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Effect of relining, cement type, and thermocycling on push-out bond strength of fiber reinforced posts

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ABSTRACT

Statement of the problem: Improving the adaptation of fiber reinforced posts through relining may affect the retention of the posts.
Purpose: To investigate the effect of post relining, cement type, and thermocycling on the push-out bond strength of fiber reinforced posts.
Materials and methods: (48) endodontically treated human teeth were excessively flared using diamond stones. The teeth were divided into two groups; group (1) (n = 24) received glassix glass fiber posts adapted to the flared canals by relining with composite resin and group (2) (n = 24) received non-relined glassix glass fiber post. Samples of each group were divided into three subgroups (n = 8) according to the type of cement used; subgroup (a): luted using Metacem Refill, a total etch resin cement, subgroup (b): luted using Rely X Unicem, a self-adhesive resin cement and subgroup (c): luted using RelyX Luting, a resin modified glass ionomer cement. Half the samples of each subgroup (n = 4) were subjected to thermocycling. The samples were sectioned horizontally into 2 mm thick slices yielding 3 sections for each sample. Retention was evaluated using push out bond strength test using universal testing machine. The maximum failure load was recorded and used to calculate the push-out bond strength. Data was statistically analyzed and mode of failure was assessed using magnifying glass.
Results: Relined posts showed statistically significantly higher mean push-out bond strength than non-relined posts. Rely X Unicem showed the statistically significantly highest mean push-out bond strength among tested cements. Metacem showed significantly lower mean push-out bond strength than Rely X Unicem. Rely X Luting showed the statistically significantly lowest mean push-out bond strengths. There was no statistically significant difference between mean push-out bond strength with and without thermocycling. Most failures occurred at the cement–dentin interface in the relined group, while adhesive failure occurred at the cement-post interface in non-relined group.

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Conclusions: Relining glass fiber posts with composite resin in order to fit wide flared canals instead of using cement for compensating the discrepancy, improves the push out bond strength of glass fiber posts to root canal dentin. Moreover the use of resin cement with high mechanical properties to lute glass fiber post is highly recommended.

1. Introduction

When fiber posts were first introduced they gained great popularity as their elastic modulus matches that of resin cements and dentin. This is considered to be advantageous for improving the performance of restorations and for decreasing the possibility of root fractures [1,2].

However, despite their cited advantages, the mismatch between the diameter of the post space and the prefabricated fiber post presented a clinical problem [3,4]. Prefabricated posts do not fit well into both non circular canals [5] and excessively flared canals resulting from carious extension, trauma, pulpal pathosis, or iatrogenic misadventure [3]. In such cases, if the post does not fit well, the layer of resin cement might be excessively thick, favoring the formation of air bubbles and hence predisposing to post debonding [6]. One of the proposed solutions for this problem is to reline the fiber post with resin composite [7]. Customizing the post increases its adaptation to the root walls and reduces the thickness of the resin cement layer [6].

Post retention depends on the intimate contact between the post and the root canal as well as on the bonding potential of the cement to the canal walls. Improving the contact between the post and the canal walls by relining may reduce the dependence on the bonding potential of the cement for retention [8]. It has been shown that cements with lower bonding potential but other favorable mechanical properties perform well in luting relined fiber posts [9].

Consequently; the main goal of fiber post relining was to reduce the thickness of the resin cement layer. Thin layers of cement present fewer defects as bubbles and voids than thick ones. The presence of these defects within the material act as crack raisers and decreases post retention [3,6]. Relining will therefore reduce the possibility of cohesive failures within the cement layer.

In addition to relining, the cement type affects post retention. The use of cements with proper mechanical properties is essential for adequate post retention. Many types of cements were suggested to successfully lute fiber posts. Dual-cured resin cement generates higher bond strength to dentin than other cements [10]. However, its high polymerization shrinkage and the resulting stresses could impair the bonding to root dentin [11]. On the other hand self-adhesive resin cements appear to have low shrinkage because of their visco-elastic properties, leading to better intimate contact of the resin cement with the root canal walls and higher frictional resistance [12]. Moreover, when Bonfante et al. [13] studied the tensile bond strength of glass fiber posts luted with different cements, resin-modified glass ionomer cement exhibited lower bond strength values than resin cements. The authors attributed this to the fact that the mechanical properties of this cement are poorer compared with the resin cements [10].

