

Comparison of the Bond Strength of Fiber-Reinforced Composite (FRC) Posts to Radicular Dentin Using Different Adhesive Cement: an in-vitro study

Original Article

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Abstract

Introduction: Retention of fiber reinforced composite posts depends on the bond strength between post and cement, and cement and root dentin. The aim of this study is to evaluate the bond strength of one type of fiber post to radicular dentin with different adhesive cements.

Materials and Methods: Crowns of 44 caries-free, human premolar were removed 2 mm below the CEJ and the roots were endodontically treated, then prepared for post cementation. The samples were randomly divided into 4 groups, group 1: Breeze (self-adhesive), group 2: ED Primer II/Panavia F2 (self-etch), group 3: Prime & Bond NT dual-cure /All-Cem (etch & rinse), and group 4: GC Fuji Plus.

After post cementation and composite filling of coronal portion (as manufacturers, s instruction) and thermocycling, each specimen was cut into 2 mm thickness from the middle third of the root and the push-out bond strength test was performed and failure modes were recorded. Data were analyzed employing ANOVA and post hoc tests (P value < 0.05).

Results: Group 4 showed significantly the highest bond strength (12.88±3.44 MPa), while group 1 showed significantly lower bond strength than the other groups (5.25±2.98MPa). Also a statistically significant difference was observed between groups 2 and 3 with group 4. (P value < 0.021)

Conclusion: Retention of fiber post was affected by cement type. The results also indicated that in GC Fuji Plus the chemical interactions be-

tween the cement and hydroxyapatite may be important for root dentin bonding. Breeze without any pretreatment procedure cannot obtain the acceptable bond strength.

Key words: •Adhesive cement •Dental bonding
•Light- cured

Introduction

Posts are commonly used in endodontically treated teeth suffering from excessive loss of coronal tooth structure. The selection of an appropriate restoration for endodontically treated teeth is guided by both strength and aesthetics. Available prefabricated posts were traditionally made of metal alloys, and their use was reported to cause serious types of root fractures, and compromise esthetic. Additionally, they bring about the risk of corrosion or allergic reactions.⁽¹⁾

As alternatives, fiber-reinforced composite (FRC) posts were developed with intensive research interest. There has been a rapidly increasing development and use of these FRC root canal posts over the last 10 years. Many investigators have suggested that these materials have the advantage of reducing the risk of root fracture thanks to their modulus of elasticity (16-40 GPa) being comparable with that of composite resins (5.7-25 GPa) and dentin (18.6 GPa).⁽²⁾

One of the major causes of fiber post failure is loss of retention.⁽³⁾ Several factors affect the retention of FRC post within the root canals, such as type of post and its adaptation to the post space, type of endodontic cement, adhesive and cementation system, and operative procedures. Furthermore, the unfavorable cavity configuration factors found within post spaces in addition to the high wall-to-wall shrinkage experienced in bonding posts are even a greater challenge to the bonding protocol in root canal walls.⁽²⁾

A range of results were reported when

different commercially available dentin adhesive and luting cement combinations were employed for cementing fiber posts.⁽⁴⁾ These materials may polymerize through a light-activated reaction, a chemical reaction or a combination of both mechanisms. Adhesive cements include resin composite cements group and glass-ionomer cements. Resin cements are more technique-sensitive than most other luting cements and they require several steps in the handling procedures. In order to solve these problems, some steps were combined. A new subgroup of resin cements, self-adhesive cements, was introduced in 2002. These materials were designed with the purpose of overcoming some of the limitations of both conventional and self-etch resin cements. The self-adhesive cements do not require any pretreatment of the tooth substrate, once the cement is mixed, the application is accomplished in a single clinical step.⁽⁵⁾ There are some controversies about the efficacy of these cements.^(2,6-12) Therefore, the aim of the present study was to compare the push-out bond strength of FRC posts to root dentin using four different adhesive cements with different mechanisms of adhesion.

