Push-Out Bond Strength Evaluation of Glass Fiber Posts With Different Resin Cements and Application Techniques

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Clinical Relevance

Conditioning with 37% phosphoric acid prior to self-adhesive cementation of glass fiber posts, applied with an elongation tip, may offer higher push-out strength compared with other cementation methods for improved clinical longevity.

SUMMARY

The purpose of this study was to evaluate the push-out strength of two different adhesive cements (total etch and self-adhesive) for glass fiber post (GFP) cementation using two differ-ent techniques (microbrush and elongation tip) of cement application. In addition, this study evaluated the effect of total-etch condi-tioning before the use of a self-adhesive ce-ment. Sixty premolar specimens with a single root canal were selected, endodontically treat-ed, and shaped for GFP cementation. The specimens were randomly placed into one of six groups according to the cement and tech-nique used: RelyX ARC (ARC): ARC + micro-brush, ARC + elongation tip; RelyX Unicem (RU): RU + microbrush, RU + elongation tip; or RelyX Unicem + 37% phosphoric acid (RUE):

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RUE + microbrush, RUE + elongation tip. Each specimen root was cut perpendicular to the vertical axis yielding six 1.0-mm-thick sections. Push-out strength test was performed, followed by statistical analysis using three-way analysis of variance and the Games-Howell test ($p<0.05$). Statistically significant differences between the groups were found ($p<0.05$). 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 elongation technique produced higher mean push-out strength values compared to the microbrush technique. The self-etch adhesive cement had the highest mean push-out strength value in all thirds. The addition of a conditioning step before the self-etch adhesive cementation appears to be effective in enhancing push-out strength with GFPs.

INTRODUCTION

Glass fiber posts (GFPs) can be used in endodontically treated teeth for indications requiring additional support of core materials and future indirect prostheses.[1] GFPs have a lower modulus of elasticity compared to metal posts and therefore have the advantage of dissipating stress along the post length.[1] This characteristic is different from metal posts with a higher modulus of elasticity that concentrate the stress in the apical third of the root.[2,3] With that in mind, it has been reported in the current literature that the use of GFPs may reduce the occurrence of root fractures compared to rigid metal posts.[1-3]

GFP cementation can be performed with various resin cements that can be classified by the polymerization mode (light cure, chemical cure, and dual cure) and conditioning requirements (total etch and self-adhesive). Due to the difficulty associated with penetration of the light to the apical third of the root, purely light-cured cements are seldom used for GFP adhesion.[4-6] Chemically-cured cements have the disadvantage of limited working time and are difficult to use in the hands of a novice.[7] For these reasons, the best option for GFP cementation is a dual-cure cement. In addition to having the advantages of command light-cure cements, dual-cured cements also contain chemical initiators for deep areas where light access is difficult to achieve.[7] However, there have been some problems reported in the current literature related to total-etch dual-cure cements, which require conditioning with 37%

phosphoric acid and the application of the elected bonding system in the root canal prior to cementation. For instance, the complexity of multiple steps and technique sensitivity can cause incomplete post seating, microleakage, and debonding.[8,9]

To decrease the numbers of steps and simplify the cementation process, a self-adhesive dual-cure cement was developed. This cement has just one step (no need for conditioning or bonding system), and it has demonstrated similar bonding performance when compared to other resin-based cements.[10-15] However, incorporating all components into one bottle (phosphoric acid, primer, adhesive, and cement) requires a lower acid concentration, which may cause limited demineralization and hybridization of root dentin.[16,17]

According to the current published literature, another potential problem related to GFP adhesive cementation is the technique used for application of the adhesive cement into the root canal.[18-20] To ensure homogeneity of cement distribution, application techniques should pay particular attention to avoid the introduction of trapped air within the cement layer.[18] Defects of any kind within the cement can cause localized high-stress areas that could initiate crack propagation at relatively low applied loads.[19,20]

There have been some modifications of manufacturer recommendations in the current literature that have been shown to improve clinical bond strength.[21,22] One example is modification of the adhesive application technique of self-etching bonding agents to both enamel and dentin. When total-etch conditioning techniques (30-second conditioning with phosphoric acid and water rinse) were used with self-etching adhesive materials, higher bond strength values were obtained *in vitro*.[21,22] This same concept can be considered for cementation of GFPs with self-adhesive cements.

