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The Influence of Time and Cement Type on Push-Out Bond Strength of Fiber Posts to Root Dentin

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Clinical Relevance

A self-adhesive resin cement can provide a significantly stronger bond than a three-step etch-and-rinse adhesive and resin cement when used to lute fiber posts.

SUMMARY

The bond strength of fiber posts luted with resin cements was evaluated after two storage times in different regions of a post space. A total of 40 single-rooted human teeth were endodontically treated and prepared for cementation of fiber posts (White Post DC). In groups 1 and 3 (G1 and G3, respectively), posts were luted with RelyX ARC, whereas the posts in groups 2 and 4 (G2 and G4, respectively) were luted with RelyX Unicem. After one month of storage at 100% humidity, G1 and G2 were transversally sectioned in 1.7-mm slices of the cervical (C), middle (M), and apical (A) thirds of the post space and submitted to push-out testing at 1 mm/min. After nine months of storage, the roots of G3 and G4 underwent the same process. Mean values were analyzed using the Mann-Whitney and Kruskal-Wallis tests (α=0.05). The bond strengths in G2 (C=4.26±2.29; M=4.67±3.54; A=7.27±4.30) were statistically higher than in G1 (C=3.81±1.07; M=1.57±1.62; A=1.99±1.60) in the middle and apical thirds (p=0.001). Bond strengths in G4 (C=3.36±1.39; M=4.49±2.17; A=3.83±1.92) were higher than in G3 (C=2.13±0.47; M=0.94±1.05; A=0.95±1.02) in all evaluated regions (*p*=0.02, *p*<0.001, and *p*<0.001, respectively). When comparing the root regions for each group, G1 had higher

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DOI: 10.2341/10-404-L

values in the cervical third than the middle third (p=0.02). The self-adhesive resin cement showed better results than the conventional resin cement at both storage times. For both materials a similar performance among the three root regions was found. Storage time did not influence the shear bond strength.

INTRODUCTION

The high rates of irreversible root fractures when posts with a high modulus of elasticity are used have contributed to the increasing use of glass fiber posts[1] associated with resin cements, resulting in better stress distribution along root canal walls.[2,3] The use of three-step etch-and-rinse adhesive systems with resin cements seems to decrease the microleakage inside the root canal when compared with self-etch adhesive systems or zinc phosphate cement,[4] which helps to maintain an aseptic endodontic treatment.

However, the main cause of failures of these new systems is related to the retention of the materials to root canal walls.[5] In the cases of root canal preparations, the cavity configuration (C-factor) is high and may even exceed 200, contributing to maximizing the polymerization stress of resin cement.[6] The stress may be so intense that the resin cement detaches from dentin walls,[7] thus creating interfacial gaps and decreasing the retention of posts.[8] Some studies indicate that friction is mainly responsible for maintaining posts inside the root canal.[9-11]

The retention of posts in the root canal may also be influenced by the degradation of the adhesive system over a long period of time,[12] known as nanoleakage,[13,14] resulting in decreased bond strength.[12,15] The control of moisture,[16] inefficient polymerization of the adhesive system or resin cement,[17,18] and aggressive etching that leaves the collagen fibrils susceptible to the action of metalloproteinases[13,19] can all accentuate the degradation of hybrid layer and adhesive interface.

The first attempt to reduce the number of steps during clinical procedures of adhesive luting resulted in the development of simplified adhesive systems. However, these adhesive systems are susceptible to an incompatibility with dual-cured and self-cured resin cements[9,20,21] and to the permeability of the adhesive interface, causing water blisters.[22,23] More recently, in an effort to reduce the technique sensitivity due to the difficult access to canal walls during handling and control of adhesive procedures,[14,24] self-adhesive resin cements were developed. These materials are not able to form a true hybrid layer,[25,26] and short-term studies show inferior bond strength values when compared with resin cements that require an adhesive system.[24,27]

The push-out test has been widely used to test bond strength of fiber posts to root canal, with fewer premature failures, less variability of data distribution, and more uniform values than the microtensile test.[10] This present study verified the bond-strength resistance of a conventional technique (resin cement plus three-step etch-and-rinse adhesive system) and a self-adhesive resin cement used to lute glass fiber posts, based on the root region and storage periods. The hypotheses tested were 1) the use of a simplified application technique does not decrease bonding effectiveness to root dentin; 2) there is a difference in shear bond strength depending on storage time; and 3) there are differences in shear bond strength values among the three regions of the post space.