The choice of resin cements that rely on the use of etch and rinse adhesives has been shown to achieve higher interfacial strengths in post spaces when compared with those utilizing mild self-etching adhesives or self-etching resin cement [14–16]. That was verified by Wang et al. [17] who studied bond strengths of an epoxy resin-based fiber post with four adhesive systems and concluded that the type of adhesive system and root region had a significant influence on the bond strengths of adhesively luted fiber posts. Total-etching technique achieved better bond strength than did the self-etching technique.

Long-term water storage and thermal cycling are the conditions most often used to test the durability of resin bonds. Both tests are considered to be clinically relevant aging parameters [18].

Bitter et al. [19] studied the effect of luting agents and thermocycling on bond strength to root canal dentine. They found that the bond strengths were significantly affected by the luting agent, and thermocycling. RelyX produced significantly higher bond strength values compared with all other investigated luting materials.

Mazzoni et al. [20] studied the effect of thermocycling on bond strength of fiber post using different luting agents. The use of the etch-and-rinse adhesive strategy in combination with the resin based cement showed the lowest susceptibility to long-term thermocycling, conversely, a self-etch approach (either with the adhesive or using the self-adhesive cement) resulted in reduced push out bond strength after thermocycling, although the self-adhesive cement performed better.

The aim of this study was therefore set to investigate the effect of post relining, cement type, and thermocycling on the push-out bond strength of fiber reinforced posts.

2. Materials and methods

To conduct the present study [48] freshly extracted human maxillary central incisors were selected. The selected teeth had straight, anatomically similar roots, with fully developed apices, and approximately similar lengths and widths. The soft tissue covering the root surface was removed with an ultrasonic scaler (Suprasson PMax; Satelec/Acteon Equipment, Merignac, France). Teeth were immediately placed in

5.25% NaOCl for 5 min and then stored in saline solution at room temperature until use.

2.1. *Endodontic procedure*

The teeth were de-coronated by being cut perpendicular to their long axis, coronal to the labial cemento-enamel junction using a diamond double-faced disk (910D; Diatech; Goltène AG, Altstätten, Switzerland) mounted in a low speed hand-piece under water coolant.

The working length was established directly by subtracting 1.0 mm from the real root length determined by introducing a number 10 K-file (Maillefer- Dentsply, Ballaigues, Switzerland) until it was visible through the apical foramen. Only roots with identical lengths (14 ± 0.5 mm) were accepted.

The pulp tissue was removed with a barbed broach (pulp Dent; stainless, Swiss made). A step-back technique using K-files (Maillefer- Dentsply, Ballaigues, Switzerland) was used for canal instrumentation. The same operator instrumented all root canals to the same size (size 50 file; Maillefer- Dentsply, Ballaigues, Switzerland). During instrumentation, canals were irrigated with 1 ml of 0.5% NaOCl preceding the use of each instrument and then dried with sterile absorbent paper points (Maillefer-Dentsply, Ballaigues, Switzerland).

The canals were obturated with gutta-percha points (Maillefer- Dentsply, Ballaigues, Switzerland) and eugenol-free sealer (Roeko, Coltene/whaledent Gmbh + Co. KGD-89129 Langenau, Germany) using the lateral condensation technique.

Cervical root canal openings were then filled with a provisional restorative material (Cavit-G; 3M ESPE, Seefeld, Germany), and the gutta-percha filled roots were placed in a humidor (100% relative humidity) for 1 week at 37 °C.

An acrylic resin (Acrostone, Idustrial area El-Salam City, Egypt) block was constructed to fix each prepared root in a vertical position. A special cylindrical shaped stainless steel root block former (20 mm length and 15 mm diameter) was machined to construct the sample block. Vertical holding device was used to ensure placement of the root in a vertical position parallel to the external wall of the block.

Coronal gutta percha was removed using sizes (2&3) Gates Glidden drills (Dentsply/Maillefer, Ballaigues, Switzerland) in a low speed hand-piece to create post spaces 10 mm in length leaving 3–4 mm apical gutta percha for apical seal. Rubber stoppers were used to adjust the length. The canals were cleaned with water and dried with paper points (Maillefer-Dentsply, Ballaigues, Switzerland).

