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Research Article

Effect of Resin Cement Adhesive Strategy and Root Region on the Push-Out Bond Strength of a Fiber Post

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Received: December 30, 2016; **Published:** January 07, 2017

Abstract

Objective: This study evaluated the push-out strength of four resin cements for glass fiber post cementation using three different adhesive approaches (total-etch, self-adhesive and self-etch).

Materials and Methods: Forty bovine incisors were selected for this study. After crown removal and endodontic treatment, the teeth were randomly divided into 04 groups (n = 10) according to the cement and adhesive approach used: Allcem CORE (AC, control group) total-etch; RelyX U200 (RU2) self-adhesive; RelyX Ultimate Clicker (RU) self-etch and NEXUS 3 (NX3) self-etch. After post cementation, each specimen root was cut perpendicular to the vertical axis producing six slices of 1mm thick, two slices in each third (cervical, middle and apical). Specimens were, then, subjected to the Push-Out Test in a universal testing machine at a crosshead speed of 0.5 mm / min. The results were analyzed using F test (ANOVA), Bonferroni and Tukey test ($p < 0.05$).

Results: Statistically significant differences among the groups were found ($p < 0.05$).The total-etch cement showed better performance in the cervical and middle thirds and in the apical third, the self-etch cements did no differ statistically from the total- etch cement. The self-adhesive resin cement had the lowest mean push-out strength value.

Conclusion: Resin cements used with etch-and-rinse and self-etch adhesive systems seem to be an effective approach for glass fiber post cementation.

Keywords: *Dentin Bonding; Glass fiber Post; Resin Cement*

Abbreviations

AC: Allcem CORE; RU2: RelyX U200; RU: RelyX Ultimate Clicker; NX3: NEXUS 3

Introduction

Resin cements are low viscosity composites used for bonding indirect restorations, providing adequate sealing between the restoration and the dental substrate [1]. These cements differ according to the pre- treatment of the dental substrate prior to cementation and they can be classified as: 1)total-etch resin cements, used after the application of an adhesive system which includes etching separately; 2) self-etch resin cements, used after applying the etching primer; 3) self-adhesive resin cements, used without any adhesive system [2,3].

The option for luting prefabricated posts with adhesive systems and resin cement is due to the best retention results, especially with fiberposts which must be inserted passively in the root canal. The adhesive cementation also contributes to improve the distribution of stresses along the root. The fiber post and resin cement act as a single unit and its modulus of elasticity is closer to that of dentin [4,5].

Although more efficient, adhesive cementation is technically more difficult and, therefore, more prone to failure. The unfavorable aspects related to the root canal, such as, the difficult light propagation in the deepest regions, the unfavorable C-factor, the collagen scarcity [6,7], the excessive moisture and the gradual decrease of tubules toward the apical region may favor failures in post retention, especially when core build -up technique is not appropriate [4,6].

In recent years, new resin cements have been developed in a self-adhesive approach. These cements have the advantage of not requiring any dentin pretreatment [8]. Some factors, such as, dentin morphology, bonding system and the kind of cement can interfere with the hybrid layer formation along the walls of the root canal, affecting the post retention [8,9]. Hybridization is critical in the root apical third, making the bonding stability more difficult in this area, which leads to the need for intensifying research.

The Push-Out Test has been widely used to test bond strength of fiber posts in the root canal, with fewer premature failures, lower variability of the data distribution, and more uniform values [10]. The present study evaluated the bond strength of glass fiber posts in the root canal, using resin cements in different bonding strategies: etch-and -rinse, self -adhesive and self- etch. The null hypothesis of the study was that there is no statistically significant difference in the bond strength values among the cements with different dentin bonding strategies and among the root thirds for each resin cement.

Materials and Methods

Forty recently extracted bovine incisors with closed apexes and similar length and root diameter were stored in 0.1% thymol solution during one week at 4°C for inhibition of bacterial growth. The teeth were decoronated to a standard 23-mm root segment.

For endodontic treatment, the crown-down technique was used. The working length was set 1 mm short of the apex. The coronal two-thirds of the root canals were prepared with Gates-Glidden drills sizes 6-3 (Dentsply, Maillefer, Ballaigues,Switzerland), followed by the use of stainless-steel K-files (Dentsply Maillefer) to instrument the apical third, under constant irrigation with 2.5% sodium hypochlorite. Apical patency was maintained throughout the procedure with a size 15 K-file (Dentsply Maillefer). Smear layer was removed from the canals using 17% EDTA. The canals were dried and then filled with gutta-percha cones (Dentsply, Petropolis, RJ, Brazil) and Sealer 26 resin cement (Dentsply, Petropolis, RJ, Brazil) using the lateral condensation technique. Subsequently, the filled roots were stored indistilled water at 37ºC for 48 hours.

