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The Effect of Light-curing Access and Different Resin Cements on Apical Bond Strength of Fiber Posts

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Clinical Relevance

Cementation of fiber glass posts with self-adhesive cement (RelyX U100) is more predictable than cementation with resin cement using a three-step etch-and-rinse adhesive system (RelyX ARC/SBMP) as its bond strength to apical dentin was not influenced by the level of light-curing access.

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SUMMARY

Purpose: This study evaluated the effect of light-curing access on the bond strength of fiber glass posts to the apical area of bovine roots using self-adhesive cement or dual-cured cement with an etch-and-rinse adhesive system.

Materials and Methods: The root canals of 60 bovine teeth were endodontically treated and filled. A 15-mm-length post space was prepared and roots were randomly divided into three groups, simulating the levels of light-curing access: coronal (C), with 15-mm post space; middle (M), in which the coronal thirds of roots were cut out, leaving a 10-mm post space; and apical (A), in which the coronal and middle thirds of roots were cut out, leaving a 5-mm post space. Fiber glass posts (Reforpost # 3, Angelus) were cemented with RelyX U100 (3M ESPE) or RelyX ARC/Scotchbond Multi Purpose Plus (SBMP) (3M ESPE) (n=10) and light-cured. After 24 hours, the apical thirds of roots were sectioned perpendicularly to the long axis and submitted to a push-out test (0.5 mm/

min, 200 N). The Kruskal-Wallis test compared the three levels of light-curing access, and the Mann-Whitney test compared the cements.

Results: The bond strength was significantly higher in the groups C (*p*=0.028) and M (*p*=0.016) when U100 was used, whereas it was similar for both cements in group A. The bond strengths of posts cemented with ARC/SBMP were significantly higher in group A compared to group C (*p*=0.031).

Conclusions: The type of cement used and the light-curing access level influenced the bond strength between glass fiber posts and root canals. The bond strength of the RelyX ARC/SBMP cement proved to be more dependent on photoactivation than was the RelyX U100 cement. The light-curing access level did not influence the apical bond strength of RelyX U100.

INTRODUCTION

Restoration of endodontically treated teeth exhibiting large coronal loss requires the use of post systems. Resin cements and fiber posts are good choices for such types of treatment.[1] In general, the results of clinical studies have been favorable with regard to the use of fiber posts. However, clinical studies[2-4] have shown post fractures and de-cementation to represent the most frequent types of failure observed.

Several factors may influence the bond strength of root canal posts, including canal depth, the type of resin cement used, and the dentinal substrate. The canal depth hinders access to operatory instruments as well as light transmission through the canal, and the use of translucent fiber posts has not improved light transmission to most apical areas.[5,6] The light intensity inside the canals is insufficient to ensure photoactivation of dual-cure resin cements.[7,8] Such resin cements exhibit lower degrees of conversion of monomers to polymers when photoactivation is not performed.[9-11] In addition, different resin cements exhibit different microhardness values at different root canal depths.[11]

Likewise, the dentinal substrate varies as a function of root canal depth. The density and diameter of the dentinal tubules decrease from the cervical to the apical areas,[12-14] but the amounts of fibrodentin[15] and secondary dentin increase in the apical areas.[16] Techniques for post cementation based on resin infiltration in the interior dentinal tubules are more sensitive and less predictable in the apical area.[14,16]

Although several studies[17-26] have shown that resin cement bond strengths inside the apical third of the post space preparations are lower than those at the cervical third, some authors[27-29] were unable to confirm this difference. Thus, it is important to investigate the factors influencing bond strength of resin cements in the apical third of the post space preparation, emphasizing the role of photoactivation and dentinal substrate in that root canal area.

The aim of the present study was to investigate the effect of light-curing access on bond strength in the apical third of glass fiber posts cemented with a self-adhesive cement system and a conventional dual-cure system (resin cement plus three-step etch-and-rinse adhesive system). The investigated null hypothesis is that the bond strength at the apical third is not affected by the location at which the light is applied or by the type of cement used.