METHODS AND MATERIALS

A push-out bond strength test was performed on glass fiber posts in flat discs of radicular dentin. After approval of the ethics committee (protocol no. 753), 40 single-rooted human teeth, extracted for orthodontic or periodontal reasons and stored in a 0.9% thymol solution at room temperature, were used in this study. The teeth had their crowns removed with a low-speed handpiece and diamond discs (7016, KG Sorensen Ind Com Ltd, Barueri, SP, Brazil) under water cooling. All teeth were endodontically treated. A step-back preparation technique was used. Apical preparation was conducted with the final master apical file size 40. The root canals were obturated with gutta-percha cones using the lateral condensation technique and a eugenol-free sealer, Sealer 26 (Dentsply Maillefer, Petrópolis, RJ, Brazil), sealed with Coltosol (Coltène/Whaledent, Altstätten, Switzerland) and left for seven days in a lightproof container with 100% humidity at 37°C.

The gutta-percha filling was removed using Gates Glidden drills (Dentsply Maillefer) with the working length established at 10 mm, leaving an apical seal of approximately 4 mm. The post spaces were enlarged with a low-speed drill from the DC White Post system no. 1 (FGM, Joinville, SC, Brazil). Roots were randomly divided into four groups of 10 specimens.

DC White Post glass fiber posts (FGM), size 1 with smooth surface, were etched with 37% phosphoric acid for 60 seconds, washed, air-dried, and coated with a silane coupling agent (Dentsply Maillefer), which was applied with a microbrush and air-dried.

Posts were not manipulated until the luting procedure to avoid contamination of the post surface.

For groups 1 and 3 (G1 and G3, respectively), the roots were etched with 37% phosphoric acid (Cond Acid, FGM) for 15 seconds, water-rinsed, and excess water was removed using absorbent paper points (Dentsply Maillefer), leaving a moist dentin surface. The adhesive system, Scotchbond Multi-Purpose Plus (3M ESPE, St Paul, MN, USA), was applied and light-cured for 60 seconds with Radii light-emitting diodes at 1100 mW/cm^2 (SDI, Bayswater, Victoria, Australia). The RelyX ARC (3M ESPE) base and catalyst pastes were hand-mixed for 10 seconds, then one portion was applied onto the post and the other inserted into the post space using a Centrix syringe (DFL, Rio de Janeiro, RJ, Brazil). The post was then immediately inserted into the post space. Excess cement was removed and light-cured for 60 seconds.

The root canals from groups 2 and 4 (G2 and G4, respectively) were water-rinsed and the excess moisture was removed with absorbent paper points before the luting procedures. Each capsule of RelyX Unicem (3M ESPE) was activated and triturated in an Ultramat 2 amalgamator (SDI; frequency, 4600 oscillations per minute) for 15 seconds. The cement was inserted into the post space with RelyX Unicem Elongation Tips (3M ESPE) and applied on the post surface. The post was then placed into the post space. The excess cement was removed and the remaining cement was light-cured for 60 seconds. The resin cement and adhesive system compositions are listed in Table 1.

To simulate the coronal restoration, all roots received a coat of resin composite TPH (Dentsply Maillefer) that sealed the cervical surface and were stored in a light-proof container with 100% humidity at 37°C for one (G1 and G2) or nine months (G3 and G4). The liquid used for 100% humidity aging was 0.9% thymol solution. It was changed every 15 days to avoid fungal growth.

After the appropriate storage periods, the roots were transversally sectioned into four slices using an Isomet 1000 (Buehler, Lake Forest, IL, USA). The first slice of 1 mm was discarded, and 1.7-mm thick slices, corresponding to cervical, middle, and apical thirds of the post space, were used for the push-out test (Figure 1). To ensure that each inverted, truncated fiber post section could be dislodged from the root slice in an apical-coronal direction,[10] each specimen was secured with cyanoacrylate glue (Super Bonder Gel, Loctite, São Paulo, SP, Brazil) on the push-out jig, attached in the Kratos Testing Machine (TRCv603, Industry Equipments Ltd, São Paulo, SP, Brazil). A compressive load was applied on the center of the fiber post at a cross-head speed of 1 mm/min until it was completely dislodged from the root slice. The retentive strength was recorded and expressed in megapascals, dividing the load at failure by the area of the segment.[10,11,28] The results were statistically analyzed using Mann-Whitney variance analysis at $\alpha = 0.05$ for independent samples and Kruskal-Wallis with the Dunn post hoc test at $\alpha = 0.05$ to verify differences among the thirds in the same teeth.

