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Effect of Glass Fiber Post Adaptation on Push-Out Bond Strength to Root Dentin

Thiago Lopes de Freitas[1], Rafael Pino Vitti[2], Milton Edson Miranda[1], William Cunha Brandt[3]

[1]Department of Prosthodontics, School of Dentistry, SLMANDIC - Faculdade de Medicina e Odontologia São Leopoldo Mandic, Campinas, SP, Brazil
[2]Department of Operative Dentistry, School of Dentistry, FHO/UNIARARAS - Centro Universitário Hermínio Ometto, Araras, SP, Brazil
[3]Department of Implantology, School of Dentistry, UNISA – Universidade de Santo Amaro, São Paulo, SP, Brazil

Correspondence: Rafael Pino Vitti - Herminio Ometto University Center - Av. Dr. Maximiliano Baruto, 500, 13607-339 Araras, SP. Tel/Fax: +55-19-3543-1400. e-mail: rafapvitti@gmail.com

The aim of this study was to evaluate the effect of different glass fiber posts (GFPs) diameters on the push-out bond strength to dentin. Forty unirradicular human teeth were endodontically treated and used for cementation of GFPs (White Post DC, FGM) with different diameters (n=10): P1 - ø 1.6 mm coronal x 0.85 mm apical; P2 - ø 1.8 mm coronal x 1.05 mm apical; P5 - ø 1.4 mm coronal x 0.65 mm apical; and PC - customized post number 0.5 with composite resin (Tetric Ceram A2, Ivoclair Vivadent). All GFPs were cemented into the root canal using a dual-curing luting composite (Variolink II, Ivoclar Vivadent). One slice (1.7 mm) of each root third of cemented GFP (cervical, middle, and apical) was submitted to push-out testing. Failure modes of all specimens were classified as: adhesive failure between resin cement and post; adhesive failure between dentin and resin cement; cohesive failure within resin cement, post or dentin; and mixed failure. The data were analyzed with two-way ANOVA and Tukey's test (α=0.05). The highest bond strength values were presented for the P2 and PC groups. There was no statistically significant difference between the GFP thirds in each group. The groups P2, P5, and PC showed predominantly adhesive failure. For P1, the most prevalent type of failure was adhesive between resin cement and post. It may be concluded that a glass fiber post that is well adapted to the root canal presents higher bond strength values, regardless of GFP third.

Key Words: film thickness, resin composite cements, adhesion.

Introduction

Root post systems have been used to rehabilitate endodontically treated teeth with partial or total destruction of dental crowns (1). Prefabricated or cast metal posts have been widely used for many years. However, these posts have some limitations inherent to root fractures, in addition to causing an aesthetic compromise (2). The fact that the modulus of elasticity of the metallic posts is greater than the root dentin results in different stresses at the dentin/post interface, which is one of the predisposing factors of root fractures (3). On the other hand, the aesthetic properties are impaired by the color and opacity inherent in the metals or metal alloys used in these types of posts, interfering negatively in the translucency and final result of the color of the prosthesis (2). In addition, some alloys may undergo oxidation, producing dark pigments that impregnate and darken the roots and the gingival margin of the teeth (2).

In the face of these problems, research has been conducted to find a new type of material for root posts. Glass fiber posts (GFPs) have emerged with promising characteristics, since these materials have a modulus of elasticity similar to dentin, which considerably reduces the risk of root fractures (3-6). In addition, GFPs have the best aesthetic result because they have a color and opacity closer to dentin and do not undergo oxidation (2). The fixation of GFPs in the root canal is based on adhesive cementation and its retention depends directly on the bond strength between the post/cement/root dentin (7). Some failures in treatment with GFPs were observed mainly due to adhesive failures, leading to the loss of bond strength to dentin and consequently to the post release (1,3-5,7).

Adhesive failures may have several causes, including root canal shape, difficulty in accessing the middle and apical root thirds, the different histology of the root dentin (quantity and direction of the dentinal tubules), and difficulty of light curing in the middle and apical thirds (4,7,8). In addition, there is the polymerization shrinkage that generates a stress at the adhesive interface that causes gaps and negatively influences the bond strength (9). The geometric configuration of the root canal increases the C-factor and the shrinkage stress within the root canal (10). The formation of gaps generally occurs at the dentin/resin cement interface, since the bond strength in this zone is lower than the bond strength to the resin cement/GFP interface (11).

Some techniques have been proposed for cementing fiber glass posts to reduce the volume of cement and consequently achieve better adaption between the post and root canal. Some studies have shown that thick cement layers decrease the bond strength (11-12), since a greater volume of cement leads to greater volume shrinkage, generating a higher shrinkage stress at the adhesive interface and causing a greater formation of gaps inside the root canal (7,9,1-12).

However, other studies have suggested that well-adapted posts may also decrease the bond strength (13-16). Therefore, post adaptation and ideal cement layer thickness to increase the bond strength are not yet very well defined in the literature. Thus, the aim of this study was to evaluate the performance of GFPs with different diameters to the root canal on bond strength to dentin. The hypothesis is that GFP relining increases the bond strength to root canal walls.