MATERIALS AND METHODS

Root Preparation

A total of 60 bovine teeth were selected and stored in distilled water under refrigeration for up to three months. The roots were sectioned at the cement-enamel junction using a silicon carbide disc (Dentorium, New York, NY, USA), under constant irrigation with water, until 19-mm root specimens were obtained. Endodontic preparation was performed with working lengths up to 1 mm from the apical foramen using rotary instruments (Xmart, Dentsply, Petrópolis, RJ, Brazil) and Easy Pro-design files (Easy, Belo Horizonte, MG, Brazil) by the crown-down technique under irrigation with 2.5% sodium hypochlorite. Next, a final irrigation was performed with trisodium ethylenediamine tetraacetic acid (Biodinamica, Ibiporã, PR, Brazil) for three minutes, and the root canals were rinsed under water and dried using absorbent paper points. The teeth were obturated by the thermoplastic technique, using gutta-percha cones and AH Plus cement (Dentsply), and were stored in water for seven days.

Post Space Preparation

The root canals were prepared for placement of glass fiber post Reforpost #3 (Ângelus, Londrina, PR, Brazil) using Largo burs #2 to #5 (Maillefer-Dentsply, Petrópolis, RJ, Brazil) with a slow rotary

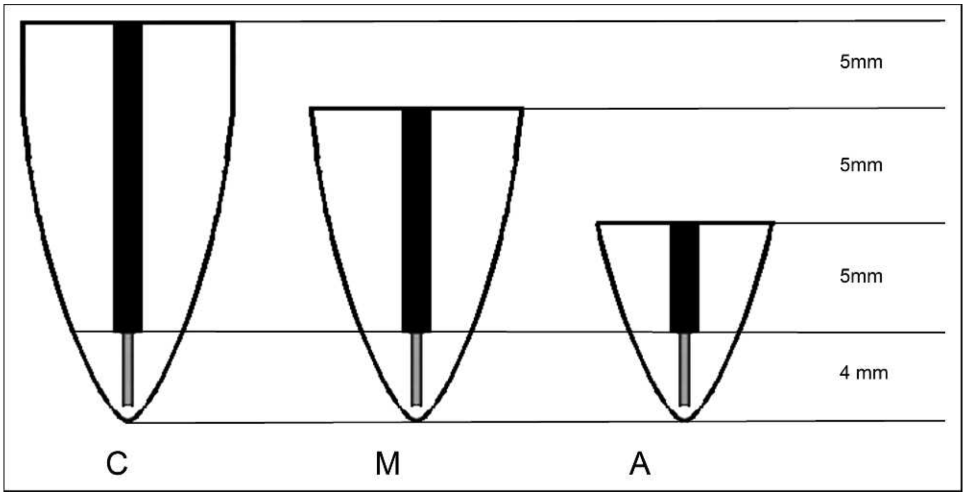

Figure 1. *Classification of roots according to the light-curing access level. C, coronal group: 15 mm; M, middle group: 10 mm; and A, apical group: 5 mm.*

speed and 15 mm of length, leaving 4 mm of apical canal filled.

The roots were then randomly separated into three groups comprised of 20 specimens each, as follows: 1) the coronal access group (group C), which exhibited 15 mm of prepared root canal; 2) the middle access group (group M), in which 5 mm corresponding to the cervical third were removed using a carborundum disc under abundant water irrigation, leaving a 10-mm length of post space preparation; and 3) the apical access group (group A), in which 10 mm corresponding to the cervical and middle thirds were removed, leaving a 5-mm length of post space preparation (Figure 1). Before the posts were cemented, the external root surfaces were covered with black adhesive tape to protect the roots from external light interference.