Materials and Methods

Forty-four single-rooted, caries-free human premolars with mature apices (nearly same root length and diameter) and extracted for orthodontic and periodontal reasons (ethical consideration), were selected for this study. All teeth were stored in 0.9 % NaCl (two months). External debris were removed with a scaler and teeth were cut 2mm below the CEJ, using a low-speed diamond saw under water cooling (the dimensions of root after cutting were 14±1mm length, 7±1mm buccolingual dimension, 5±1mm mesiodistal dimension). The roots were endodontically instrumented at a working length of 1 mm from the apex using a 35 master apical file. All root canals were instrumented by the same operator. A step-

back technique was used with stainless-steel K-files and Gates Glidden drills (No.2,3). Irrigation was performed using a normal saline solution after each change in the size of the file throughout the shaping process. The canals were rinsed with distilled water, dried with paper points, and obturated with gutta-percha cones and sealer AH-26 (non-eugenol type, Dentsply, DeTrey, Konstanz, Germany) using a lateral condensation technique.

After the completion of endodontic treatment, cervical root canal openings were filled with a provisional restorative material (Cavit, 3M™ ESPE™, USA), and the teeth were stored in normal saline solution for 7 days.

After 1 week, gutta-percha was removed using # 3 Gates Glidden leaving a minimum 4–5 mm apical seal and creating a standard post space of 9 mm from the coronal surface. After preparing the post spaces, the canals were cleaned with 70% ethanol, distilled water and dried with paper points. The prepared roots were equally and randomly divided into four treatment groups (n=11) according to the adhesive cement: group 1: Breeze (self-etch/self-adhesive cement-Pentron Clinical, USA); group 2: ED Primer II/Panavia F2 (self-etch cement- Kuraray Dental, Japan); group 3: Prime & Bond NT dual-cure (Dentsply Caulk, USA)/ All-Cem (total- etch cement- FGM Dental, Brazil), group 4: GC Fuji Plus(GC Corporation, Japan). The step-by-step application procedures of all materials are described in Table 1.

In this study, we used Angelus post number 1(Angelus Dental,Brazil) because of the size of prepared root. This post contains glass fibers. All posts were marked at the distance of 9 mm from the apical end. One layer of Margin Bond (Coltene-Whaledent, Switzerland) was applied on the surface of the post for better wetting of posts by cements and being light-cured before place-

ment in the root. The materials were handled in strict accordance with the manufacturer's instructions. Following the placement of the fiber post in the post space, in each group, the excess luting cement was removed by microbrush. The luting agent in group 1,2 and 3 was light cured (520mw/cm²) using a conventional quartz–tungsten–halogen light in the standard mode (Litex 628; Dentamerica Inc., USA) by placing the light tip perpendicularly through the post for 40 s.

After the cementation procedures, the coronary part of the exposed dentin was completely covered with Tetric N Bond (Ivoclar-Vivadent, Lichtenstein) and composite A2 (Opalis–FGM Dental, Brazil), and the teeth were stored in distilled water for a week. Then the samples were thermocycled (1000 cycles, 5–55°C, immersion time of 30 sec. and dwelling time of 15 sec.). Bonded specimens were sectioned horizontally at the middle of the root with a slow-speed diamond disc (TC-3000) under water coolant to produce one 2-mm thick post/dentin section for each group. Each specimen was marked on its coronal side with an indelible marker, and the exact diameter of the fiber post segments in each section was measured using a digital caliper. Each section was attached to the push-out jig, ensuring that the coronal surface faced it and that the post was centered over the hole of the jig. The post segments were loaded with a cylindrical plunger 1 mm in diameter centered on the post segment (Figure1).