The purpose of this study was to evaluate the push-out strength of two different adhesive resin cements (total etch and self-adhesive) for GFP cementation using two different techniques (microbrush and elongation tip) of cement application. In addition, this study evaluated the effect of a conditioning step before the use of a self-adhesive resin cement. The null hypotheses tested were as follows: 1) there will be no statistically significant difference in GFP push-out strength between the total-etch and the self-adhesive resin cements, 2) there will be no statistically significant difference between the different resin cement GFP push-out

strengths among different root thirds, 3) there will be no statistically significant difference between the different adhesive resin cements in terms of application techniques on GFP push-out strength, and 4) there will be no difference in GFP push-out strength in comparing the use of an elective conditioning technique prior to self-adhesive resin cements compared to the use of self-adhesive resin cements alone.

METHODS AND MATERIALS

Sixty human premolar teeth meeting the inclusion criteria with a ≥18-mm single root canal were selected for the study. Exclusion criteria were the presence of resorption, caries, root fractures, or previous endodontic treatment. The teeth were sterilized, numbered, radiographed, and stored in 10% thymol during the study to prevent dehydration.

The root canal systems were accessed through the occlusal surface under a copious amount of water and located using a #15 K-file (Senseus K-Flexofile, Dentsply, Maillefer, Switzerland). Working length of the root system was determined to be 1 mm from the root apex and verified with an apex locator. The root canals were shaped by rotary instruments (ProTaper system, Dentsply) sequenced in order (SX, S1, S2, F1, F2) applying the crown-down technique. Irrigation was performed with 1 mL of 6% sodium hypochlorite (NaOCl) solution (Vista Dental, Racine, WI, USA), using a syringe and a 27-gauge needle throughout progression of file sizes. Final irrigation was done with 17% ethylene diamine tetra acetic acid (EDTA; Vista Dental) for one minute followed by 6% NaOCl solution for one minute. The root canals were obturated using a warm vertical condensation technique performed with gutta-percha cones (Protaper F2, Dentsply DeTrey Gmbh, Konstanz, Germany) and root canal sealer (AH-Plus, Dentsply DeTrey).

A careful demineralization and tubule opening of the root dentin with ultrasonic instrumentation in association with EDTA was performed. Post spaces were prepared to depths of 10 mm, leaving an apical seal of 5 mm of gutta-percha in the canal space. A series of sequential reamers provided for GFP #2 (Rely-X Fiber Post, 3M ESPE, St Paul, MN, USA) were used for this process. The specimens were randomly assigned into one of six groups under three different adhesive cement procedures: RelyX ARC (ARC): ARC + microbrush, ARC + elongation tip; RelyX Unicem (RU): RU + microbrush, RU + elongation tip; or RelyX Unicem + 37% phosphoric acid (RUE): RUE + microbrush, RUE + elongation tip (all 3M ESPE).

All GFP surfaces were cleaned with 70% isopropyl alcohol (Cumberland Swan, Smyrna, TN, USA) and air-dried. The root canal systems were treated with 2% chlorhexidine solution (VEDCO, St Joseph, MO, USA), irrigated with water, and slightly dried prior to the cementation process.

For adhesive cementation, all manufacturer recommendations were followed for each material according to Table 1. After cementation, all teeth were light cured for 60 seconds (Optilux 500, Kerr Corp, Orange, CA, USA) on the occlusal surfaces.

After cementation of the GFPs, the roots of each specimen were cut perpendicular to the vertical axis by means of a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) under copious amounts of water. Six 1.0-mm slices for each root were obtained, which were then separated into three different subgroups by specimen area (two cervical, two middle, and two apical; see Figure 1).

The push-out test for each specimen section was performed with a Universal Testing Machine (#8841, Instron, Canton, MA, USA) at a crosshead speed of 0.5 mm/min. The push-out test load was applied in an apical to cervical direction until the post dislodged from the specimen. The push-out strength values were measured at failure and recorded in MPa ± standard deviation.