Post Cementation

Each post was cleaned with 32% phosphoric acid (Uni-etch, Bisco, Schaumburg, IL, USA) for 30 seconds, rinsed with water, and dried using air spray. Two different resin cements were used for cementation (n=10): RelyX ARC dual resin cement with a chemically activated polymerization adhesive system SBMP (ARC/SBMP; 3M ESPE, St Paul, MN, USA) and self-adhesive resin cement RelyX U100 (U100; 3M ESPE). The compositions and manufacturers of the cements are described in Table 1.

For application of ARC/SBMP, dentin was etched with 32% phosphoric acid, Uni-etch, for 15 seconds, rinsed under water, aspirated with endodontic cannulae, and dried with absorbent paper points. The activator was applied using a microbrush, and the excess was removed. Subsequently, the same procedure was performed with the primer and the catalyst. The cement was mixed and inserted into the root canal using a Lentulo bur (Maillefer-Dentsply). The posts were inserted, and a 10-N static load was applied on them during the resin cement photoactivation with a light-emitting diode at 1340 mW/mm^2 (Bluephase, Ivoclar Vivadent, Liechtenstein) for 40 seconds .

For the application of U100, the root canals were rinsed with water, aspirated with endodontic cannulae, and dried with absorbent paper points. The cement was mixed and inserted into the root canal using a Lentulo bur. The posts were then inserted, and the resin cement was photoactivated as described above for ARC/SBMP. The specimens were stored in water for 24 hours and then the push-out test was performed for the apical third of the roots.

Preparation for the Push-out Test

The cemented specimens were transversely sectioned 8.5 mm from the apex with a diamond disc (Isomet 1000, Buehler, Lake Bluff, IL, USA) under water cooling. Two slices that were approximately 1 mm thick were obtained (Figure 2). The thickness of each slice was measured using a digital caliper (Mitutoyo Digimatic Caliper Serie 500, Mitutoyo Sul Americana, Suzano, SP, Brazil), and the posts were subjected to the mechanical test using a plunger with a 1-mm-diameter tip (placed in contact only with the posts). The load was applied to the most apical face of each slice, which was mounted in an

Table 1: *Compositions, Lot Numbers, and Manufacturers of the Resin Cement Systems*

Resin Cement Systems	Composition	Manufacturer
RelyX ARC/Adper Scotchbond Multi-plus	Silicon-treated ceramic, triethylene glycol dimethacrylate (TEGDMA), bisphenol A diglycidyl methacrylate (Bis-GMA); silicon-treated silica, functionalized dimethacrylate polymer: Lot No. FX8HW	3M ESPE
	Activator: ethylic alcohol, sodium benzenesulfinate: Lot No. 8LA	
	Primer: water, 2-hydroxyethyl methacrylate, polycarboxylic acid co-polymer: Lot No. 8BU	
	Catalyst: (1-methyl ethylidene) bis[4,1-phenylene oxi (2-hydroxy-3,1,-propanediyl)] bis methacrylate, 2-hydroxyethyl methacrylate, benzoyl peroxide: Lot No. 8BE	
RelyX U100	Base: glass fiber, methacrylate phosphoric acid esters, triethylene glycol dimethacrylate, silane-treated silica, sodium persulfate	3M ESPE
	Catalyst: glass fiber, substitute dimethacrylate, silane-treated silica, sodium *p*-toluenesulfonate, calcium hydroxide: Lot No. 415462	

apical to coronal direction, using a universal test machine (Emic DL 3000, Emic, São José dos Pinhais, PR, Brazil) with a 200-N load cell (CCE200N, Emic) and a speed of 0.5 mm/min. The maximal extrusion load (Newtons) was recorded (Tesc Version 3.05, Emic). To express the bond strength in MPa, the load was divided by the bond interface area obtained according to the following equation:

$$A = 2\pi rh,$$

where π is the constant 3.14, r is the post radius, and h is the slice thickness in millimeters.