The gutta-percha filling was removed using Gates Glidden drills (Dentsply Maillefer) to depths of 18 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 size 1 (FGM, Joinville, SC, Brazil). Roots were randomly divided into four groups (n=10), according to the cement and adhesive approach used: Allcem CORE (AC, control group) total-etch; RelyX U200 (RU2) self-adhesive; RelyX Ultimate Clicker (RU) self-etch and NEXUS 3 (NX3) self-etch. The materials tested in the current study are listed in Table 1.

In all groups, the posts were cleaned with 37% phosphoric acid (Condac 37/FGM, Joinville, SC, Brazil) for 60 seconds, washed and air-dried. For AC group, the posts were coated with Prosil silane (FGM, Joinville, SC, Brazil) for 60 seconds and, then, the adhesive Ambar (FGM, Joinville, SC, Brazil)was applied onto their surface. For RU2 and RU groups, the posts were coated with Single Bond Universal Adhesive(3M ESPE, Sumaré, São Paulo, Brazil). For NX3 group, the posts were coated with the adhesive OptiBond All-in -One (KERR, Orange, CA, USA).

For AC group, 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 Ambar adhesive was applied, dried with paper points to remove the excess and light-cured for 20 seconds with a halogen light-curing unit Optilight Max (Gnatus, Ribeirão Preto, SP, Brazil) with an intensity of 1,200 mW/cm^2.

For RU2, RU and NX3 groups, the root canal dentin was cleaned with sodium hypochlorite, rinsed with water and dried with gentle air and paper tips. For RU2, no pretreatment of root dentin was necessary. For RU and NX3, the subsequent step consisted of applying 2 layers of their adhesive systems in the self-etching technique (Single Bond Universal, OptiBond All-in-One, respectively). The adhesive systems were light-cured for 20 seconds.

For cementation of the glass fiber posts (DC White Post size 1 /FGM, Joinville, SC, Brazil), each resin cement system was 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 removed. All teeth were light-cured for 60 seconds on the occlusal surfaces.

After the cementation process, the roots were cut perpendicular to the vertical axis with a diamond disc (102mm x 0.3mm x 12.7mm / Erios, São Paulo, Brazil) in a precision cutting machine (ELQUIP, São Carlos, SP, Brazil) at low speed and under constant cooling. Six 1.0-mm thick slices for each root were obtained, which were identified according to the area (two cervical, two middle and two apical). The push-out test for each specimen section was performed with a Universal Testing Machine (KRATOS, São Paulo, Brazil) at a crosshead speed of 0.5 mm/min. The push-out test load (50N) was applied in an apical to cervical direction until the post dislodged from the specimen. The push-out strength values were recorded in MPa ± standard deviation.

Statistical Analysis

To compare the thirds in each cement, the F test (ANOVA) with repeated measures was used because they were from the same specimen and the F test (ANOVA) for independent samples among the cements. When statistically significant difference was detected, Bonferroni multiple comparisons were used for the F test (ANOVA) for repeated measures. For the independent groups, which showed statistical differences, the Tukey test was used for paired comparisons. Verification of data normality and equality of variances between groups by third or between thirds per group was performed using the Shapiro-Wilk test and when data were normally distributed the Levene F test was used. The margin of error used in the statistical tests was 5% ($p < 0.05$). Statistical analysis was performed with SPSS (Statistical Package for Social Sciences) version 21.

Materials	Composition	Manfacturer / Batch Number
Allcem CORE	Base Paste: TEGDMA, Bis-EMA, Bis-GMA, camphorquinone, co-initiators, glass microparticles of barium-aluminum silicates, silicone dioxide nanoparticles, inorganic pigments and preservatives. Catalyst Paste:methacrylate monomers, dibenzoylperoxide, stabilizers and barium-aluminum-silicate glass microparticles.	FGM, Joinville, SC, Brazil 051213
RelyX™ U200	Base Paste: Methacrylate monomers containing phosphoric acid groups, Methacrylate monomers, Silanated fillers, Initiator components, Stabilizers, Rheological additives Catalyst Paste**:** Methacrylate monomers, Alkaline (basic) fillers, Silanated fillers, Initiator components, Stabilizers, Pigments, Rheological additives	3M ESPE, Sumaré, SP, Brazil 506680
RelyX™ Ultimate Clicker	Base Paste: Methacrylate monomers, Radiopaque, silanated fillers, Initiator components, Stabilizers, Rheological additives. Catalyst Paste: Methacrylate monomers, Radiopaque alkaline (basic) fillers, Initiator components, Stabilizers, Pigments, Fluorescence dye, Rheological additives, Dark cure activator for Scotchbond Universal adhesive.	3M ESPE, Sumaré, SP, Brazil 524133
Nexus 3	Not available by the manufacturer	KERR, Orange, CA, USA 4636703
White Post DC1	Glass fiber (80%), epoxy resin (20%)	FGM, Joinville, SC, Brazil 250613

