Original Article

Failure Modes of New Fiber Post Systems Using Stereomicroscope: *An in Vitro Study*

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Abstract

Objective: Failure of the glass posts is a major and the main concern of practical dentistry. This study conducted to evaluate the mode of failure among prefabricated bundle fiber posts, prefabricated taper fiber posts, and short fiber-reinforced composite as a post and luting material using a stereomicroscope.

Methods: Thirty mandibular premolars were divided into three groups (n=10). Group 1: prefabricated taper fiber post cemented with a resin core, group 2: prefabricated bundle fiber post cemented with a resin core and group 3: short fiber-reinforced composite used instead of post and cement. Each root specimen cut into three slices of 2 mm thickness from the cervical, middle, and apical parts of the posts. Push-out tests were performed using a universal testing machine at three sites in each root at a crosshead speed of 0.5 mm/min. Then, the specimens evaluated under stereomicroscope 40X to classify the failure mode.

Results: Sixty two specimens failed adhesively between dentin and cement in all groups, adhesive failure between the post and cement was in the second group, prefabricated taper fiber post (GC fiber post) followed by prefabricated bundle fiber posts (Rebilda GT) (17 sections), and the mixed failure was second for prefabricated bundle fiber posts (Rebilda GT) and third for prefabricated taper fiber post (GC fiber post) (11sections).

Conclusions: Adhesive failure between cement and dentin is dominant in all post systems in three sites of the roots (cervical, middle, and apical). The second most frequent failure is adhesive between post and cement in all regions in post systems.

Keywords: *Fiber post; Bundle post, Short fiber-reinforced composite, Failure modes.*

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Introduction

The glass fiber posts were introduced in 1992 with the increasing demand for aesthetics, in today's era post and core system used for supporting translucent all-ceramic restoration[(1)].

Glass fiber posts provide increased light transmission through the root, giving a more life-like appearance to the prosthesis. The modulus of elasticity of the glass fiber post is comparable with that of dentin, which reduces the chances of root fracture due to stress concentration. Glass fiber posts also eliminate the problem of corrosion and hypersensitivity that occurs with metal posts[(2)]. For endodontically treated teeth, the fiber-reinforced post is becoming a paramount restorative option. Although fiber-reinforced post systems are becoming very popular, however, they have reported some drawbacks and failures[(3)].

To preserve heavily fractured, pulpless teeth in the dental arch is a big challenge for most dentists, to preserve function and aesthetics, this issue has led to the development of alternatives to improve the retention of glass fiber posts, such as the use of accessory fiber posts, and the association of composite resin with glass fiber posts to obtain customized well-fitting posts[(3,4)].

VOCO Company developed a new type of dental posts, which is a radiopaque, translucent, glass fiber-reinforced composite post. This is a bundled post. The new approach is not a single post but rather composed of a bundle of thin individual posts gathered in one sleeve. Once a sleeve is removed, the bundle is spread in fine individual posts that are distributed in the entire root canal, which can be adapted to suit any root canal anatomy. Accordingly, this approach can be used in situations where strongly curved root canals or oval root cross-sections[(5)].

Nowadays, mechanical properties of short fiber-reinforced composite (SFRC) is widely investigated, which are superior to normal composite materials. Bond strength of short fiber reinforcement composites (used instead of post) to root canal dentin is promising because of no luting cement between dentin walls and Fiber-reinforced composite[(6)].

In the situation of failure of adhesive bonding, there are three possible mechanisms; cohesive failure, adhesive failure, and mixed failure. Cohesive bond failures characterized by the clear presence of adhesive material on the matching faces of both adherents and result in fracture of the adhesive; also, the adhesive surface typically appears rough and may have a lighter color than the bulk adhesive material[(7)]. Adhesive failures occur at the interface between the adhesive and the adherent, the residual adhesive remaining at any place on one surface only, and the absence of adhesive on one of the bonding surfaces. The surface of the adhesive is smooth and often replicates surface features from the adherent. Adhesion failures exhibit low strength and may occur with minimum or no applied load if degradation of the interface is complete[(7)].

Mixed-mode failure which is least understood where there is a combination of cohesion and adhesion failure within the same bond. This lack of understanding how adhesive bond transitions from a strong bond which exhibits cohesion failure, to a weak bond which exhibits adhesion failure, make it difficult for the investigator to confirm if the bond failure started with cohesive failure within the cement itself, or started on the adhesive joint[(7)].