Statistical Analysis

The push-out strength values were measured at failure and recorded in MPa ± standard deviation. Inferential statistical analysis of the data was evaluated using three-way analysis of variance (ANOVA) and the Games-Howell test ($\alpha=0.05$) to compare cement types, application techniques, and root thirds (SPSS version 20.0, SPSS, Chicago, IL, USA).

RESULTS

The three-way ANOVA comparing multiple independent and dependent variables showed statistically significant differences among all groups independent of cement type, application technique, or root third ($p=0.000$; $p<0.05$). The descriptive statistics are given in Table 2, with statistical differences noted by different uppercase letters in columns and different lowercase letters in rows.

In evaluating root thirds, the cervical third displayed the highest push-out strength values,

Table 1: *Groups, Composition, Root Canal Treatment, and Techniques of the Cement Application for All Materials Used in the Present Study*

Adhesive Cement	Cement Composition	Conditioning	Procedures	Cement Application
RelyX ARC (ARC)	HEMA, bisGMA, dimethacrylate resins, methacrylatemodified polycarboxylic acid copolymer, photoinitiator/water, ethanol	Yes	Etching with 37% phosphoric acid for 15 s Rinsing with 10 mL of distilled water Removing water excess with paper point #80	Application of the adhesive cement into the root canal with a microbrush Application of the adhesive cement on the post Insertion of the post into the root canal Light cure for 60 s
			Irrigation with 2% chlorhexidine Removing water excess with paper point #80 Application of multistep adhesive system	Insertion of the cement with the elongation tip Insertion of the post into the root canal Light cure for 60 s
RelyX Unicem (RU)	Methacrylated phosphoric esters, dimethacrylates, acetate, initiators, stabilizers, glass fillers, silica, calcium hydroxide	No	Rinsing with 10 mL of distilled water Removing water excess with paper point #80 Irrigation with 2% chlorhexidine Removing water excess with paper point #80 Capsule activation	Application of the adhesive cement into the root canal with a microbrush Application of the adhesive cement on the post Insertion of the post into the root canal Light cure for 60 s
				Insertion of the cement with the elongation tip Insertion of the post into the root canal Light cure for 60 s
RelyX Unicem + etching (RUE)	Methacrylated phosphoric esters, dimethacrylates, acetate, initiators, stabilizers, glass fillers, silica, calcium hydroxide	Yes, optional	Etching with 37% phosphoric acid for 15 s Rinsing with 10 mL of distilled water Removing water excess with paper point #80	Application of the adhesive cement into the root canal with a microbrush Application of the adhesive cement on the post Insertion of the post into the root canal Light cure for 60 s
			Irrigation with 2% chlorhexidine Removing water excess with paper point #80 Capsule activation	Insertion of the cement with the elongation tip Insertion of the post into the root canal Light cure for 60 s

and the apical third showed the lowest push-out strength values independent of the cement type or cement application procedure ($p<0.05$) The cervical thirds were statistically higher than both the middle thirds and the cervical thirds.

When comparing the different cement application techniques according to root thirds, statistically significant differences were found ($p<0.05$). In the apical third, ARC with the elongation tip and the microbrush differed significantly ($p=0.000$), RU with the elongation tip and the microbrush differed significantly ($p=0.000$), and RUE with the elongation tip and the microbrush differed significantly ($p=0.000$). In the cervical third and middle thirds, only the RU with the elongation tip and the microbrush differed significantly ($p=0.000$). The ARC and RUE application technique in the cervical and middle thirds did not differ significantly.