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

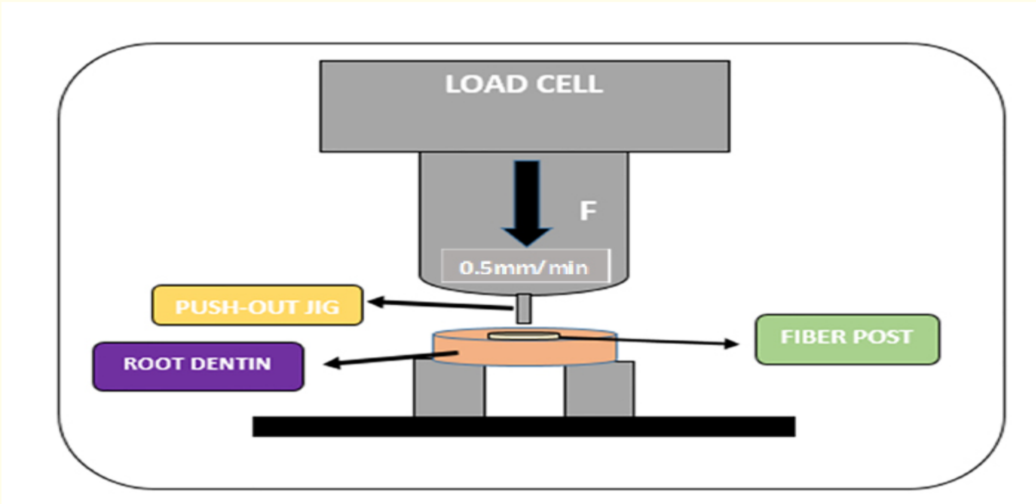

Figure 1: *Schematic illustration of push-out test.*

Results

There were significant differences in bond strength values among the cements. AC (control) showed statistically higher bond strength results in the cervical and middle third, therefore, RU2 (self-adhesive cement) and the self-etch cements (RU, NX3) did not differ statistically. The self-etch cements (RU and NX3), in the apical third, had greater bonding value than RU2, but they did not differ from AC.

When comparing the three root thirds for each cement, the results showed that RU2 demonstrated statistically lower bonding values in the apical third when compared with the cervical and middle thirds. AC had lower values in the apical third when compared with the middle third.RU and NX3had no significant differences along the root thirds. The descriptive statistics are given in Table 2.

	Region			
Cement	**Cervical**	**Middle**	**Apical**	**p-value**
• Allcem Core (AC) (Control)	$18.77 \pm 7.16^{(ab,A)}$	$24.92 \pm 11.97^{(a,A)}$	$11.64 \pm 4.07^{(b,AB)}$	$p^{(1)} = 0.015*$
• RelyX U200 (RU2)	$11.29 \pm 4.00^{(a,B)}$	$11.69 \pm 3.95^{(a,B)}$	$7.45 \pm 2.03^{(b,A)}$	$p^{(1)} = 0.007*$
• RelyX Ultimate Clicker (RU)	$12.38 \pm 5.46^{(B)}$	$9.51 \pm 2.85^{(B)}$	$13.69 \pm 4.68^{(B)}$	$p^{(1)} = 0.197$
• NEXUS3 (NX3)	$10.45 \pm 3.17^{(B)}$	$12.63 \pm 5.53^{(B)}$	$15.07 \pm 5.96^{(B)}$	$p^{(1)} = 0.124$
p-value	$p^{(2)} = 0.004*$	$p^{(2)} < 0.001*$	$p^{(2)} = 0.003*$	

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

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

Discussion

Based on the results, the null hypothesis was rejected. There was statistically significant difference in the bond strength values among the cements with different dentin bonding strategies, as well as among the root thirds. The resin cement Allcem Core, which was preceded by the application of an etch-and-rinse adhesive system, showed better results than the other cements in the cervical and middle thirds. When the different root thirds were compared for each resin cement, Allcem Core and RelyX U200 showed lower bond strength values in the apical third.

The quality and stability of the glass fiber post cementation with resin cements depend on many factors, such as, the frictional retention [11,12], the characteristics of resin cements [13], the proper curing [14], the root canal cleaning, the gutta percha removal [15], the dentin bonding strategy (total-etch, self-etching and self-adhesive) [16] and the dentin characteristics [17].

Regarding the frictional retention, all experimental groups had the same expected level of retention, once the final phase of the root canal preparation was done with a proper drill, compatible with the post.

Allcem Core has a higher filler content compared to the other cements. The filler content in resin cements is one of the factors responsible for lower polymerization shrinkage stress and it may have strengthened the bonding interface due to the resin cement higher elastic modulus [10,18]. This characteristic may have influenced the greater results of this cement in the cervical and middle thirds.

