The influence of different cements on the pull-out bond strength of fiber posts

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Statement of problem. Glass fiber posts are commonly used to provide adequate support and retention for the restoration of endodontically treated teeth, but their resistance to dislodgement depends on their adhesion to root dentin.

Purpose. The purpose of this study was to assess the effect of cement type on the pull-out bond strength of fiber posts.

Material and methods. Seventy maxillary canines were endodontically treated and then divided into 7 groups according to the cement used for fiber post cementation as follows (n=10): RelyX Unicem, BisCem, RelyX Luting 2, RelyX ARC, Panavia F, Enforce, and Allcem. The specimens were subjected to a pull-out bond strength test in a universal testing machine at a crosshead speed of 0.5 mm/min. The results, in newtons, were analyzed with 1-way ANOVA and the Tukey post hoc test (α=.05).

Results. RelyX Unicem (472.3 ±8.9 N), BisCem (506.6 ±9.2 N), RelyX ARC (498.0 ±8.2 N), Panavia F (502.3 ±7.0 N), and Allcem (470.0 ±11.3 N) presented significantly higher bond strength than RelyX Luting 2 (241.8 ±9.70 N) and Enforce (309.5 ±6.3 N) cements (mean ±SD; $P<.05$).

Conclusions. Except for Enforce, all resin cements produced pull-out bond strength values twice that of resin modified glass ionomer cement. However, all cements promoted adequate retention to fiber posts to withstand functional loads.
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Clinical Implications

Resin cements produced the highest pull-out bond strength values; however, resin modified glass ionomer cement may also be useful in patients who are susceptible to caries and in situations in which moisture control is difficult, because it promoted pull-out values superior to those needed to withstand functional loads.

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Fiber-reinforced composite resin posts (FRC) are commonly used to provide adequate support and retention for the restoration of endodontically treated teeth. FRCs have a similar elastic modulus to dentin; such a characteristic promotes favorable stress distribution and reduces the prevalence of catastrophic failures (root fracture beneath the bone level and longitudinal fractures).[1] Because FRCs are passively retained inside the root canal, the introduction of adhesive resin cements has encouraged studies of the adhesion at the post-cement-dentin interfaces.[2,3] The resistance to dislodgement achieved by fiber posts depends on their adhesion to root dentin.[4]

Numerous cements and adhesive approaches have been proposed to bond FRCs to root dentin.[5-9] Dual-polymerizing resin cements associated with previous dentin conditioning (2- or 3-step etch and rinse adhesive systems) have achieved high bond strengths.[10] The hybridization of root dentin that occurs after removing the smear layer with acid etching and the chemical polymerization of dual-polymerizing adhesives are responsible for the adhesiveness of dual-polymerizing resin cements.[11] However, some etch-and-rinse protocols are strongly dependent on the degree of residual moisture on dentin surfaces, which is difficult to control.[12] The introduction of self-adhesive cements emerged as an alternative to conventional dual-polymerizing resin cements because they contain the ideal water content.[12-16] This eliminates the critical drying step and makes post cementation less time consuming.[10]

Recently, glass ionomer (GIC) and resin modified GIC cements (RMGIC) have been investigated for cementation of FRCs.[13,17] The major advantage of GICs and RMGICs is their post-maturation hygroscopic expansion, which offsets their initial setting shrinkage, and the interface dentin-cement remains more stable.[18,19] Thus, the residual water within dentinal tubules may be advantageously used to achieve postmaturation hygroscopic expansion of GICs and RMGICs that are used for FRC cementation.[20,21] The lack of long-term clinical results indicates a need for additional investigation of the adhesion of FRCs to root dentin to develop a better understanding of its behavior when used for the restoration of endodontically treated teeth. The purpose of this study was to assess the bond strength of FRCs cemented with different agents to root dentin by using a pull-out test. The null hypothesis was that the cement composition does not affect the bond strength of FRCs to root dentin.

MATERIAL AND METHODS

Seventy maxillary canines with straight roots and a single canal were selected for this study. All teeth were obtained from a tooth bank after project approval by the ethical committee of the University of Southern Santa Catarina. The roots were cut transversally to obtain a remaining root length of 15 mm. Before endodontic preparation, the specimens were embedded in epoxy resin (Silaex) to facilitate the root canal preparation and the FRC cementation. The parallelism between teeth and resin blocks was achieved with a surveyor (Bioart).