When comparing cement types, application techniques, and root thirds, the RU group showed significantly higher push-out strength values in all

thirds and application techniques compared to the ARC groups ($p<0.05$). For the RUE, when adding an additional conditioning step (total etch), the push-out strength values obtained were statistically
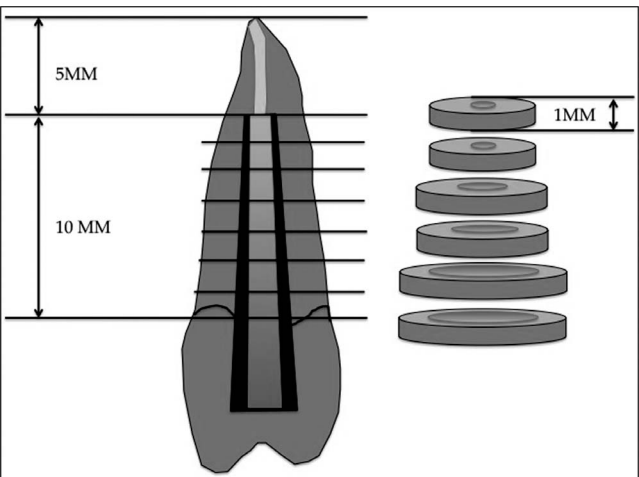

Figure 1. *Sectioning of the cemented glass fiber posts into six slices (two cervical, two middle, and two apical).*

		Study Results		
Groups	**Techniques**	**Apical Third**	**Middle Third**	**Cervical Third**
RelyX ARC (ARC), n = 20	Microbrush n = 10	3.95 ± 1.82 Dc	7.09 ± 2.06 Db	10.44 ± 1.89 Da
	Elongation tip n = 10	5.85 ± 1.53 Cc	8.24 ± 1.70 Db	11.13 ± 2.40 Da
RelyX Unicem (RU), n = 20	Microbrush n = 10	7.23 ± 3.07 Cc	11.32 ± 2.55 Cb	14.81 ± 3.45 Ca
	Elongation tip n = 10	9.42 ± 1.21 Bc	14.97 ± 1.94 Bb	18.68 ± 2.01 Ba
RelyX Unicem + etching (RUE), n = 20	Microbrush n = 10	9.34 ± 3.26 Bc	17.19 ± 3.36 Ab	21.57 ± 3.08 Aa
	Elongation tip n = 10	14.72 ± 3.03 Ac	18.61 ± 2.53 Ab	22.17 ± 2.83 Aa

Table 2: *Descriptive Statistics (Mean Group Push-Out Strength [MPa] ± Standard Deviation [MPa]) With Statistical Differences Noted by Different Uppercase Letters in Columns and Different Lowercase Letters in Rows[a]*

[a] *Groups connected by the different uppercase letters in columns and different lowercase letters in lines represent statistical different (p<0.05).*

significantly higher for both application technique and root thirds.

DISCUSSION

According to Dietschi and others,[1] prefabricated GFPs, due to their lower modulus of elasticity and inherent flexibility, help to distribute stress more uniformly to the entire root surface. In this study, a double-tapered GFP was utilized. Precise fitting of the tapered GFP into the endodontic canal avoids the need for a wider preparation, preserving dental hard structure in the apical third, where the anatomical root form narrows.[23]

The postspace preparation in the root canal system is a critical step, as it can be difficult to completely remove all gutta-percha filling materials. Aggressive removal often leads to an oversize post-space preparation, which has been documented in the current literature as the most frequent cause of adhesive or cohesive failure.[23] In this study, careful removal of gutta-percha and the tubule opening of the root dentin with ultrasonic instrumentation in association with EDTA was performed.[24] Final irrigation was performed with a 2% chlorhexidine solution, which has demonstrated antibacterial properties in the current literature, restricting microbial ingress into dentinal tubules.[25] In the current literature, chlorhexidine also has been shown to have the ability to inhibit matrix metalloproteinases,[26] preserving composite-dentin hybridization over time.[27] GFPs were disinfected with alcohol only prior to cementation. No acid conditioning or sand blasting was performed prior to the cementation of the GFPs due to reports of the structure weakening.[28]

Considering the structural variability of the dentinal substrate inside the root canal, the push-out strength test allows for a more accurate analysis of the overall bonding mechanism and the ability to better simulate a clinical scenario.[29] Considering the push-out strength of the three different resin cements, the null hypothesis was rejected. The results showed that the total-etch adhesive cement (ARC) had lower push-out strength values to dentin when compared with the self-adhesive cement (RU), similar to the findings of previous studies.[12,13,15,30] However, other research has reported higher bond strength values for the total-etch adhesive cement when compared with the self-adhesive cement.[31-33] Conflicting results between the different luting cements can be explained by variability in research methodology and the lack of a systematic review in the current published literature.[8] Additionally, the complexity of a clinical technique utilizing multiple steps can cause inherent problems, including the introduction of operator error and subsequent failure.