Materials and methods

Sample selection and preparation

Thirty intact freshly extracted human mandibular premolars, extracted for orthodontic reasons, the teeth collected from patients an age range of 15 to 30 years. Radiographic images obtained for the mesiodistal and buccolingual views to exclude teeth with calcifications, anatomic abnormalities, signs of internal resorption, or previous endodontic treatment. Teeth were stored in distilled water at room temperature, and decornated at the cementum-enamel junction from the buccal side of each tooth[(8)]. The roots adjusted to have the same length of 12 mm. The working length of each canal determined by inserting a size 10 K type file (Dentsply, Malifer, Switzerland), and the file reduced 1mm from the measured working length[(9)].

Root canal instrumentation and obturation

The roots prepared with the PROTAPER® Next rotary files (Dentsply Tulsa Dental, Tulsa, Oklahoma) driven at 250 rpm with 2N/cm torque (X Smart, Dentsply, Maillefer). Up to size (X3) with Root Canal Preparation Cream EDTA (SURE-PREP, Sure Endo, KOREA) and 2 mL of 5.25% sodium hypochlorite (NaOCl) irrigation performed between each file size. After that, the canals received final irrigation of 5 mL 17% ethylene diamine tetra-acetic (EDTA) acid and 5 mL 5.25% NaOCl; after that, the canals flushed with 10 mL distilled water to avoid the prolonged effect of EDTA and NaOCl[(10)].

The canals subsequently dried with paper points size (X3). Finally, the canals obturated with a single cone technique using size (X3) gutta-percha cones (Dentsply–Maillefer, Ballaigues, Switzerland) in conjunction with AD SEAL root canal sealer (META

BIOMED CO.LTD, Korea). After the completion of endodontic treatment, cervical root canal openings were filled with Temporary filling material MD-Temp (META BIOMED, KOREA). All teeth stored at 37 C and 100% humidity for 24 hours in an incubator to allow the setting of the sealer[9].

Fiber posts procedures and grouping

The roots were randomly assigned to three groups with respect to the post type and luting material:

(1) Prefabricated taper fiber post (GC FIBER POST, GC AMERICA) (1.4 mm in diameter tapered posts) (*n* = 10).

(2) Prefabricated bundle fiber post (Rebilda GT 1.4 mm in diameter bundle posts) (Voco Cuxhaven, Germany), (*n* = 10).

(3) Short fiber reinforcement composite used instead of post-material and luting cement (Ever X Posterior, GC Corp., Tokyo, Japan) (*n* = 10).

After 24 hours, the temporary filling was removed using spoon excavator and the gutta-percha removed with PROTAPER® universal retreatment files (Dentsply), leaving a minimum 4 mm to ensure a clinically acceptable apical seal. A post space was prepared to a depth of 8 mm[11]. Peso reamers number (1) to number (3) used in this study with all groups then fiber post drills of GC fiber post system diameter 1.2 mm 1.4 mm used with all roots because in Rebilda GT system have no specific drills and compatible with all drill systems as manufacture instructed. All the prepared root canals finally flushed with 2 mL NaOCl solution (5.25%) and dried with paper points Dentsply–Maillefer[11].

Before cementation, each fiber post was disinfected with alcohol and dried with air free of water. A silane coupling agent (Ceramic Bond, Voco) applied to the bonding surface of each post and allowed to act for 1 min and air-dried according to manufacture instruction.

After applying self-etching and dual curing bonding agent (Futurabond U Voco Cuxhaven, Germany) for 20 seconds to allow etching agent to etch dentin, the root canal was gently dried with air syringe and not light-cured as manufacture instructed then the core-built-up composite (Rebilda DC, VOCO Germany.) inserted into the canal using application tip for first two groups: GC fiber post and Rebilda post-Gt, after that the post inserted and light-cured using a LED light-curing unit (Dia-lux, Dia Dent Korea)1600mW/mm^2 intensity for 40 seconds in each of four directions (buccally, lingually, mesially, and distally)[7, 8].