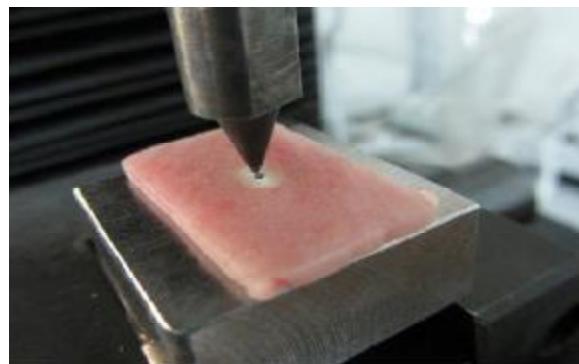


Figure.1: push-out bond strength test

Loads were applied in an apical-to-cervical direction with respect to individual test specimens using a universal testing machine (CH. 8224, Switzerland) at a cross-head speed of 0.5 mm/min until the post was dislodged. Push-out bond strengths were calculated for each specimen by using the formula:

$$\text{Debond stress} = \frac{\text{Debonding force (N)}}{A(\text{surface area of samples})} = \frac{\pi (r_1 + r_2) \sqrt{(r_1 - r_2)^2 + h^2}}{A}$$

r_1 : coronal radius of post
 r_2 : apical radius of post
 h : Height of post

After the push-out bond strength evaluation, the failure mode of all specimens was evaluated under a stereomicroscope (Olympus of Plapo LX-4, JAPAN SZX7). The failure modes were classified according to the following criteria:

- (1) Adhesive failure between dentin and luting cement (AD)
- (2) Adhesive failure between luting cement and post (AP)
- (3) Mixed failure (M) (combination of adhesive and cohesive failures)
- (4) Cohesive failure within the post (C)

The average dentin bond strengths were calculated for the groups, and then the mean values were compared by running one-way analysis of variance (ANOVA). As variances were homogeneous (Levene's test), one-way ANOVA was followed by LSD test for post hoc comparisons. The level of significance was set at the 0.05 probability level in all analysis, and calculations were handled using the SPSS 16.0 software.

Results

The mean push-out bond strengths and failure modes of the tested samples are shown in Table 2. In the first analysis, one-way ANOVA test revealed that the bond strength was significantly affected by the different adhesive cements (P value < 0.0001). In this study, GC Fuji plus cement achieved the highest bond strength values. Self-adhesive cement (group 1) showed a significantly lower bond strength than the conventional cements (group 2, 3) (P value < 0.02) and the cement in group 4 (P value < 0.0001) (Figure 2). Also a significant difference was recorded between the conventional cements (group 2, 3) and cement in group 4 or GC Fuji Plus (P value < 0.02).

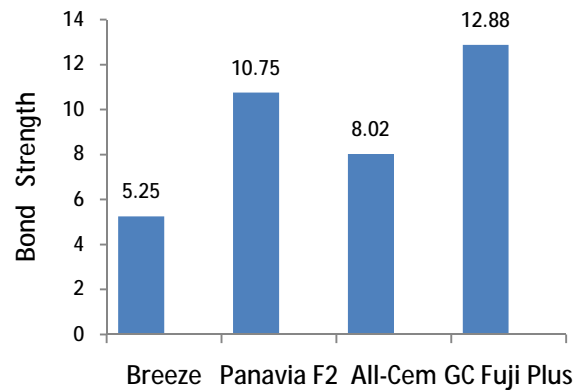


Figure 2. comparison of mean bond strength in different adhesive cement

The failure modes recorded were mostly adhesive at the dentin/ cement interface. Cohesive failure within the fiber post was only observed for GC Fuji plus cement. Mixed failures also occurred in the four adhesive cements investigated.

Table 1. Application procedures of the adhesive cements investigated in this study

Group	Bonding system	Application procedure
Breeze (Pentron Clinical, USA)		After mixing base & catalyst, apply to root canal & coat the post. Light cure for 40 sec.
Panavia F2 (Kuraray Dental, Japan)	ED Primer II	Mix equal amounts of ED primer liquids A and B, apply mixture to the post space with a micro brush for 30 s, gently air- dry and then remove excess with paper points. Mix Panavia F 2 paste A and B for 20 s, apply the mixed paste to the post and seat it in place, light cure for 40 s.
All-Cem (FGM Dental, Brazil)	Prime & Bond NT Dual-cure	35% phosphoric acid etching for 15 s Rinse with water for 15 s and blot dry, dry the apical end of canal with paper point, Mix Prime & Bond NT and Activator, apply on the walls, dry gently with air, remove excess with a paper point, light-polymerize for 20 s, mix base & catalyst, apply to root canal & coat the post, light cure for 40 sec.
GC Fuji Plus (GC Corporation , Japan)	-	Apply conditioner (10% Citric acid , 2% ferric chloride) on the walls for 20 s, rinse then dry gently, dry epical end of canal with paper point, mix powder and liquid for 20 s, apply to root canal & coat the post, wait 3-4 min for setting.

