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Pullout Bond Strength of Fiber Posts Luted to Different Depths and Submitted to Artificial Aging

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Clinical Relevance

Increased depth of luting tended to improve the fiber post retention. The bond strength of the self-adhesive resin cement was less affected by aging than the conventional resin cement.

SUMMARY

Introduction: The extension of fiber post cementation often does not seem to influence the fracture resistance of restorations. This study evaluated the effects of cementation depths on the retention of fiber posts submitted to artificial aging.

Methods: One hundred and sixty bovine incisors were selected to assess post retention. Following endodontic treatment, the canals were flared with diamonds burs. Postholes were prepared in lengths of 5 or 10 mm, after which fiber posts were relined with composite resin and luted with RelyX ARC or RelyX Unicem. The samples were then submitted to thermal and/or mechanical cycling before testing their pullout bond strengths. Absence of cycling was used as a control. The results of

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each cement were submitted to two-way and *post hoc* Tukey tests (α=0.05).

Results: **Independent of the aging protocol, a depth of 10 mm showed higher pullout bond strength than did 5 mm, except for RelyX Unicem without cycling. For RelyX ARC, thermomechanical cycling resulted in lower values than in the absence of cycling. Mechanical cycling alone promoted the highest bond strength when the posts were luted with RelyX Unicem.**

Conclusion: **The effect of artificial aging on the pullout bond strength is dependent on the type of material and the depth.**

INTRODUCTION

Fiber posts are widely used to restore endodontically treated teeth, mainly when their remaining coronal tissue can no longer provide adequate support and retention for the restoration.[1,2] The low elastic modulus of a fiber post is considered to be advantageous for improving the performance of restorations in endodontically treated teeth, thereby reducing the occurrence of root fracture.[3-5] Another advantage of this low rigidity is that fiber posts do not need to be inserted into a length equal to or longer than the depth of the clinical crown to reduce the risk of root fracture.[6] This is advantageous with short roots or with roots presenting with a high degree of curvature.

Despite these advantages, post debonding is one of the most common failures in endodontics.[4] Post retention can be compromised by a mismatch between the diameters of the post space and the fiber post itself.[7-9] Prefabricated posts do not fit well into either elliptically shaped or flared canals that can result from carious extension, trauma, pulpal pathosis, or iatrogenic misadventure. Another cause of debonding is the complexity associated with bonding to root canals. Improper adhesion, which may arise from multistep procedures required for post bonding, can interfere with the ability of the luting materials to retain the post.[10,11] Therefore, easier-to-handle luting agents are gaining increased attention.[12]

Self-adhesive resin cements have been marketed to simplify clinical procedures and overcome the technique sensitivity of multistep systems. Self-adhesive cements do not require any pretreatment of the dental surfaces, as their application is accomplished via a single clinical step. The main adhesive mechanism of self-adhesive cements is attributed to a chemical reaction between phosphate methacrylates and hydroxyapatite.[12] Furthermore, although degradation of the bonding interface can occur during aging conditions,[13,14] self-adhesive cements have demonstrated adequate performance when used to lute fiber posts after thermal[15] and mechanical[16] cycling. However, this performance has not been evaluated involving posts luted at longer depths. Thus, it remains unclear whether post cementation to shorter extensions can compromise bonding stability.

The aim of the current study was to evaluate the effect of thermal and/or mechanical cycling on the pullout bond strength of posts luted to a depth of 5 or 10 mm. The null hypotheses were that the aging protocol and the depth of luting do not intervene with fiber post retention.

MATERIALS AND METHODS

One hundred and sixty extracted bovine incisors with similar root sizes and lengths were selected for this study. Regarding endodontic treatment, a step-back preparation technique was used; to flare the coronal and middle thirds of the canal, a #2 Gates Glidden drill was inserted several millimeters into the canal. This was repeated with #3 and #4 drills. Apical preparation was conducted with a final master apical file of size 40; the flaring of the canal was completed by filing to size 70. All enlargement procedures were followed by irrigation with a 2.5% sodium hypochlorite solution. The prepared root canals were filled with gutta-percha cones using the lateral condensation technique and Sealer-26 resin sealer (Dentsply Ind. Com. Ltda, Petrópolis, RJ, Brazil).