Analysis of Failure

Following the push-out test, each specimen was photographed using a stereomicroscope (Zeiss, Jena, Oberkochen, Germany) at 40× magnification and the images were examined to establish the modes of failure. The modes of failure were assessed by two independent calibrated examiners (kappa=0.72; 95% CI=0.62-0.82) and classified as follows: 1) adhesive failure between dentin and cement; 2) adhesive failure between post and cement; 3) cement cohesive failure; and 4) mixed failure. Interexaminer disagreements were solved by consensus.

Statistical Analysis

The Kolmogorov-Smirnov test showed that the data did not assume a normal distribution (F=0.137; p=0.007), and the Levene test did not identify differences between variances (F=1.979; p=0.162). The nonparametric Kruskal-Wallis test was used to evaluate the effect of the light-curing access on the bond strength of the cements. The Mann-Whitney test was used to investigate differences between the two cements. Statistical analysis was performed using SPSS version 16.0 software (SPSS, Chicago, IL, USA) with a significance level of $\alpha = 0.05$ used in all tests.

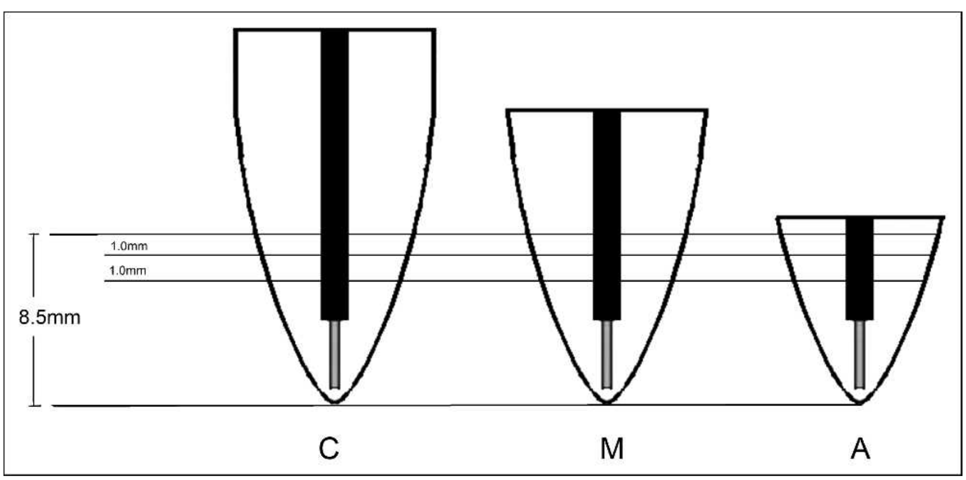

Figure 2. *Illustration of the root sections obtained from each group for the push-out test. C, coronal group; M, middle group; and A, apical group.*

Table 2: *Means (Standard Deviations) of Push-out Bond Strength in the Apical Third of Root Space Preparation (MPa) (n=10)*[a]

Light-curing Access	Resin Cement System	
	Mean (SD)	
	U100	ARC/SBMP
Coronal	8.95 (3.43) Aa	4.35 (3.50) Ba
Middle	8.05 (4.05) Aa	4.79 (2.15) Bab
Apical	9.29 (3.99) Aa	7.60 (3.83) Ab

[a] *Matching capital letters refer to equality in the same line (Mann-Whitney Test, $p \leq 0.05$). Matching lowercase letters refer to equality in the same column (Kruskal-Wallis Test, $p \leq 0.05$).*

RESULTS

Table 2 describes the means of the push-out bond strength (MPa) obtained from the experiment. The bond strength was significantly higher in groups C (p=0.028) and M (p=0.016) when U100 was used, whereas it was similar for both cements in group A. The light-curing access showed a significant effect on the bond strength only when ARC/SBMP was used (p=0.031). The bond strengths of posts cemented with ARC/SBMP were significantly higher in group A compared to group C but did not differ between the A and M groups.