2.2. *Post-hole preparation*

A centralized position of the post was obtained during flaring of the canal following the procedure recommended by Egilmez et al. [21]. The total length of the post space preparation was 11 mm. Only, the coronal 8 mm of the root canal was flared. A difference of 3 mm was kept prepared with the corresponding drill size of the post (i.e. without flaring) for its central positioning. Fig. (1).

Size 2 Glassix post drill (Harald Nordin sa, Montreux, Switzerland) of 1.2 mm in diameter was mounted in a low speed hand piece and inserted for 11 mm depth into the root canal in order to obtain a standard central position of post. A tapered diamond stone (D15923 kennesaw, GA 30156-9017, USA) of 8 mm length and 2.2 mm diameter was used to obtain a standardized flaring. The stone was mounted in a low speed hand-piece. The whole cutting end of the stone was gradually inserted into the root canal to ensure 8 mm depth of flaring. Enlargement was proceeded under copious water irrigation.

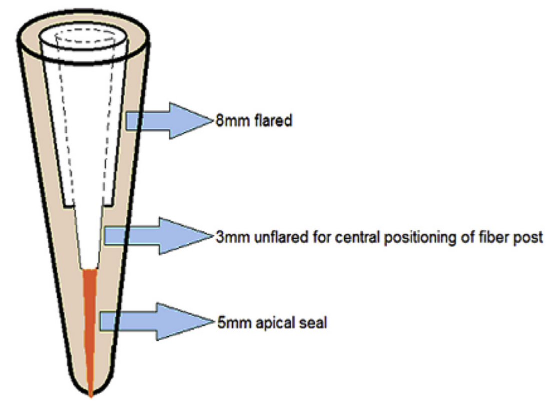

Fig. 1 – Diagram showing root canal preparation.

2.3. *Samples grouping*

The prepared root canals were divided into two equal groups (n = 24) according to the type of post used.

- *Group (I): Relined fiber posts:*

After lubricating the canal walls with glycerin gel (PURE Misr, Egypt) using microbrush (META BIOMED CO., Korea) size 2 Glassix fiber post (Harald Nordin sa, Chailly/Montreux, Switzerland) was covered with composite resin (Composan Ceram, PROMEDICA Domagkstr, Germany) and inserted into the canal. The composite resin was light-cured for 20 s. The relined fiber post was removed and the composite resin was inspected for any deficiencies. Accepted relined post was light-cured for additional 20 s. Copious water rinsing of the canal using a plastic syringe, was done to remove lubricant gel from the root canal.

- *Group (II): Non-relined fiber posts:*

Samples of group (II) received size 2 Glassix fiber post without relining. The discrepancy between post and preparation diameter was compensated through increasing cement thickness.

2.4. *Post cementation*

- *Construction of load applicator:*

A specially designed pressure jig with 5 kg weight was machined from stainless-steel, in order to aid in load application upon the samples during cementation procedure.