The coronal gutta-percha was removed with a heated Rhein instrument. To obtain standardized flared canals, they were enlarged using #4138 and #4137 high-speed diamond burs, (KG Sorensen, Ind. e Com. LTDA, São Paulo, SP, Brazil) under water irrigation. Two posthole depths were prepared: 5 or 10 mm. To facilitate handling, the roots were embedded in polystyrene resin blocks. Parallelism between the post and resin block was obtained using a parallel meter. A glass fiber–reinforced epoxy post system (Reforpost #3; Angelus, Londrina, PR, Brazil) was relined prior to the cementation procedures. The adhesive system Adper Single Bond 2 (3M ESPE, St. Paul, MN, USA) was applied and light cured over the previously silanized post. Afterward, the canal walls were lubricated with hydrosoluble gel before the fiber post was covered with resin composite Filtek Z-250 (3M ESPE) and inserted into the canal. The

Table 1: *Description of Cements Used in This Study and the Application Protocols*

Cement	Classification	Application Protocol
RelyX ARC	Conventional resin cement	The canal walls were etched with 35% phosphoric acid for 15 seconds, rinsed for 15 seconds, and gently air-dried. Excess water was removed from the post space with absorbent paper points. The Scotchbond Multipurpose Plus Activator was applied into the root canal with a microbrush of compatible size and air-dried for 5 seconds. Afterward, the Scotchbond Multipurpose Plus Primer, followed by Catalyst, were applied and air-dried. The dual-cured resin cement RelyX ARC was mixed and placed over the posts, which was inserted into the root canal with light pressure. The excess of luting material was removed, and light activation was performed for 40 seconds.
RelyX Unicem	Self-adhesive resin cement	The root canal walls were rinsed with water using a syringe and then gently dried with paper points. The cement was mixed and placed over the posts, which was inserted into the root canal with light pressure and inserted. The excess of luting material was removed, and light activation was performed for 40 seconds.

resin composite was light cured for 20 seconds, the relined fiber post was removed, and the resin composite was light cured for another 40 seconds. Copious rinsing removed the lubricant gel from the root canal.

The relined fiber posts were luted with a conventional resin cement RelyX ARC (3M ESPE) or RelyX Unicem clicker (3M ESPE). The cements used and the details of the luting procedures are described in Table 1. The samples were tested after being stored for 24 hours in 100% humidity or submitted to artificial aging. For the latter, samples were submitted to thermal and/or mechanical cycling. The designed number of cycles for thermal stress was 6,000 cycles using a thermocycling machine (521-4D, Nova Ética, Vargem Grande, SP, Brazil). Each cycle involved the immersion of samples in water at 5 ± 2°C followed by 55 ± 2°C, with a dwell time of 30 seconds for each bath. The transfer time between the baths was 2 seconds. For mechanical cycling, samples were positioned in a metallic base at a 45-degree angle (immersed in water at 37°C), and 1,200,000 pulses were induced with a force of 45 N at a frequency of 3.6 Hz in the aging testing machine (ER-11000, Erios Equipamentos Tecnicos e Cientificos Ltda, São Paulo, SP, Brazil). For thermomechanical cycling, samples were submitted simultaneously to both mechanical and thermal cycling as previously described in the thermomechanical aging testing machine (Erios Equipamentos Tecnicos e Cientificos Ltda).

The pullout test was performed parallel to the long axis of both the post and the tooth at a crosshead speed of 0.5 mm/min using a universal testing machine (Emic DL 1000, São José dos Pinhais, PR, Brazil). The load required to dislodge each post was recorded in kgF. Statistical analysis was performed by applying a two-way analysis of variance for each of the cements, followed by a Tukey *post hoc* test at a 95% confidence level.

RESULTS

The results of the pullout bond strength tests are shown in Table 2. For RelyX ARC, the factors "aging protocol" (p=0.01) and "depth of cementation" (p<0.001) were significant, whereas the interaction between the factors was not significant (p=0.55). Independent of the luting depth, the absence of cycling was associated with higher bond strengths than was observed after thermomechanical cycling. There were no differences observed between either the mechanical or the thermal aging protocols and the control. For all aging protocols, the highest bond strength was obtained when the posts were luted at a depth of 10 mm.

For the RelyX Unicem, the factor "depth of luting" (p<0.001) and the interaction between factors (p=0.03) were significant, whereas the factor "aging protocol" was not significant (p=0.58). At a depth of 5 mm, there was a difference between the aging protocols. The absence of cycling and thermomechanical cycling showed lower bond strengths than did mechanical cycling when the posts were luted at a depth of 10 mm. There was no difference between the luting depths in the absence of cycling. For all conditions, a depth of 10 mm promoted the highest fiber post retention.