In the third group, the same post space was prepared, as mentioned previously. Ever X Posterior was used instead of both post-material and luting agents to fill the post space, which was inserted into the canal with a small micro brush in increments, and each increment was 2mm measured with an endodontic ruler. Each increment light-cured for 20 seconds as manufacture instructed until the post space is filled. Therefore, no additional luting agent will be used in this group[7]. Specimens stored at 37 C and 100% humidity for 24 hours in an incubator to allow the setting of the luting agent[7].

Root sectioning

The root sectioned using (0.3) mm in the thickness of diamond-coated blades in a linear precision cutting device (Micra Cut 176, Metkon, Turkey). Each root specimen cut into three slices of 2 mm thickness from each coronal, middle and apical part of the posts. So each group had 30 test specimens[9]. Four cuts made during the sectioning procedure (first cut to separate the extruded part of the post and the next three cuts made to separate the cervical, middle, and apical slices) so 2 mm lost during the cutting procedure, added to 6 mm (the thickness of three slices), this created a total of 8 mm, which was equal to the length of the cemented post because the thickness of the diamond disc is 0.3 mm, it made a cut of 0.5 mm in thickness.

Push-out bond strength test procedure

For the push-out bond strength test, Universal testing machine (TERCO, MT 3037, Sweden) used Figure 1. Two rods were used, and their diameters were 0.6 mm and 1.0 mm. The special base for holding specimens during push out test had been manufactured shown in Figure 2.

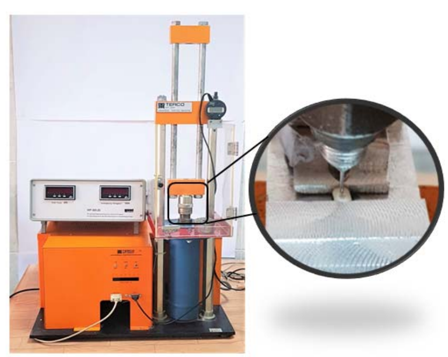

Figure 1: Universal testing machine for the push-out test.

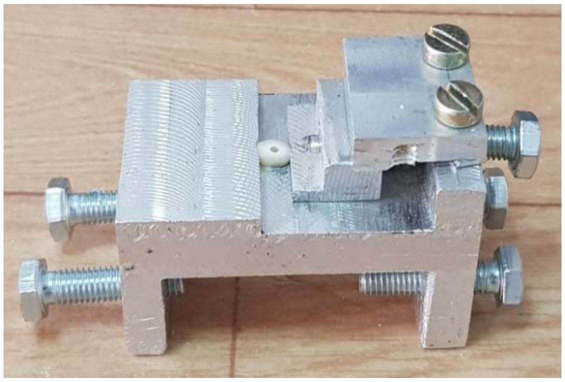

Figure 2: The special base for holding specimens of the roots.

The posts inside the specimens were loaded on the apical to the coronal direction. The punch pin was positioned to contact only the post, without stressing the surrounding media. The speed was 0.5 mm/min at room temperature 25 centigrade. The maximum push-out force for bond failure recorded in (n). But the retentive strength of the post segment will be expressed in MPa[9].

The formula that used for calculating the total bonding area for each post is:

De bond stress (Mpa) = De bond force (N) / Area of the post (A)

The adhesive surface (A) was calculated using equation 1:

$A= 3.14 \times L \times (R_1+R_2)$

where A is the adhesive surface area (mm^2), L is the slant height of the inverted cone (mm), R_1 is the smaller base radius of the post (mm), and R_2 is the larger base radius (mm).

The slant height was calculated using Equation 2:

$L= [H^2 +(R_2-R_1)^2]^{½}$

Where H is the height of the post in the specimen[12].

Classification of the mode of failure for posts after the push-out test

The failure mode of each deboned specimen evaluated under a stereomicroscope at 40 x magnification and classified as:

A. Adhesive failure between post and cement.

B. Adhesive failure between cement and dentin.

C. Mixed failure with resin cement covering the post surface and dentin.

D. Cohesive failure (within the Post)[12].

Statistical analysis

The data were collected, tabulated, and statistically analyzed, and the number of each type of failure was calculated.