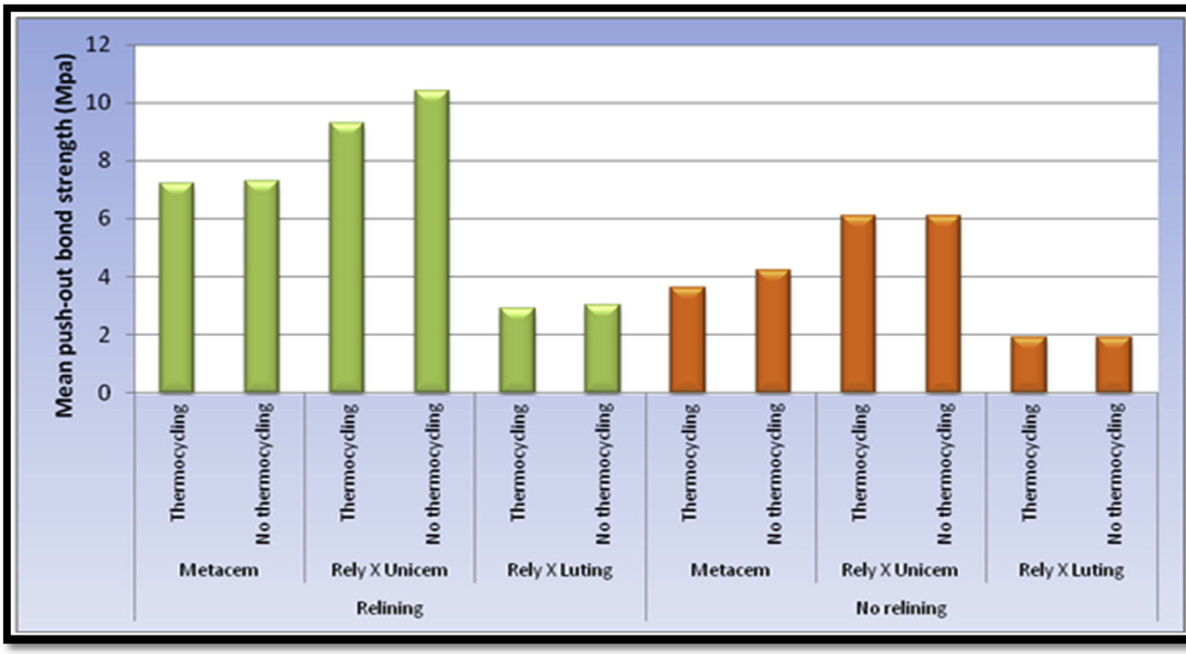

Fig. 2 – Bar chart representing mean push-out bond strengths with different variables interactions.

- *Cementation procedure*:

Specimens of each group were divided into [3] subgroups (n = 8) according to the type of cement used. All cements were manipulated according to the manufacturer instructions as follows:

i. **Cementation using Metacem Refill, subgroup (1):**

Specimens of subgroups (1) were luted using Metacem Refill resin cement (META BIOMED CO., Korea). Meta Etchant gel was applied for 15 s, rinsed for 20 s then dried for 2 s. Excess moisture was removed with paper point. A double coat of Meta P& Bond was applied by using micro-brush (META BIOMED CO., Korea). Excess was removed with a dry paper point, gently air dried for 5 s then light cured for 10 s. Metacem was directly dispensed into the canal and on the post using the mixing tip. The post was immediately seated, and the block was mounted on the load applicator, then light cured for 40 s.

ii. **Cementation using RelyX Unicem, subgroup (2):**

Specimens of subgroups (2) were luted using RelyX Unicem resin cement (3M ESPE AG ESPE Platz 82229 Seefeld, Germany). The cement capsule was activated for 2 s then mixed automatically in a high-speed triturator (ADM 9002, Germany) for 10 s. Afterwards, the resin cement was applied into the root canals by means of elongation tip (Skin Syringer REF/UP 1681, Ultradent, South Jordan, UT, USA). The post was then seated in the root canal; the excess resin was subsequently removed. The block was mounted on the load applicator. Then, the light activation was performed for 40 s.

iii. **Cementation using RelyX Luting, subgroup (3):**

Specimens of subgroups (3) were luted using RelyX Luting resin cement (3M ESPE AG ESPE Platz 82229 Seefeld, Germany). The cement was mixed for 10 s inserted into the canal with 50 K-file. The post was inserted into the canal with light pressure and stabilized during 2 min. Then, the excess material was removed. The block was mounted on the load applicator.

2.5. *Thermocycling*

Half the specimens of each subgroup (n = 4) were subjected to 3000 thermocycle shocks using thermocycling device (Willytec, Germany)The thermocycled specimens were cycled repetitively 3000 times between water baths at 5 °C and 55 °C, with a dwell time of 30 s. After thermocycling, the samples were immediately sectioned and tested.

3. Push out bond strength evaluation

To assess the adhesion of the fiber posts, the push-out test was performed. The samples were sectioned horizontally perpendicular to their long axes with a slow-speed diamond blade (Isomet1000, Buehler Ltd.) under water cooling. Three horizontal sections of (2 ± 0.1 mm) thick were obtained from coronal, middle and apical regions of each root. Each section was coded and photographed from apical and coronal surfaces using stereomicroscope (SZ-PT, Olympus, Tokyo, Japan) at an original magnification of 50X. Calibration was done by comparing an object of known length, a ruler in this study, using the 'Set Scale' tool generated by the image analysis software (Image J, Earl F, Glynn II, Over-Park, USA). The diameter of the post was then measured and the radius was calculated.

Each acrylic embedded root slice was secured in a custom made loading fixture. Each sample was subjected to compressive loading via a computer controlled materials' testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) with a load cell of 5 kN at a crosshead speed of 0.5 mm/min in an apical-coronal direction. The plunger was positioned so that it only contacts the post to displace it downward. This way, it was guaranteed that the overlaying root dentine was sufficiently supported during the loading process.