The canals were flared at their coronal and middle thirds by using Gates Glidden drills of 3 sizes: the no. 2 drill to a depth of 10 mm, the no. 3 drill to 7 mm, and the no. 4 drill to 5 mm. Next, all canals were hand prepared with K-files up to a master file size 55 (K-file; Dentsply Maillefer) at a working length of 1 mm from the anatomic apex. After each file change, the canals were alternately irrigated with 3 mL of 1% sodium hypochlorite and 1 mL of 17% EDTA (Pulpdent). Final irrigation was performed with 2 mL of saline solution. The irrigants were delivered with a disposable 5 mL syringe (Ultradent Products Inc) and a 30-gauge needle (Endo Eze Tip; Ultradent Products Inc). The needle was introduced to 1 mm from the working length to allow back flow for the irrigant. The roots were dried with paper points (Tanari; Tanariman Industrial LTDA) and then filled with a resin sealer (Sealer 26; Dentsply Maillefer) and gutta percha cones with the lateral condensation technique. All roots were stored in 100% humidity at 37°C for 1 week to allow the sealer to set. After a 1-week storage period, the gutta percha was partially removed with a heated instrument (Rhein). Next, a post space was prepared with a drill equivalent to an FRC size no. 2 (White Post DC kit; FGM) to a depth of 10 mm. After post space preparation, the canals were flushed with 2 mL of 1% NaOCl and 2 mL of saline solution. The length of the size no. 2 FRC (WhitePost DC; FGM) (1.8 mm diameter at the coronal portion and 1.05 mm at the apical portion) was standardized to 14 mm that 4 mm of the post remained above the root to facilitate the pull-out test. Thereafter, the FRC were cleaned with 95% ethyl alcohol and air-dried.

All roots were divided into 7 groups (n=10) according to the type of cement and the protocols of cementation (Table I). All cements were manipulated according to the manufacturers' instructions. RelyX Luting 2, RelyX ARC, Panavia, Enforce, and Allcem were delivered into the post space with a Lentulo spiral. The other cements were delivered with special tips. The FRC were positioned into the post space and the excess cement was removed with a microbrush before light polymerizing. Except for RelyX luting 2, all cements were light polymerized for 40 seconds with a light source with a power of 600 mV/cm^2 (Bisco Inc) at the coronal aspect. The power of the light source was measured with a radiometer before each post cementation (Optilux Radiometer; Sds Kerr). Afterward, the specimens were stored on wet gauze at 37°C for 24 hours.

The pull-out test was performed parallel to the long axis of the post at a cross-head speed of 0.5 mm/min with a universal testing machine (Kratos). The force required to dislodge the FRC was recorded in newtons. The Kolmogorov-Smirnov test, Levene test,

Table I. Trade name of cements, manufacturer, type of cement, batch number, and protocol of cementation