In the failure analysis (Figure 3), the ARC/SBMP cement exhibited a predominance of adhesive failures between the cement and the dentin (95%) in groups C and M with one single mixed failure in each group (5%). Group A exhibited a reduction of adhesive failures between the cement and dentin (65%), an increase in mixed failures (20%), and adhesive failures to posts (15%). With regard to cement U100, group C exhibited 50% mixed failures, 45% adhesive failures to dentin, and 5% adhesive failures to posts; group M exhibited 65% mixed failures, 30% adhesive failures to dentin, and 5% adhesive failures to posts; and group A exhibited 50% adhesive failures to dentin, 35% mixed failures, 10% adhesive failures to posts, and one single cohesive failure on resin cement (5%).

DISCUSSION

The aim of the present study was to assess, by means of the push-out test performed 24 hours after cementation, the bond strengths in the apical third of the fiber posts cemented to root canals. The push-out test enables bond strengths to be measured at different sites and accurately represents the bonding

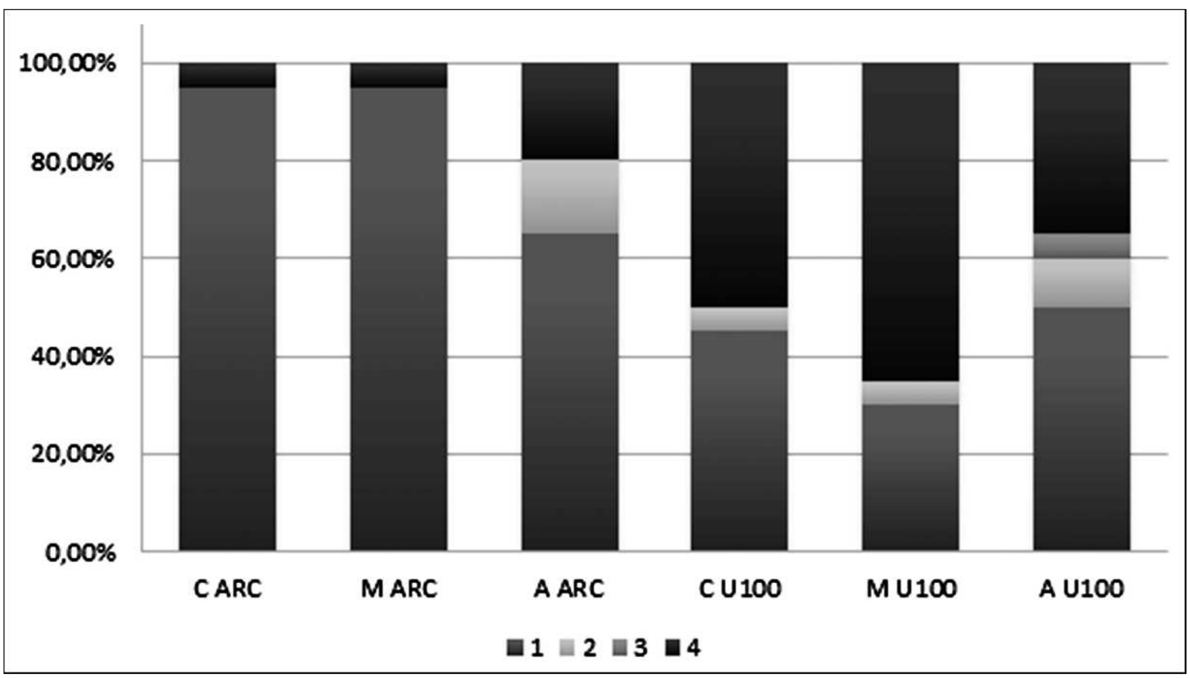

Figure 3. *Types of failures found (n=10). Legend: (1) Adhesive failures between dentin and cement; (2) adhesive failures between posts and cement; (3) cement cohesive failures; and (4) mixed failures.*

conditions of posts in root canals.[17] The photoactivation of resin cements across the entire root canal cannot be achieved in clinical practice. However, the experimental model used herein assumed the hypothetically ideal direct incidence of light on the three root sections to evaluate the effect of light access on bond strength in the apical third of the root. If the approach to light-curing close to the apex became clinically applicable (for instance, in the case of an effective translucent post), the effect of factors other than photoactivation could be further explored.