The maximum failure load was recorded in Newton using computer software (Nexygen-MT; Lloyd Instruments) and was used to calculate the push-out bond strength in mega-pascals (MPa) according to the following formula [22].

$$\text{Bond strength} = F/A$$

$$A = \pi h(r_1 + r_2)$$

Where,

F is the applied load,
A is the area of the post/dentin surface,
π is the constant 3.14,
r_1 apical radius, r_2 coronal one,
and h is the thickness of the sample in millimeters

4. Statistical analysis

Regression model using three-way Analysis of Variance (ANOVA) was used in testing significance for the effect of post relining, cement type, thermocycling and their interactions on push-out bond strength. Tukey's post-hoc test was used for pair-wise comparison between the mean values when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM (IBM Corporation, NY, USA) SPSS Statistics Version 20 for Windows (SPSS, Inc., an IBM Company).

5. Failure mode assessment

Mode of failure was assessed under magnifying glass, (X = 15), and scored as follows;

a. In the relined group:
   - Score 1: Adhesive failure at cement/dentin interface.
   - Score 2: Adhesive failure at composite/cement interface.
   - Score 3: Adhesive failure at composite/post interface.
   - Score 4: Cohesive failure within composite resin layer.

b. In the non-relined group:
   - Score 5: Adhesive failure at cement/dentin interface.
   - Score 6: Adhesive failure at cement/post interface.
   - Score 7: Cohesive failure within cement layer.

6. Results

I. Statistical analysis of push out bond strength values (Mpa)

- **Results of three-way ANOVA:**

The results showed that post relining, cement type and the interaction between the three variables had a statistically significant effect on mean push-out bond strength. Thermocycling had no statistically significant effect on mean push-out bond strength, Table (1).

Relined posts showed statistically significantly higher mean push-out bond strength than non-relined posts, Rely X Unicem showed the statistically significantly highest mean push-out bond strength among tested cements. Metacem showed significantly lower mean push-out bond strength than Rely X Unicem. Rely X Luting showed the statistically significantly lowest mean push-out bond strengths. There was no statistically significant difference between mean push-out bond strength with and without thermocycling, Table (1).

- **Comparison between different variables interactions**

Relined posts cemented with Rely X Unicem without thermocycling showed the statistically significantly highest mean push-out bond strengths, Table (2).

There was no statistically significant difference between (non-relined posts cemented with RelyX Luting cement and thermocycled) and (non-relined post cemented with RelyX Luting without thermocycling); both showed the statistically significantly lowest mean push-out bond strengths (Fig. 2).

II. Mode of failure analysis

On examination of fractured samples, it was observed that most failures occurred at the cement–dentin interface in the relined group, fig. (3), while adhesive failure occurred at the cement-post interface in non-relined group, fig. (4), Table (3).

7. Discussion

Customizing prefabricated fiber posts by relining, as a treatment modality for non-circular and excessively flared canals will widen the scope of restorative dentistry [6,7&23]. Therefore, the aim of this study was to determine the push out bond strength of fiber posts relined by composite resin and cemented using three types of cements to root canal dentin. Moreover, the durability of this bond was examined using thermocycling.

To conduct the present study, three types of cements were selected and manipulated according to their manufacturer's instructions. RelyX Unicem, Metacem and RelyX luting were selected to represent; self-adhesive system, total-etch system, and resin modified glass ionomer cements, respectively.

Various methods are available to analyze the adhesive bond of resin cements and the bond strength of fiber posts. The two most commonly used techniques are the micro-tensile and the push-out bond strength tests. By using the push-out test, the risk of premature loss of samples during

Table 1 – Results of three-way ANOVA for the effect of relining post, cement type, thermocycling and their interactions on push-out bond strength.

Source of variation	Subgroups	Mean (SD)	Sum of squares	df	Mean square	F-value	P-value
Post relining	Relining	6.7 (3)	113.2	1	113.2	1046.2	<0.001*
	No relining	4.1 (1.8)					
Cement type	Metacem	5.6 (1.8)	325.7	2	162.9	1505.8	<0.001*
	Rely X Unicem	8 (2.1)					
	Rely X Luting	2.4 (0.8)					
Thermocycling	Thermocycling	5.2 (2.6)	0.4	1	0.4	2.1	0.068
	No thermocycling	5.5 (3.1)					
Post relining × Cement type × Thermocycling			1.1	2	0.5	4.9	0.011*

df: degrees of freedom (n−1), *: Significant at $P \le 0.05$.

