6**: 37.6 ± 8.0[a]; **Gr7**: 5.2 ± 2.8[c] [Similar letters indicate statistical similarity; different letters indicate statistical difference]).*

The current study also observed that the resin cement RelyX ARC, associated with a single-bottle etch&rinse adhesive (G2), presented lower mean values than cementation with the same resin cement without an adhesive system (G5). Goracci and others[20] found similar results when applying or not applying an adhesive system (self-etch primer or three-step etch&rinse adhesive systems). According to those authors, the friction between the resin cement and root canal walls is very important for the fixation of root posts.[20] The low pull-out bond strengths of the single-bottle etch&rinse adhesive system (G2) can be explained by poor photo-activation of the adhesive, leading to a poor degree of conversion. Alternatively, the current investigation disagrees with the findings of Goracci and others,[20] since greater pullout values were observed with the three-step etch&rinse adhesive system (G1) when compared to the group without application of an adhesive (using the respective resin cement) (G5). It has been concluded that the adhesive approach with a three-step etch&rinse adhesive can lead to a high bond strength performance, which is dif-

Table 3: *Type of Fracture of the Specimens Submitted to the Pullout Test*

	Testing Groups						
Type of Fracture*	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**
post	4	----	----	----	2	----	5
cement-post	6	----	----	4	1	----	4
cement-dentin	----	9	----	5	3	----	1
Cem-dent + cohes cem	----	----	10	----	----	----	----
Cem-dent + cem-post	----	1	----	2	4	----	----
cohes-cem + cem-post	----	----	----	----	----	10	----



ferent from the single-bottle etch&rinse light cured adhesive system (G2), a conclusion also noted by Valandro and others.[26]

The self-adhesive simplified resin cement (G6) promoted high values of pullout strength similar to the three-step etch&rinse adhesive system (G1 and G4). This simplified approach to using a self-adhesive resin cement appears to have low shrinkage due to its viscoelastic properties, leading to better intimate contact of the resin cement with the root canal walls and higher frictional resistance.[16,20,39] In cases where the C-factor is high, slow setting self-cured resin cements are indicated as being capable of providing viscoelastic parameters for maintaining bond integrity under extreme conditions.[16,20,39] De Munck and others[40] affirmed that high-density, low-porosity RelyX Unicem could optimize contact to dentinal substrates. It has already been related that this cement produces effective adhesion with dentin.[29,40] Thus, during the retention test, Relyx Unicem better resists the pullout test.

It has been indicated that RelyX Unicem only interacts very superficially and without any appearance of a smear layer or resin tags, showing a low demineralization effect despite its low initial pH.[41] However, it appears that RelyX Unicem forms an increased chemical interaction with the calcium in hydroxyapatite, explaining the improved mechanical properties.[41]

De Durâo and others[21] utilized the push-out test to assess the root dentin–fiber post bond, showing that glass ionomer had the lowest bonds also found by the current investigation. However, contrary to the current study, De Durâo and others found significantly lower bond strength values for a self-adhesive resin cement that could be explained by the omission of photoactivation of this dual-cure cement.[21] Moreover, De Durâo and others tested samples with a thickness of 1 mm, providing a reduced effect from friction on the results.[42] Thus, they mainly evaluated bond strength,[21] while the current study assessed the global effect (bond strength + resistance to friction) by applying the pullout retentive test, which justified the different results. The self-adhesive simplified resin cement appears to have poor adhesion to dentin in dry and aging conditions[21,23-24,43-44] but appears to promote high resistance to friction between its cement and the concerned

Figure 5: *Representative micrographs from the pulled-out fiber post.* Figures 5a-b (G1): *It notes a fracture predominantly cement-post, with fragments of cement on the post surface;* Figures 5c-d (G2)*: it observes a fracture between the cement and root dentin—the portion of the fractured tags can be observed on the cement, which coated the post;* Figures 5e-f (G3): *fracture between the cement-dentin interface associated with fracture cohesive of the cement (mixed fracture);* Figures 5g-h (G4)*: fracture at the cement-dentin interface;* Figures 5i-j (G5)*: fracture between the cement and dentin;* Figures 5k-l (G6)*: cohesive fracture of the cement associated with the adhesive fracture at the interface post-cement;* Figures 5m-n (G7)*: cohesive fracture of the cement associated with the adhesive fracture at interface dentin-cement.*

substrates/materials, as shown in the current investigation. Even though future study is necessary, this simplified approach presents a good option for cementing root posts, metal-free crowns or fixed partial dentures (FPDs) made of dense, high-purity alumina, yttrium-tetragonal zirconia polycrystal, glass-infiltrated alumina/zirconia ceramics, metal-ceramic crowns or FPDs and full metal crowns. On the other hand, inlays, onlays and laminates made in silica-based ceramics appear to be highly adhesion-dependent clinically[45-48]—as the self-adhesive resin cement appears to not adhere very well to enamel/dentin[23-24,43-44] and feldspathic ceramics.[49] Therefore, this one-step cementation approach should not be recommended for the latter types of restorations.

Bonfante and others[50] also related that the bond strength values obtained for resin-modified glass ionomer cements were significantly lower when compared to those obtained for resin cements. They affirmed that the failure mode observed for RelyX luting indicates that retention of this cement probably is more dependent on mechanical retention than on bonding to dentin, and the high number of cohesive failures that occurred may be associated with its low intrinsic resistance and the presence of bubbles within the cement.[50]

Even though self-adhesive resin cement simplifies post cementation, it should be noted that it is essential to apply adhesive agents on crown dentin for core build-up with resin composite.

The proposal of simplified cementation utilized in G6 (self-adhesive universal resin cement) showed high values of resistance to dislocation, similar to a conventional adhesive system, indicating that this can be a future alternative for post cementation. Nevertheless, the findings from the current study were stated in dry conditions, therefore, further *in vitro* studies related to an aging condition and prospective randomized controlled clinical trials should be conducted.

CONCLUSIONS

The three-step etch&rinse adhesive system, combined with a Bis-GMA-based resin cement and simplified self-adhesive resin cement, provided higher pullout strengths of glass FRC when compared to the single-bottle etch&rinse and self-etching primer adhesive systems associated with a glass-ionomer cement.

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