The null hypothesis of the present study (ie, that neither light access nor cement type influences the bond strengths in the apical third) was rejected. The results showed that ARC/SBMP performed best in the group in which light was directly applied to the apical third and that the U100 cement exhibited better bond strength compared to ARC/SBMP in the groups in which the light was not directly applied to the apical third.

The present study showed that the ARC/SBMP system exhibited lower bond strength in the apical third when the photoactivating light was applied to the coronal level. These results agree with those of previous studies[9-11] showing that dual-cure resin cements depend on photoactivation to achieve the highest values of conversion of monomers into polymers. It was suggested that such lower degrees of conversion result in lower bond strengths at those root-canal depth levels at which photoactivation is ineffective.[17-26,30] In the group in which the light was directly applied to the apical area of the root canal, the bond strength showed significant improvement. Studies have shown that in the apical third, dentin exhibits conditions that are less favorable for adhesion,[14,16] such as a lower number of dentinal tubules,[12-14] and a greater probability of presenting endodontic treatment remnants.[31] However, the results of the present study indicate that the bond strength may be more closely related to the photoactivation condition of RelyX ARC cement. The failure analysis showed that adhesive failures to dentin were predominant in the groups in which the light was not directly applied to the apical third, whereas in the groups in which photoactivation occurred at the apical third, the number of mixed failures increased from 5% to 20% and the occurrence of adhesive failures to posts was 15%. These results indicate that the bonding between the ARC/SBMP system and dentin was more effective in group A, in agreement with the push-out test results, which were higher in that group.

Resin cement U100 exhibited statistically similar values under all conditions investigated, in agreement with previous studies[17,25,26,32,33] that found uniform bond strength values at different root canal levels when U100 was used. In addition, compared to other types of dual cements, the U100 cement appears to polymerize more effectively at different root canal levels.[11] Compared to other self- and dual-cure cements, higher microhardness values were observed at different root canal levels when the U100 cement was used.[11] The performance of U100 at different root canal levels was similar to that of self-activated resin cements, indicating that U100 is likely less dependent on light to attain higher bond strength.[26] The lower variation exhibited by the failure patterns of the various U100 groups provides further evidence of its greater uniformity of adhesion to dentin independent of the site at which light is applied.

The high standard deviation observed in some groups, especially for ARC/SBMP, would be partially explained by the uncontrolled experimental effects such as the variations in the structure of root canal dentin, remnants of root canal obturation materials, moisture control inside the root canal, and technique sensitivity of adhesive application.

Conventional resin cements, such as ARC/SBMP, are based on total acid-etching or self-etching adhesive systems that are associated with low-viscosity resin composites. This multistep technique is complex and highly sensitive and may affect bond quality.[34] Conversely, U100 resin cement involves a simplified technique in which pretreatments of teeth and posts are not necessary.[15] In addition, U100 contains acidic monomers that demineralize and infiltrate the dental structure, thereby promoting micromechanical bonding, and a subsequent chemical reaction promotes integration with hydroxyapatite.[29,31,35] The results of the present study may reflect the effectiveness of that bonding mechanism inside the root canal.

CONCLUSIONS

The type of cement used and the light-curing access level influenced the bond strength between glass fiber posts and root canals. The bond strength of the RelyX ARC/SBMP cement proved to be more dependent on photoactivation than that of the RelyX U100 cement. The light-curing access level did not influence the apical bond strength of RelyX U100. This cement was shown to be suitable for cementing the fiber glass post evaluated in this study.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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