Table 2 – The mean, standard deviation (SD) values and results of comparison between push-out bond strength of the different interactions.

Relining	Cement type	Thermocycling	Mean	SD	P-value
Relining	Metacem	Thermocycling	7.2^{c}	0.6	0.011*
		No thermocycling	7.3^{c}	0.6	
	Rely X Unicem	Thermocycling	9.3^{b}	0.3	
		No thermocycling	10.4^{a}	0.4	
	Rely X Luting	Thermocycling	2.9^{f}	0.3	
		No thermocycling	3^{f}	0.1	
No relining	Metacem	Thermocycling	3.6^{f}	0.2	
		No thermocycling	4.2^{e}	0.2	
	Rely X Unicem	Thermocycling	6.1^{d}	0.1	
		No thermocycling	6.1^{d}	0.3	
	Rely X Luting	Thermocycling	1.9^{g}	0.3	
		No thermocycling	1.9^{g}	0.3	

*: Significant at $P \le 0.05$, Different letters are statistically significantly different.

specimen preparation and the large data distribution associated with micro-tensile testing are reduced [24]. Push-out tests result in a shear stress at the interface between dentin and cement as well as between post and cement comparable with the stresses under clinical conditions [24]. The present study therefore evaluated the bond strengths to root canal dentin using a push-out model.

The results of the present study revealed a significant difference in push out bond strength between relined and non-relined fiber posts, Table (1). Push out bond strength values were significantly higher in relined posts than in non-relined posts. The same results were found by Pedrosa and Celso [25] in 2006, Silva et al. [8] in 2009, and Macedo et al. [26] in 2010. These studies had attributed the improvement in bond

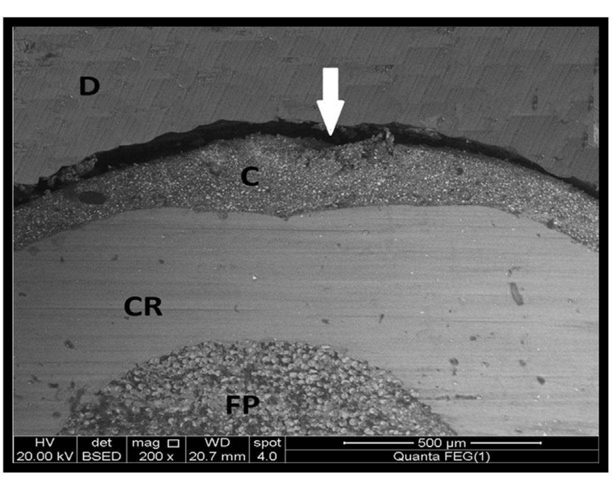

Fig. 3 – Adhesive failure at cement/dentin interface in a relined sample (Arrow). FP: fiber post, CR: composite resin, C: cement layer, and D: dentin.

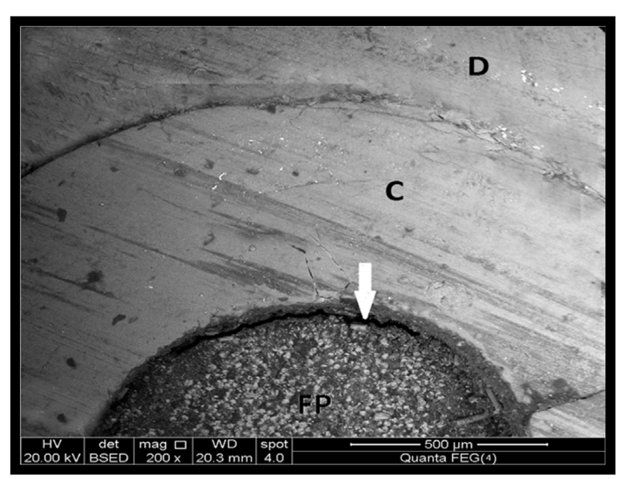

Fig. 4 – Adhesive failure at cement/post interface in a non-relined sample (Arrow). FP: fiber post, C: cement layer, and D: dentin.