RESULTS

As shown in Table 2, the Mann-Whitney test showed differences between G1 and G2 in the middle and apical thirds (p=0.001) and between G3 and G4 in

Table 1: *Chemical Composition, Manufacturer, and Batch Number of the Tested Materials*

Materials	Composition	Manufacturer/Batch No.
Scotchbond Multi-Purpose Plus	Activator: ethyl, alcohol, benzene sulfinic acid, sodium salt. Primer: water, HEMA, Vitrebond copolymer. Catalyst: Bis-GMA, HEMA, benzoyl peroxide.	3M ESPE/Catalyst: 7BB; Primer: 7BP; Activator:7KY
RelyX ARC	Silane, treated silica filler, TEGDMA, Bis-GMA, dimethacrylate polymer. Filler content: 67.5 wt%.	3M ESPE/GHHM
RelyX Unicem	Powder: glass fillers, silica, calcium hydroxide, self-curing initiators, pigments, light-curing initiators. Filler content: 72 wt%. Liquid: methacrylated phosphoric esters, dimethacrylates, acetate, stabilizers, self-curing initiators.	3M ESPE/233749

Abbreviations: Bis-GMA, bis-phenol-A diglycidyl dimethacrylate; HEMA, 2-hydroxy ethyl methacrylate; TEGDMA, triethyleneglycol dimethacrylate.

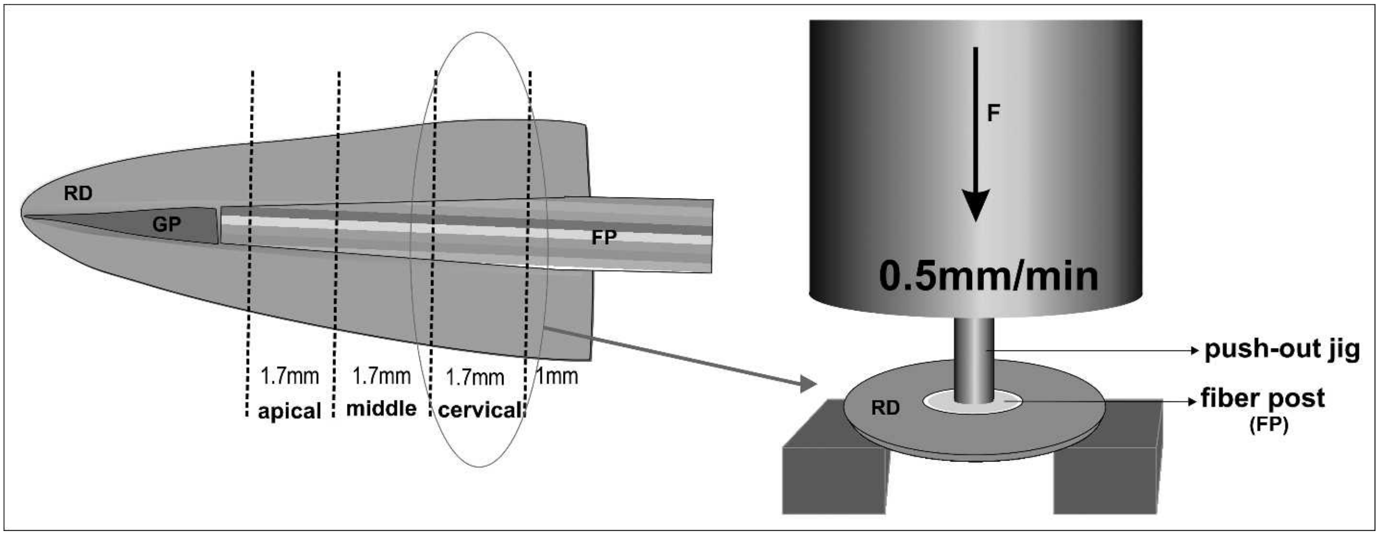

Figure 1. *Schematic representation of specimen sectioning model to obtain cervical, middle, and apical root sections and push-out test. Abbreviations: RD, radicular dentin; FP, fiber post; F, compressive force; and GP, remaining gutta-percha.*

Table 2: *Material's Push-Out Bond Strength (MPa) According to Tooth Region and Time*

Tooth Region	Time, mo	Material's Bond Strength, MPa	
		ARC (G1/G3)	Unicem (G2/G4)
Cervical	1	3.81 (1.07) Ba*	4.26 (2.29) Ba
	9	2.13 (0.47) Bb	3.36 (1.39) Aa
Middle	1	1.57 (1.62) Ba*	4.67 (3.54) Aa
	9	0.94 (1.05)Ba	4.49 (2.17) Aa
Apical	1	1.99 (1.60) Ba	7.27 (4.30) Aa
	9	0.95 (1.02) Ba	3.83 (1.92) Aa

Abbreviations: G1, group 1; G2, group 2; G3, group 3; G4, group 4.
[a] *Values in mean (standard deviation); results with the same letter (uppercase—within resin cement; lowercase—within storage time) means not statistically significant different* p>*0.05.*
* *Statistically significant difference (*p<*0.05) among root regions.*

the cervical, middle, and apical thirds (p=0.02, p<0.001, and p<0.001, respectively). G2 and G4 achieved better results.