Results

Mode of failure for the push-out strength test

In the assessment of failure modes under a stereo-microscope, the results of failure patterns of each fiber post were shown as the frequency distribution of specimen members in each type of failure mode. The mode of failure for the push-out test is presented in Table 1 and Figure 3**.** Adhesive failure between the dentin and cement (Figure 4A) occurred in 62 specimens, and it is the most frequent type of failure for (GC fiber post) and (Rebilda GT) fiber post and for (Ever X) since no additional cement was used between (Ever X) Posterior material and dentin, all the failures were between resin-based material (instead of post) and dentin. Adhesive failure between the post and cement was the second type for GC fiber post, and third for Rebilda GT - 17 sections (Figure 4B and 3C). Mixed failure was second for Rebilda GT and third for GC fiber post – 11 sections (Figure 5A and B). Cohesive failure was not observed, and Cohesive fracture of fiber post and root dentin not occurred.

Discussion

Type of materials used in the study

Rebilda GT is a new type of dental posts, which is a bundled of glass fiber-reinforced composite post, different from conventional root posts, this new approach is not a single post but rather composed of a bundle of thin individual posts[5].

Rebilda GT can spread in fine individual posts that are distributed in the entire root canal, which adapt optimally to suit any root canal anatomy; accordingly, this approach can be used in situations where strongly curved root canals or oval root cross-sections and pronounced conicity occur[11]. In this study, Rebilda GT No. 12 (~ 1.4 mm diameter) used, which contains 12 individual thin posts that hold together. It is a new concept of fiber posts that not widely tested with push-out bond strength tests.

Table 1: Mode of failure for the push-out test.

Post Type	Root Sections	Mode of Failure				
		Adhesive (C-D)	Adhesive (P-C)	Mixed	Cohesive (luting cement)	Cohesive failure (within the Post)
Rebilda GT	Cervical	5	2	3	-	-
	Middle	4	2	4	-	-
	Apical	5	3	2	-	-
GC Fiber Post	Cervical	6	4	-	-	-
	Middle	7	3	-	-	-
	Apical	5	3	2	-	-
Ever X	Cervical	10	-	-	-	-
	Middle	10	-	-	-	-
	Apical	10	-	-	-	-

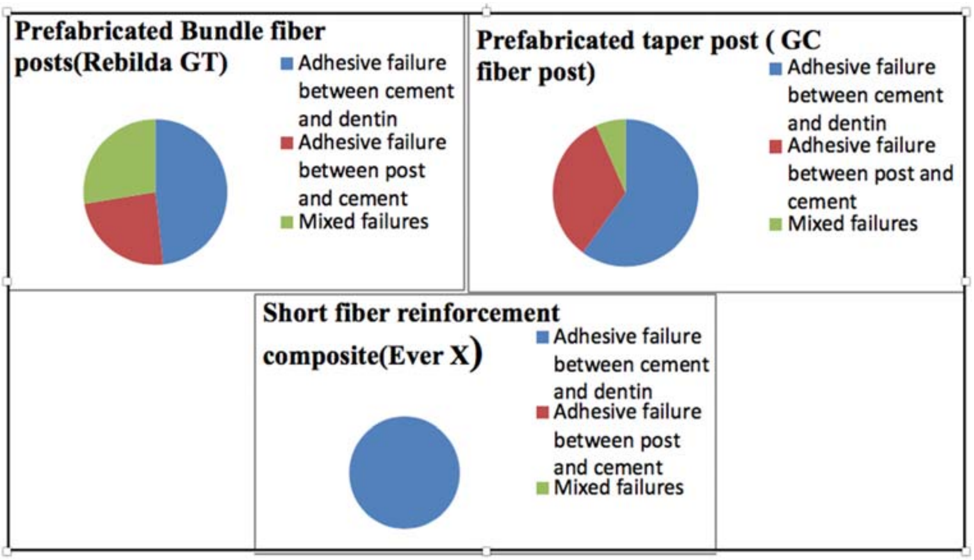

Figure 3: Failure modes charts of the three posts.