Cement Manufacturer	Type of Cement	Batch No.	Protocol of Cementation
RelyX Unicem (3M ESPE)	Self-adhesive resin cement	365022	(1) Root canal walls were gently dried with paper points; (2) cement capsule was activated for 2 s (Aplicap, 3M ESPE) and mixed automatically in high-speed triturator (Rotomix, 3M ESPE) for 10 s; (3) resin cement was applied into root canals by means of Elongation Tip (3M ESPE) and FRC was placed in canal.
BisCem (Bisco)	Self-adhesive resin cement	900012320	(1) Root canal walls were rinsed with water with syringe and then gently dried with paper points; (2) auto-mix dual-syringe delivered cement with Endotips (RTD), and finally, posts were inserted into canal.
RelyX luting 2 (3M ESPE)	Resin-modified glass ionomer	WM9RR	(1) Root canal walls were gently dried as described before; (2) cement was mixed for 10 s and inserted into canal; (3) post was positioned into canal with light pressure and stabilized for 2 min.
RelyX ARC (3M ESPE)	Dual polymerized resin cement	gx9jk	(1) Canal walls were etched with 35% phosphoric acid for 15 s, rinsed for 30 s, and gently air-dried with paper points; (2) Single Bond (3M ESPE) was applied in dentin walls with microbrushes and air-dried for 5 s, and light polymerization for 20 s; (3) cement was mixed and inserted into canals and then posts were positioned with light pressure.
Panavia F (Kuraray)	Dual polymerized resin cement	051214	(1) Panavia F 2.0 ED PRIMER II A&B (Kuraray) adhesive system was applied with microbrush; after 1 min, excess of adhesive was removed with air spray and paper points; (2) equal amounts of A Paste and B Paste were dispensed and mixed.; cement was mixed and inserted into canals; (3) posts were inserted into canals.
Enforce (Dentsply Maillefer)	Dual polymerized resin cement	179683B activator, 170524B base	(1) Canal walls were etched with 35% phosphoric acid for 15 s, rinsed for 30 s, and gently dried with paper points; (2) posts were coated with A and B silane; (3) Adhesive Prime Bond 2.1 was mixed with Self Cure Activator (Dentsply) and applied over dentin for 30 s and light polymerized for 20 s; (4) cement was proportioned and manipulated and inserted into canals.
Allcem (FGM)	Dual polymerized resin cement	200111	(1) Canals were etched with 35% phosphoric acid for 15 s, rinsed for 30 s, and dried with paper points; (2) Single Bond was applied in dentin walls and air-dried for 5 s, then light polymerized for 20 s; (3) posts were coated with Prosil (FGM) silane; (4) cement was manipulated and inserted into canals with Lentulo spiral.

Table II. Mean pull-out bond strength (N) and standard deviations (SD) for tested cements[a]

Cement	Biscem	Panavia	RelyX ARC	RelyX Unicem	Allcem	RelyX Luting 2	Enforce
Bond strength, mean (SD)	506.6 ±9.2 N[a]	502.3 ±7.0 N[a]	498.0 ±8.2 N[a]	472.3 ±8.9 N[a]	470.0 ±11.3 N[a]	241.8 ±9.7 N[b]	309.5 ±6.3 N[b]

[a,b]Same lowercase letters mean that there were no statistical differences among groups ($P>.05$).

1-way ANOVA test, and Tukey post hoc test ($\alpha=.05$) were used. Because the post spaces all had the same length and surface area, the force, in newtons, was not divided by the surface area.

RESULTS

The pull-out bond strengths for all the cements evaluated are shown in Table II. The Kolmogorov-Smirnov test confirmed the normality ($P=.27$) and the Levene test confirmed the equal variance ($P=.86$) of the data. One-way ANOVA showed that the pull-out bond strength was significantly affected by the cement ($P<.05$) (Table III). FRC cemented with BisCem, Panavia F, RelyX ARC, and RelyX Unicem had significantly higher bond strength values than those obtained with RelyX Luting 2 and Enforce ($P<.05$, Tukey post hoc test). Failure modes are described in Table IV.

DISCUSSION

This study assessed the effect of cement type on the pull-out bond strength of fiber posts. The null

TABLE III. One-way ANOVA

ANOVA	*df*	F	*P*
Cements	6	115068.378	.001
Residual	63	77.390	
Total	69		

TABLE IV. Failure modes (as percentages) for all groups

Cement Failure	Biscem	Panavia	RelyX ARC	RelyX Unicem	Allcem	RelyX Luting 2	Enforce
Adhesive between cement-dentin	60	100	100	70	100	80	100
Cohesive	40			30		20	

hypothesis was rejected because differences were found between the bond strength of FRC cemented with the tested cements ($P<.05$). GICs and RMGICs set with 2 different reactions. The first reaction consumes all the water available in their composition. The second reaction uses water from other sources, such as from the dentin tubules.[18] Initially, the water absorption leads to a slight setting contraction, but subsequent hygroscopic expansion causes an increase in volume after the material matures.[20] The hygroscopic expansion plays an important role in the retention of FRC because it enhances the frictional resistance to post dislodgment in materials such as GICs with low adhesive strength.[19] In this study, the teeth were manipulated with wet gauze during all laboratory procedures. In addition, care was taken not to dehydrate the dentin before post cementation. Even so, RelyX Luting 2 exhibited low pull-out bond strength. Pereira et al[17] found higher bond strength values when fiber posts were cemented with GICs than with dual polymerizing cements. This result may be explained by the teeth remaining immersed in water during all cementation procedures and for 1 week after cementation. Procedures that may have provided the necessary water for the second reaction could explain why 80% of specimens failed because of adhesive failure between the cement and dentin.