Regarding dentin, it must be taken into consideration that it is a tissue with a variable and modifiable composition [19,20]. It has been advocated in the literature that the root canal dentin has greater amount of large tubules especially next to the cervical third of the root [16,21]. Moreover, it is known that the orientation of the dentinal tubules has an effect on bond strength tests [22]. These root dentin characteristics can justify the Allcem Core results, since unlike the other cements a prior application of an etch-and-rinse adhesive system is necessary and the etching procedure facilitates the removal of the smear layer, increasing the width of the tubules and allowing the formation of a great number of thicker and larger resinous tags, when compared to the self-etching adhesive systems [19]. Although it is known that bonding takes place in the intertubular dentin and that the tags are not important in the adhesive process [23], interlocking promoted by the tags may have influenced the results, due to the characteristics of the mechanical test used. According to the position of the dentinal tubules, the tags would assume a radial position and parallel to the ground. During the mechanical test, force was applied perpendicular to the tooth, so it is possible that a greater interlocking may have occurred.

The lower bond strength result for the apical third of Allcem core cement, when compared to the middle third, but statistically similar to the cervical third, can be partially explained due to the interlocking described above, since in this third there is a smaller amount of dentinal tubules in addition to the peculiarities associated with the apical third. Uzun and others [24], using micro tomography, concluded that the cervical third was the most associated with bubble formation during the cementation procedure, making the interaction of cement with dentin more difficult. This factor may have influenced the bond strength value for the cervical third.

Soares and others [25] compared the bond strength of fiber posts in each region of the root using the Push-Out Test. The cervical region showed the best performance, even when a dual-cured material was used. This is because photoactivation was closer to the cervical region. Thus, the materials, in the cervical region, polymerize primarily due to the reactions triggered by light, while in the apical region, due to the chemical reactions. Therefore, the properties of these resinous materials should be different along the root canal due to the lower light transmission in the deeper regions and it may also affect their bonding to the root dentin.

Due to the low capacity of dentin demineralization of the self-adhesive resin cements, they are known as not able to form hybrid layer and they show contradictory results when compared to other resin cements [5,26]. Systematic reviews are categorical in affirming the bond strength superiority of the self-adhesive cements [27] or the equivalence of results [28] when compared to the conventional ones.

In vitro studies [5,26] report lower bonding effectiveness of self-adhesive resin cements when compared to resin cements associated with the etch-and-rinse technique. It corroborates the findings of the present study, in which the self-adhesive resin cement showed lower bond strength values than the etch-and-rinse resin cement but its results were similar to the self-etch cements, except in the apical third in which it showed the worst mechanical behavior.

Rely X Ultimate and Nexus 3 showed uniform mechanical behavior in the three root thirds. Before the cementation procedure, the adhesive systems, recommended by the manufacturers, Single Bond Universal and Optibond All- In-One, respectively, were applied on the root dentin. The adhesive strategy used was the self-etching one. Probably, such resinous systems are not affected, during the polymerization process, by the acidic monomers present in the self-etching adhesive systems, thus, simplifying the technique. Self-etching adhesive systems are able to uniform the variable characteristics of dentin [29]. So the amount and diameter of dentinal tubules are not important to the biomechanical behavior of these systems, as they are for the etch-and-rinse ones [30]. This feature was considered important for the self-etch resin cements, Rely X Ultimate and Nexus 3, as their bond strength was uniform in the three root thirds, besides the frictional retention and appropriate characteristics of these cements such as good viscosity, filler content and dual polymerization.

Some studies [31-33] confirm that the self-etch adhesive systems show similar bond strength values when compared to the etch-and-rinse systems, with the great advantage of eliminating the etching/drying procedure. It was confirmed, in this study, only in the apical third. Durski and others [34] compared the push-out bond strength of glass fiber posts with different resin cements and they concluded that the self-etch resin cements had the highest mean push-out strength value in all thirds when compared with the total-etch cement, which was not corroborated by the present study. The authors also stated that the cervical third of the roots had the highest mean push-out strength values, while the apical third had the lowest mean values, regardless of the technique used.

The results of the present study show the need for further studies to evaluate the behavior of these resin cements, such as long-term evaluation to determine the stability of the adhesive interface. It is also important to have studies with other methodologies and randomized clinical trials. Based on this study, the total-etch cement shows greater performance in the cervical and middle thirds, but the self-etch cements show good bonding stability in all root thirds.

Conclusion

Resin cements used with etch-and-rinse and self-etch adhesive systems seem to be an effective approach for glass fiber post cementation.

Acknowledgements: N/A

Conflict of Interest

No financial interest or any conflict of interest exists.

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Volume 7 Issue 1 January 2017