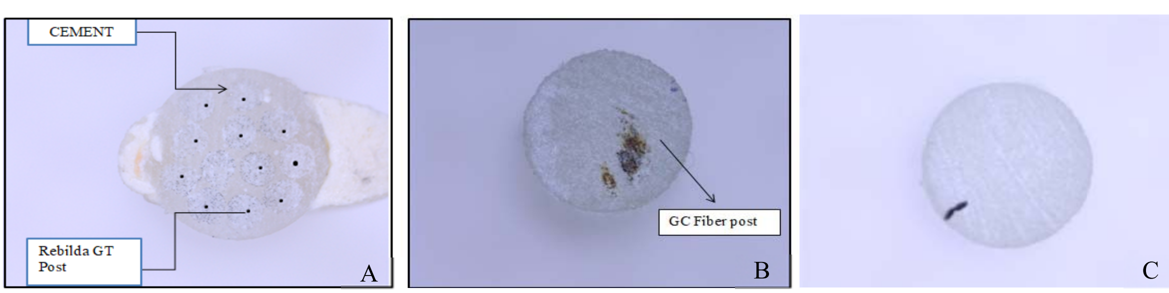

Figure 4: A - Adhesive failure between cement and dentin, B - Adhesive failure between cement and post.

C: Adhesive failure between cement (Ever X) and dentin.

Figure 5: A - Mixed failure with resin cement covering the post surface and dentin, B - Mixed failure with resin cement covering the post surface and dentin (GC fiber post).

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A short discontinuous fiber composite (FRC) (EverX Posterior, GC Corp.) has been introduced for dentin replacement in large, deep, and high-C factor design cavities. Furthermore, a previous study provided that EverX Posterior could be used in 4 mm increments in extensive posterior cavities to mimic the stress absorbing properties of dentin since these composites enable 4–5 mm thick increments to be cured in one step, they are time-saving and easy-handling composites(6).

Fiber-reinforced composite restoration, used in the present study, FRC has been introduced as a dental restoration to enlarge the indication of direct composites to extensive posterior cavities. It is a compound consisting of a resin matrix, short E-glass fibers, and inorganic particulate fillers. In addition, randomly oriented short E-glass fiber structure in Ever X Posterior results in a degree of toughness that is equivalent to dentin and provides the anisotropic reinforcing effect(6).

Analysis of the failure modes

The analysis of failure modes after the push-out test revealed that a majority of adhesion between dentine and cement, implying that the weak link was the bond between the resin cement and the root dentine probably because of root canal walls debris that might have remained and interfered with effective bonding. These results agree with those of other studies(13,14).

This may be explained by the inability of the self-adhesive resin cement to form a distinct hybrid layer between dentin and resin tags like the etch-and-rinse cement and, therefore, unable to demineralize the dentin surface and etch a thick smear layer(15). In all groups, the failure mode was mostly in the dentin–cement interface, which means either the cement could not dissolve the smear layer and demineralize the dentin substructure or that the residual chemical adversely affected the bonding process(16).

The third occurring failure mode in this study was of an adhesive nature at the cement and post interface for the Rebilda GT and second for the GC fiber post groups. It seemed that the fact that the Rebilda DC as a Dual cure system did not make a well hybrid layer in dentine, for better bonding would make the lower bond strength than the strength between cement and post which has better conditions for bonding with the silanization that used in the study(17).

One difficulty with some of the available prefabricated fiber posts is that the polymer matrix between the post material fibers is highly cross-linked and, therefore, less reactive. This makes it difficult for these posts to bond to resin luting agents and tooth structure, Although the adhesion in the root canal represents the weakest point of the post-endodontic restoration, the post/composite adhesion needs to be considered. Bonding of fiber posts to composite materials relies only on the chemical interaction between the post surface and the resin material used for luting or building-up the core(18).

In the Ever X Posterior group, since no additional cement was used between Ever X Posterior material and dentin, all the failures were between resin-based material (instead of post) and dentin. Long, narrow, and deep cavities have high C-factor causing shrinkage stress during polymerization, which might exceed the bond strength(19). Additionally, the curing light loses too much intensity due to attenuation before reaching the bottom of the cavity, and inadequate polymerization can occur in the deep sections of the cavity(20).

Conclusions

Within the limitations of this in vitro study, the following conclusions could be drawn:

The most frequent failures for prefabricated bundle post (Rebilda GT) and prefabricated taper fiber post (GC fiber post) are adhesive failure between cement and dentin in all site areas - cervical, middle and apical. The second frequent failure is also Adhesive but between post and cement. The adhesion between fiber post and cement in the two groups is better than the adhesion between cement and dentin. For the fiber reinforcement composite (Ever x), all the failures were adhesive between cement and dentin because it was used instead of the post and cement.

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