Table 2. Push-out bond strengths and the percentage of respective failure modes

Experimental groups	Failure mode				Mean±SD (MPa)
	AD	AP	C	M	
Breeze	63.6%	18.2%	0%	18.2%	5.25 ± 2.98
Panavia F2	54.5%	27.3%	0%	18.2%	10.75 ± 4.47
All-Cem	63.6%	27.3%	0%	9.1%	8.02 ± 4.4
GC Fuji plus	36.4%	27.3%	9.1%	27.3%	12.88 ± 3.44

AD:adh.failure between cement and dentin
C:cohesive failure in the post

AP: adh.failure between cement and post
M: mixed failure(combination of adhesive and Cohesive failure)

Discussion

The resistance to dislocation of fiber posts bonded to intact root canals with resin-based cements may be considered a net sum of micromechanical interlocking, chemical bonding and sliding friction. The good immediate performance of adhesive systems when bonded to enamel and coronal dentin has been well documented, however, some

aspects related to intraradicular dentin remain uncertain.⁽²⁾The bond strength level may depend on the compatibility between the luting agent and the adhesive system, the way in which the luting agent was polymerized, the root canal anatomy, the moisture within the canal, and the density and orientation of root dentinal tubules.⁽³⁾ The success of fiber post-and-core restorative procedures depends in part on the cementation tech-

nique used to create a link between the post and root canal dentin.

In an attempt to reduce the clinical steps involved in post cementation to root canal, a new type of luting material that requires no pretreatment of the tooth surface has been developed, and is called a self-adhesive cement. This cement does not require conditioning and rinsing. As the result, it decreases the problem of substrate moisture control; thus, simplifies the clinical procedure.⁽²⁾

According to the previous SEM studies, adhesive bonding to root canal dentin is predominantly based on the formation of resin tags.⁽¹³⁾ The number and length of the resin tags decrease from coronal to apical, and the adhesion of cements can be influenced by the anatomical and histological characteristics of the root canal. Besides, there were problems related to manipulation and insufficient access to apical of root. So, it was expected that the bond strength decreases from coronal to apical area of root.⁽¹⁴⁾ Since this finding was assessed by many previous studies; in this study, we prepared only one slice in the middle area of roots, for economic reasons.

Bond strength can be determined by several techniques, but the push-out bond strength test is believed to provide a better estimation of the actual bonding effectiveness than a conventional shear bond strength test. In addition, when measuring the bond strength of fiber posts adhesively luted to root canal dentin, the push-out test is more efficient and dependable than the microtensile technique^(15,16). Although it was reported that a nonuniform stress may be developed at the adhesive interface when the push-out test is performed on the whole post or on the thick root sections using a thin slice specimen, the thin slice push-out test permit a more uniform stress distribution along the bonded interface.⁽⁶⁾ Therefore, the push-out design with 2 mm sections similar to Bitter et al.⁽¹⁰⁾, Farina et al.⁽¹⁾ and Kremeier et

al.⁽¹⁷⁾ was used in the present investigation.

An adequate polymerization of the luting agent is necessary to provide its mechanical properties, which clinically ensure the post retention. Dual-cure and self-cure resin cements have been recommended to cement fiber posts because light is not able to ensure adequate polymerization in deep areas of the root canal. However, the chemical reaction of dual-cure cements is not capable of the total compensation for poor polymerization in deep areas where light intensity is low.⁽³⁾ In the present study, we used Dual-cure resin cements and self-cure cements.

The null hypothesis of the present study was rejected because according to the results, the bond strength was significantly affected by adhesive cement type that confirms the result of many previous studies^(1, 2,8,10,12,18,19). In contrast to our results, Kremeier et al.⁽¹⁷⁾, Giovannetti et al,⁽²⁰⁾ showed that the push-out bond strength of FRC posts were not different. These variations can be due to differences in thermocycling, cement type, storage duration and slice thickness.