The self-adhesive cements are only mildly acidic, resulting in limited demineralization and hybridization of the root system dentin.[34] However, even with limited hybridization,[17] the push-out strengths in this study are statistically higher than that of the total-etch adhesive cements. These results can be explained by the fact that the chemical interactions between the adhesive cement and hydroxyapatite may be more important for root dentin bonding than the ability to hybridize dentin.[13] According to the current literature, this interaction is based on calcium ion chelation by acidic groups from the self-adhesive cements, producing chemical interaction with the dentin hydroxyapatite.[35] Despite the fact that the hybrid layer makes an important

contribution to micromechanical bonding, the chemical interaction and the simplicity of application may contribute to the success of self-adhesive cements.[10]

Considering the push-out strength between the different root thirds, the null hypothesis for this study was rejected. The total-etch and the self-adhesive resin cement showed higher cervical third values compared with the middle third, while the apical third presented significantly lower push-out strength values. The results are in agreement with results reported in the current literature.[15,36,37] However, some investigators presented equal bond strength values for the total-etch and self-adhesive cements in different root thirds.[38,39] Additionally, some studies are in disagreement, reporting higher push-out strength values in the apical third for the self-adhesive cements.[38,40]

The lower push-out bond strength in the apical third, compared with the middle and cervical thirds, can be explained. Some explanations are difficulty accessing the narrow and deep areas, incomplete removal of the smear layer before cementation, and poor cement penetration into the dentin in the root canal.[8] Factors that also should be considered are the difficulty of phosphoric acid demineralization in deep areas and maintenance of ideal moisture before cementation.[36] In addition, these regions are most distant from curing light access, likely impacting the degree of conversion of the resin cement. Dual polymerization has better conversion values when light activation is used during polymerization.[8,41] In this study, a tapered translucent GFP was used to improve the light penetration in the apical third of the adhesive cement.[42]

Considering the push-out strength between application techniques, the null hypothesis was rejected. The results obtained in this study found that the push-out strength values are lower for the microbrush technique when compared with the elongation tip technique. Corroborating these results, other studies have found similar results.[43,44] The higher push-out strength values obtained in this study for both adhesive cements, when the elongation tip was used, can be explained by the tip creating a more homogeneous cement application along the entire root surface. Another reason beyond the use of the elongation tip is that the cement is mixed mechanically inside the capsule. This can eliminate human manipulation, which can incorporate air bubbles inside the cement during the mixing and application process with the microbrush technique.

In considering the additional conditioning step for self-adhesive cements, the null hypothesis was rejected. The higher push-out strength values collected for RUE, after the optional conditioning step, can be related to better hybridization of the root dentin. This, acting together with the chemical interaction between the adhesive cement and the hydroxyapatite, can explain the better push-out strength values. The low acid concentration associated with the self-adhesive cements limits decalcification and resin tag infiltration,[16,17] but this can be changed when an additional conditioning step is applied.

The higher push-out strength results achieved for cementation of GFPs with a self-adhesive cement, using an elongation tip application technique and additional conditioning step, should be considered a treatment alternative. A clinical evaluation of these principles are needed to validate the *in vitro* finding to resolve conflicting reports within the current published literature.

CONCLUSIONS

Within the limitations of this *in vitro* study, the results suggest the following:

1. Self-adhesive cement has a higher push-out strength values when compared to total-etch cement in all thirds of the root canal dentin.
2. The cervical third region of the root canal dentin displayed the highest push-out strength values, while the apical third had the lowest results.
3. The cement application technique utilizing the elongation tip had higher push-out strength values when compared with the microbrush technique.
4. The optional conditioning step before self-adhesive cementation obtained the highest push-out strength values regardless of application technique or root area.

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