DISCUSSION

The fiber posts in the present study were relined prior to cementation to standardize the thickness of

Table 2: *Means (SD) of Pullout Bond Strength in MPa (n=10)*[a]

Cement	Post Length	Cycling			
		Absence	Thermal	Mechanical	Thermomechanical
RelyX ARC	5 mm	32.5 (6.9) Ab	27.5 (8.2) ABb	24.2 (8.7) ABb	15.7 (5.6) Bb
	10 mm	40.0 (12.9) Aa	38.6 (18.1) ABa	34.6 (11.5) ABa	33.1 (12.5) Ba
RelyX Unicem	5 mm	31.1 (5.9) Aa	25.1 (9.5) Ab	26.1 (9.8) Ab	24.1 (6.6) Ab
	10 mm	40.3 (9.6) Ba	46.3 (14.8) ABa	55.5 (18.1) Aa	37.6 (10.2) Ba

[a] *For each cement, capital letters in the same line indicate differences for cycling type, whereas lowercase letters in the same column indicate differences for post length ($p<0.05$).*

the cement film.[8,17] Furthermore, higher adaptation between posts and root canal walls increases the sustained pressure during cementation and reduces blister formation in the cement.[18] Both multistep and self-adhesive resin cements were used in this study. RelyX ARC was used with the Scotchbond Multipurpose system, whereas the use of primer, catalyst, and activator can improve the polymerization of the cement.[19] However, techniques involving more cementation steps are in conflict with the overall trend of simplified adhesive techniques, with self-adhesive resin cements gaining increasing popularity.[12] In addition to bonding strategies, these materials present differences regarding composition that may help to explain the results observed in this study.

Considering that the aging protocol and depth of luting affected the fiber post retention, the null hypotheses were rejected. Independent of the cycling type, RelyX ARC showed the highest bond strengths when luted to depths of 10 mm. Several studies have demonstrated that the bond strengths of resin cements to root canals are more effective in cervical areas, with decreased strength toward the apical third.[10,20] Despite the low bond strengths in the more apical regions, extension of cementation depths may enhance the contact area between the cement and dentin. It also has been demonstrated that sliding friction contributes significantly to fiber post retention to root canals, with sliding friction being directly proportional to the contact area.[8,21]

For both cementation depths, thermomechanical cycling reduced the pullout bond strength when RelyX ARC was used, while neither thermal nor mechanical cycling alone altered the bond strength. Thermal and mechanical aging protocols generate stress that can disrupt the bonding interface.[14] However, these aging protocols may not be able to promote bond strength reduction individually.[16,22] In contrast, samples submitted to both mechanical and thermal cycling received higher stress, which may explain the lowest pullout bond strength observed. Similar post retention reduction after thermomechanical cycling was demonstrated in a previous study.[14]

Different from RelyX ARC, the aging protocol influenced the pullout bond strength for RelyX Unicem only when the fiber posts were luted at depths of 10 mm. One possible explanation is that alterations promoted by cycling altered the frictional retention, which significantly influenced post retention only for longer cementation depths. Interestingly, samples submitted to mechanical cycles showed the highest post retention values, while the absence of cycling and thermomechanical cycling resulted in the lowest bond strengths. Despite the stress generated by cycling, the maintenance of samples in water during the cycles may have promoted cement expansion, increasing the frictional retention along the root canal.[23] This would occur only with RelyX Unicem, as its components include glass ionomer cements.[12] Furthermore, unlike conventional resin cements, self-adhesive cements chemically bond to dentin, which can improve the hydrolytic stability of the bonding interface.[24]

Despite a positive effect of cement expansion, significant improvements in bond strength were observed only when the samples were submitted to mechanical cycling. It is possible that mechanical cycling enabled the increased penetration of water in the interface between the resin cement and dentin than did thermal cycling, resulting in greater hygroscopic expansion. Nevertheless, the combination of thermal and mechanical cycling can promote excess stress in both the bonding interface and the cement. This can result in debonding and reduction in the cohesive resistance of the resin cement, explaining the lowest bond strengths observed when the samples were submitted to this aging protocol. In conclusion, self-adhesive resin cements seem to present a higher stability with artificial aging, while the cementation depth influences the longevity of the cementation.

CONCLUSIONS

Within the limitations of the current study, the following conclusions can be drawn:

- Increased cementation depth improved the post retention luted with RelyX ARC, while only the combination of thermal and mechanical cycling was able to reduce the bond strength.
- The aging protocol affected the bond strength of fiber posts luted with RelyX Unicem only at 10 mm depth. At this depth, thermomechanical cycling reduced the post retention.

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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