In our study, GC Fuji Plus achieved the best bond results. The bonding mechanism of this cement has been reported by the manufacturer to be based on the glass ionomer technology, modified by resin incorporation. Water in the cement composition is expected to aid the conditioning reaction, reducing the time needed for interacting with the substrate.⁽¹⁹⁾ By using GI cement (Ketac Cem), Ebert et al.⁽⁶⁾ and Macedo et al.⁽²¹⁾ reported different results. One reason can be about using a 40% citric acid and 3% NaOCl before cementation in those studies.

Panavia F2 cement in the present study showed higher bond strength than Breeze cement. This finding is similar to results achieved by Zicari et al.⁽²²⁾. The major concern with the self-etching primers is their efficacy in infiltrating thick smear layers such as those produced during post space preparations. The etching effect of ED Pri-

mer II is related to the acidic monomer, 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), which does not dissolve the smear layer and results in a mild demineralization of dental tissues.⁽¹⁷⁾ However, this molecule has been necessary to form chemical interactions with Hydroxylapatite remaining around the collagen within the hybrid layer, and because of the low solubility of the MDP-calcium salt in water, this bond is expected to be stable.⁽¹⁰⁾ Although because of the interaction of this acidic monomer with cement, the bond strength may be decreased which is confirmed by the results of the present study (bond strength in group 2 is lower than group 4).

It was revealed that bond strength of self-adhesive cement is lower than the total-etch cement. The lower bond strength recorded for the self-adhesive cement is probably related to the limited ability of cement to demineralized and infiltrated dentin substrate. Despite their initial low PH, the higher viscosity of the self-adhesive cements may explain why no true hybrid layer is formed when applied to dentin.⁽¹⁹⁾ This result is consistent with those of many articles^(12, 16, 18,19, ,23). In agreement with the present study results, Goracci et al.⁽¹²⁾ and Wang et al.⁽²⁴⁾ also showed that the push-out bond strength of self-adhesive cement was lower than the conventional resin cements. In contrast to our results, Erdemir et al.⁽¹⁾ and Bitter et al.⁽¹⁰⁾ reported a higher bond strength in self-adhesive cements. Different study designs and various materials used might account for these discrepancies.

Results of this study expressed that bond strength of FRC posts to radicular dentin in total-etch cement is lower than the self-etch cement. We can explain that the narrow canal holds water by surface tension, making it difficult to replace water with bonding agents .Therefore, enhanced moisture content inside the root canal might have led to reduced bond strength values of total-etch

systems, even though the root canals were dried carefully using paper points⁽⁵⁾.The results of studies carried out by Goracci et al.⁽¹⁶⁾ and Mazzoniet et al.⁽⁸⁾ are in contrast to our finding. The reason for this controversy could be the type of cements and duration of curing.

In microscopic evaluation, the failure modes recorded were mostly adhesive at the dentin/cement interface in all groups. The chemical compatibility between the resinous matrix of the fiber post and the cement⁽⁴⁾ (both containing methacrylate resin) and sufficient wetting of post by cement(application of margin bond on the surface of fiber post) may be the major factors for the low incidence of adhesive failure along the post/cement interface. The majority of the failures showed cement remnants on the post surface. This finding is consistent with those of other studies^(3,10,19,23).

Cohesive failure in the fiber post was only observed in group 4, which might be due to greater bond strength in this group.

It should be mentioned that limitations may as well exist in direct application of the results of the present study to clinical situations. Further studies evaluating the ultra-morphological features of bonding interfaces created by such products over short and long terms are required to explain these results.

Conclusion

Within the limitations of this in-vitro study, it may be concluded that the bond strengths were significantly affected by the adhesive cement type. Bond strength values of GC Fuji Plus were significantly higher than those of other adhesive cements. Breeze (self-adhesive resin cement) without any pretreatment procedure could not obtain the acceptable bond strength.

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