Table 3 – Failure mode assessment using magnifying glass after push-out test.

Post type	Cement type	Score 1	Score 2	Score 3	Score 4	Score 5
Relined group (1)	Metacem (Th)	16	0	0	–	0
	Metacem	12	0	4	–	0
	Unicem (Th)	16	0	0	–	0
	Unicem	10	0	6	–	0
	Luting (Th)	12	4	0	–	0
	Luting	14	2	0	–	0
Non-relined group (2)	Metacem (Th)	2	0	–	14	0
	Metacem	4	2	–	10	0
	Unicem (Th)	4	0	–	12	0
	Unicem	6	0	–	10	0
	Luting (Th)	0	0	–	14	2
	Luting	0	0	–	12	4

strengths after relining to the fact that the cement layer is decreased with relining.

Grandini et al. [6] in 2005 and D'Arcangelo et al. [3] in 2007 studied the effect of resin cement film thickness on the pull-out strength of a fiber-reinforced post system and concluded that thin layers of cement present fewer defects as bubbles and voids than thick ones. The presence of these defects within the material may act as crack raisers and will decrease post retention. Relining will therefore reduce the possibility of cohesive failures within the cement layer.

Moreover, Polymerization stresses which develop within the low-thickness film of cement are minimal because the stress development increases associated with increased volume of the resin cement [7].

Relined fiber posts present more intimate contact with the root canal walls than non-relined posts. Fiber post relining may therefore reduce blister formation by increasing the pressure during cementation. Good adaptation of the post increases the pressure on the resin cement, which is transmitted to the cement–adhesive interface. Pressure application suppresses water sorption and blister formation, resulting in a better contact between the cement/post assembly and dentin. This results in higher sliding frictional retention compared to non-relined posts and consequently in higher push out bond strength [27].

A third explanation is related to the C-factor of the post hole which means ratio between bonded and non-bonded surfaces. It is reasonable to assume that the closer the contact between resin cement and root dentin, the higher C-factor, the higher sliding friction, the better fiber post retention [28].

Most failures 'in the relined group' in the present study, occurred at the interface between the resin cement and root dentin, Table (3), eliminating the effect of reducing defects and increasing the cement layer strength. Thus, the possible explanation for the improvement in retention with fiber post relining may be associated with the type of cement used.

In this study, Rely X Unicem showed the statistically significantly highest mean push-out bond strength. Metacem showed significantly lower mean push-out bond strength than Rely X Unicem. Rely X Luting showed the statistically significantly lowest mean push-out bond strength, Table (1). These findings agree with Bitter et al. [19] in 2006, Yahya et al. [29] in 2008, Toman et al. [30] in 2009, and ElSayed et al. [31] in 2009, as well.

Some studies reported high bond strength values to dentin with RelyX Unicem although the fact that it is self-adhesive resin cement and interacts superficially with the substrate [32]. However, RelyX Unicem interacts well with the calcium in hydroxyapatite, improving their mechanical properties [33]. Furthermore, self-adhesive resin cements have low shrinkage because of their viscoelastic properties, leading to better intimate contact of the resin cement with the root canal walls and higher frictional resistance [34].

In contrast to these findings, Wang et al. [35], Rathke et al. [36], and Goracci et al. [37] showed the superiority of the "etch & rinse" adhesive system regarding the push-out strength of fiber-reinforced posts when compared to self-adhesive resin cements. Conflicting results could be attributed to differences in luting procedures employed and/or different types of cements used.

In the present study, RelyX Unicem was applied into the root canal by means of 'Elongation Tips', while Metacem was inserted with its mixing tip, and RelyX Luting was inserted with 50 K file. The elongation tip of Unicem facilitates reaching the cement into the most apical portion of the root canal space, spreading the cement onto the entire walls. In addition, forceful application of the cement inhibits air bubbles or voids formation [38].

Moreover, in **Goracci et al** [24] study, RelyX Unicem was chemically initiated. **Foxton et al** [39] have reported a significant reduction in bond strength when polymerization of the dual-cure resin composite was chemically initiated.