In this study, the lower retention of RelyX Luting 2 may be linked to the lack of a previous acid conditioning to alter or remove the smear layer within the root canal before applying the cement.[2] However, this study followed the manufacturer's guidelines for RelyX Luting 2, which do not recommend an acidic treatment before cementation. Possibly, the use of wet gauze did not provide sufficient water for the second reaction.[17]

Dual-polymerizing resin cements (RelyX ARC, Allcem, Panavia, and Enforce) have produced high adhesion to root dentin,[2,5,6,16] even with their shrinkage during the polymerization reaction. The association between shrinkage and unfavorable features of the root canal may lead to high stress areas at the post-cement and dentin-cement interfaces.[14] Post spaces have high C factors. The higher the C factor, the higher is the stress at the interface during polymerization reaction.[6] However, despite being a dual-polymerized material, deeper portions of cement are inaccessible to light and make the cement dependent on the chemical polymerization. However, chemical polymerization can reduce the degree of conversion of the cement and consequently affect its mechanical properties.[2] Although in this study a 2-step adhesive system was used (Single Bond), the results agree with Macedo et al,[2] who used a 3-step etch and rinse adhesive system. The use of a primer that is activated before the insertion of the cement enhances the polymerization reaction of the cement because the activator generates additional free radicals.[7] This fact could also explain why all specimens with these cements presented adhesive failure between cement and dentin.

The variation in results obtained with different resin cements can be partially explained by the multiple factors that may affect the retention of fiber posts. According to Ferrari et al,[8] the critical steps in adhesive systems are the light-polymerization process, root anatomy, tooth position in the arch, operator experience, and the presence of residual acid. Moreover, despite the use of a clinical operative microscope in endodontics, in this study, the root canal filling was removed without a microscope. Residual root filling will impair the adhesion of fiber posts to root dentin.[9]

The high mean pull-out forces of posts cemented with self-adhesive cements (Rely X Unicem and BisCem) are in agreement with previous reports.[2,3,10,12,17] Self-polymerizing cements present multifunctional monomers with phosphoric acid groups, which demineralize and infiltrate the root dentin. According to Radovic et al,[16] the setting reaction results in extensive cross linking of monomers and the creation of high-molecular-weight polymers. To neutralize the acid system, the pH increases from 1 to 6 because phosphoric acids react with alkaline fillers and with tooth apatite. In this process, water is formed, which contributes to the cement's hydrophilicity, which leads to a better adaptation to root canal walls and moisture tolerance.[16] Theoretically, water is reused by reacting with acidic functional groups and during the cement reaction with ion-releasing basic filler particles. Such a reaction would finally result in a more hydrophobic matrix. In this study, the high adhesion values obtained with self-polymerizing cements were probably due to the micromechanical retentions within the hybrid layers and the chemical interaction between monomer acidic groups and hydroxyapatite; this could explain the cohesive failures found with these cements.[16]

The maximum pull-out force test does not completely simulate clinical conditions. Low intermittent mechanical forces from different directions would better simulate masticatory forces.[5] Such test designs generally are performed after the complete restoration of the endodontically treated teeth (post, core, and crown). Clinically, the complex dentin-cement-post is subjected to forces from many directions. This study was not designed to answer all these questions. Thus, further studies must investigate the effect of the long-term mechanical cycling and thermocycling of endodontically treated teeth restored with cores and crowns.

CONCLUSION

Within the limitations of this study, it can be concluded that the resin cements evaluated in this study provided adequate retention to fiber posts. Although resin cements produced higher pull-out bond strength values that were twice that of resin-modified glass ionomer, RMGICs might be useful in patients susceptible to caries and in situations in which moisture control is difficult.

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