There was a statistically significant difference between G1 and G3 only in the cervical third (p=0.01). When comparing the three thirds of the post spaces for each group, the Kruskal-Wallis test showed that only G1 was significantly different (p=0.02). The Dunn post hoc test indicated that the mean value of the cervical third was higher than the mean of the middle third.

DISCUSSION

The self-adhesive resin cement, RelyX Unicem, achieved better results than the conventional dual-cured resin cement, RelyX ARC, for both storage periods. The chemical composition of these materials might have been a determinant in this study, because the quantity of inorganic fillers by wt% in the RelyX Unicem resin cement is higher than in the RelyX ARC (72% and 67.5%, respectively). In general, the higher the inorganic filler content in a resin-based material, the lower its polymerization shrinkage and the greater its stability, due to a smaller resin matrix/filler ratio.[29] Some studies have shown that RelyX Unicem does not promote the formation of a satisfactory hybrid layer[25-27] because it is not able to dissolve the thick smear layer present after canal wall instrumentation for post cementation.[24] Thus its stability during storage gives additional evidence to support the idea that the retention of posts inside the root canal space is predominantly frictional.[9-11]

After nine months' storage in 100% humidity, some decrease of shear bond strength was expected; however, these values were not statistically different when compared with the one-month storage specimens. RelyX ARC resulted in low shear bond strength for both periods, which might be due to a degradation process of the adhesive interface,[13] contributing to the lower values for both storage periods.

When submitted to a microtensile test, differences among storage periods are more evident.[15,30,31] This test is more susceptible to failures related to the adhesive interface (eg, nanoleakage, basic degradation)[13,14] and to permeability of the adhesive layer[22,23] and incompatibility between the simplified adhesive system and dual cured or chemical cured resin cements.[9,20,21] The push-out test did not suffer negative influences due to alterations of the hybrid layer formed with the three-step etch-and-rinse adhesive system or from adverse effects on the interface between the tooth structure and self-adhesive resin cement.[24-27]

The three root thirds presented similar performances with the exception of G1, where the cervical third mean bond strength was higher than that of the middle. This might be related to the better handling of material in this area, because conditions are better for etching, washing, drying, applying the adhesive system, photo-curing, and luting procedures.[6] The apical area represents the worst scenario for achieving effective and durable adhesion.[31] The self-adhesive resin cement is applied in a single step and is not acidic enough to etch the dentin surface and dissolve the thick root dentin smear layer[24]; therefore, it interacts only superficially.[25] Thus, differences in morphology of the substrate of the three root thirds[32,33] did not influence the shear bond strength of this material. On the other hand, for the conventional etch-and-rinse resin cement, the three-step adhesive system was applied with a microbrush, which can result in the formation of a hybrid layer, in all root thirds.[34-36] The difficulty of light to penetrate to the apical third[17,18] could cause incomplete polymerization of the material. To minimize its effects on materials' properties, a dual-cure resin cement and adhesive system was used.

Dual-cured resin cements that need pretreatment of dentin with phosphoric acid and adhesive systems present some problems, especially in long-term studies. Therefore, self-adhesive resin cements present as a reliable alternative to conventional resin cements to lute fiber posts in root canals. In addition to the fact that they need less complex and sensitive handling, they also present a satisfactory performance, as indicated in the results of the laboratory push-out bond strength test in this study. However, clinical research is still required.

CONCLUSIONS

Considering the methodology applied in this *in vitro* study, it can be concluded that the self-adhesive resin cement, RelyX Unicem, had higher bond strength values than the adhesive resin cement, RelyX ARC. Neither storage time nor location within the root canal influenced the push-out bond strength.

Acknowledgements

The authors are grateful to 3M ESPE and FGM for supplying the products used in this study. Special thanks to Paulo Francisconi from the Department of Operative Dentistry, Dental Materials, and Endodontics of Bauru School of Dentistry and Alessandro De Carli and Rodrigo Trentin for advice and support with data analysis. This work was supported by grant 23/200.084/2007, FUNDECT.

(Accepted 4 April 2011)

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