In this study, **Metacem** gave statistically significantly lower bond strength values compared to RelyX Unicem, Table (1). Two-steps total-etch resin cements are technique sensitive [15]. The delivery of etchants and adhesive materials deep into the post space can be very challenging [15]. Moreover it had been shown that the curing depth of light is limited [40] thus deeper portions of dual-cured cements depend on the chemical curing only. This can reduce the degree of conversion of the cement and consequently affect its mechanical properties [41]. These factors when coupled with difficulty of humidity control in deep root areas may have compromised the bond strength of Metacem cement.

Moreover, acid etching of the dentin surface with phosphoric acid removes the smear layer and the smear plugs, increasing tubule diameter and dentin permeability. Rinsing with water probably results in the retention of a substantial volume of water within the widened tubule entrances. As such water may not be completely removed by absorbent paper points; it may contribute to blister growth at the adhesive/resin cement interface. Considering the evidence that sliding friction is the main factor responsible for fiber post retention, these blisters may have reduced the contact between the resin cement and root canal walls, resulting in lower push-out bond strength values [42]. Blister growth is related to the availability of water and the polymerization rate of the resin cement, which in a slow polymerization reaction results in more water blisters [43].

On the other hand, the significantly lowest bond strength of RelyX Luting, a resin-modified glass ionomer, is probably related to the application over the smear layer because no acid solution is applied before cementation. Thus, the retention provided by RelyX Luting is more dependent on frictional retention than on its bonding to dentin [44]. Because the mechanical properties of this cement are poorer compared with the resin cements, it was expected that this cement would have the lowest retention [45], Table (1).

In the present study, the push-out bond strength was reduced after thermocycling. However, statistical results showed no significant differences before and after thermocycling (TC), Table (1). These findings are concordant with Purton et al. [45] who reported that the bond strengths were not susceptible to reduced retention after thermocycling. While, Bitter et al. [19] and Mazzoni et al. [46] observed a significant influence of TC on the bond strength of resin cements to root canal dentin which was contradictory to results of the present study.

Bitter et al. [19] observed a significant decrease of the bond strength of resin cements to root canal dentin after 5.000 cycles. However, in another study by the same author, the bond strength was not affected by thermocycling [47]. While, Mazzoni et al. [46] observed a significant reduction in bond strength of resin cements to root canal dentin after 40,000 thermal cycles. The controversy of the results can be attributed to the different thermal cycles employed in each study.

During thermal cycling, the samples are subjected to thermal changes and also to additional exposure to water. The main cause for the reduction in bond strength after thermocycling is believed to be the possible effect of hydrolysis at the interfaces of the bonding resin and hybrid layer [48]. Water molecules are absorbed during TC into composite resin and fiber posts by diffusion, which is a time dependent process [49,50]. This could be the basis for the lower bond strength values obtained after thermocycling in the present study. However the difference was not statistically significant.

After assessment of failure mode using magnifying lens, adhesive failure at cement–dentin interface, cement–composite interface, composite-post interface, cement-post interface, and cohesive failure within cement layer were detected with different ratios, Table (3).

Generally, in relined group, most failures occurred at the interface between the cement and root dentin. Bonding to dentin is a more difficult process due to the anatomical and histological characteristics of dentin as well as the smear layer on the cut dentin surface [51]. The peculiar conditions of hydration in dentin on endodontically treated canal walls [51], the degradation of dentin collagen [52], the effect of irrigation and eugenol-containing root-filling material, the regional differences in the density of the dentinal tubules [53], and the fluidity of the bonding materials [38] are all variables that can possibly influence the quality of adhesion at the cement∖dentin interface.

On the other hand, in non-relined group, most failures occurred at the interface between the post and the cement. In this study, because the Glassix fiber posts were used without any surface treatment, bonding between cement and dentin seemed to be stronger than bonding between cement and post. Compared with relined group, relining of Glassix fiber posts with composite resin resulted in stronger bonds at the post∖composite interface, shifting the failure to the cement∖dentin interface, recording significant higher values of push-out bond strength than non-relined group. The strong bond achieved between post and composite resin used for relining depends mainly on chemical bonding as no surface treatment of the post was performed.

8. Conclusions

Within the limitations of the present study the following could be concluded:

1. The relining procedure and the cement type are important factors for improving the retention of fiber posts.
2. Although the weakest link in post cementation is the interface between resin cement and root dentin, relining with composite resin seems to be an effective method to improve the retention of fiber posts to flared root canals.
3. The use of cement with proper mechanical properties is essential for adequate post retention.

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