Material and Methods

Experimental Design

This study had a randomized block design in a 4×3 factorial scheme. The independent variables were: GFP diameter, at 4 levels (non-relined post P1; non-relined post P2; non-relined post P5; and relined post) and GFP cemented thirds, at 3 levels (apical, middle and cervical). The experimental units were composed of forty unirradicular human teeth (incisors and canines) with circular canal shape (visually checked after crown/root separation), randomly divided into four groups, according to the GFP diamenter (n=10). The dependent variable was the push-out bond strength to dentin. In addition, fracture mode was qualitatively evaluated. This study was approved by the local Ethics Committee (protocol #1.006.256). The inclusion criteria were mandibular and maxillary unirradicular teeth, absent of restoration, caries, root cracks, previous endodontic treatments, posts or crown, and a root length of 12 mm measured from the cementoenamel junction (CEJ). Radiographs were taken to confirm the presence of a single canal without previous endodontic treatment, resorptions, or calcifications. The teeth were stored in a 0.2% chloramine solution at 4°C, for no longer than three months. The crowns were removed approximately 2 mm above the CEJ using a high-speed diamond saw (KG Sorensen, São Paulo, SP, Brazil), under water cooling.

Preparation of Root Canals

The teeth were treated endodontically using the step-back technique and Gates Glidden drills (Mani, Utsunomiya, Japan). Working length was established by inserting #10 K-file (Mani, Tochigi, Japan) into canal until the apical foramen. One millimeter was subtracted from this length to establish the working length. Apical stop was established using #35 K-file (Mani). The cervical and middle thirds of the root canals were enlarged using #4, 3, and 2 Gates-Glidden drills in low-speed handpiece. The canal apices were prepared up to a #35 K-file and the working length was determined. During the biomechanical preparation, the root canals were irrigated with 5 ml of 1% sodium hypochlorite (Milton Liquid, Asfer, São Paulo, SP, Brazil) after each file was used.

After the biomechanical preparation, the root canals were submitted to treatment with ethylenediaminetetraacetic acid (EDTA, Asfer) for 5 min. A final rinse was performed with 0.9% saline solution (Sanobiol, São Paulo, SP, Brazil). The root canals were then dried with paper points (Tanari, Tanariman, São Paulo, Brazil) and obturated using gutta-percha (Tanari, Tanariman) and Endofill sealer (Dentsply, Switzerland) utilizing the lateral compaction technique. After endodontic treatment, the samples were stored in distilled water at 37°C for up to 30 days.

The gutta-percha was removed and root canals were prepared again using #4, #3, and #2 Gates-Glidden drills (Mani), respectively, using low-speed handpiece in cervical and middle thirds. Specific drills for root canal preparation of GFPs (White Post DC, FGM, Joinvile, SC, Brazil) were used following the sequence of diameters: 0.5, 1, and 2 (the step-back technique was used to avoid overheating). In all teeth, 12 mm of the root canal were prepared using drill #2 in the cervical region (1.8 mm diameter) and apical region (1.05 mm diameter). After preparation, the root canal was again irrigated with saline solution and EDTA (5 ml each) to remove the smear layer, and dried with paper points.

Preparation of Glass Fiber Posts

Four custom adapted fiber post (different diameters) were used in the current experiment (n=10): P1 - post number 1 (1.6 mm coronal diameter x 0.85 mm apical diameter); P2 - post number 2 (1.8 mm coronal diameter x 1.05 mm apical diameter); P5 - post number 0.5 (1.4 mm coronal diameter x 0.65 mm apical diameter); PC - post number 0.5 customized using composite resin (Tetric Ceram A2, Ivoclair Vivadent, Liechtenstein). In PC group, the post + composite resin assembly was then placed into the root canal and light-cured for 20 s (Valo, Ultradent, South Jordan, UT, USA). The customized fiber post was removed and the composite resin light-cured for additional 20 s. The root canal was again rinsed with saline and EDTA before cementation.

Translucent GFPs (White Post DC, FGM) were used for all groups. These posts are composed of 70% glass fiber, 25% epoxy resin, and 5% epoxy hardener. All posts were cleaned with 37% phosphoric acid (Condac 37, FGM) for 60 s, followed by water-rinsing (30 s) and air-drying (30 s). Then, a silane (Prosil, FGM) was applied on each post, followed by air-drying for 30 s. The catalyst of the adhesive system (Adper Scotchbond Multipurpose Plus, 3M ESPE) was applied using a micro-brush and air-dried for 5s. The adhesive system (Adper Scotchbond Multipurpose Plus, 3M ESPE) was applied as follows: activator for 10 s, drying for 5 s with absorbent paper points, two layers of primer (10 s each) under friction (microbrush) on the dentin, drying for 5 s with absorbent paper points and application of the catalyst for 5 s.

Bond Strength Test

Twenty-four hours after root canal preparation, the root canals were etched with 37% phosphoric acid (Condac 37, FGM) for 15 s, rinsed with physiological serum, and gently dried with paper points. Then, the adhesive system (Adper Scotchbond Multipurpose Plus, 3M ESPE) was applied according to manufacturer's instructions (adhesive system plus activator applied to the root canal, dried for 5 s, followed by application of primer and dried for 5 s, and adhesive system plus catalyst using a paper point).

A dual-curing luting composite (Variolink II, Ivoclair Vivadent) was used for luting all posts. The posts were placed within the root canal (12 mm) and held in position under manual pressure for 5 s during light-curing, which was performed using a multiwavelength light-emitting diode (VALO, 1400 mW/mm^2, Ultradent, USA) for 60 s. The samples were stored in distilled water in an incubator at 37°C for 24 h.

Samples were sectioned transversely using a precision saw (Isomet 1000, Buehler, USA). The first cut was made at 1 mm from the enamel-cement junction and discarded. Thus, five specimens with 2.0 mm thickness were obtained of each GFP third (apical, middle and cervical). Thus, five specimens with 1,7 mm thickness were obtained of each root canal/cemented GFP. The first slice corresponded to cervical, third slice to middle, and fifth slice to apical thirds. The second and fourth slices were discarded. A digital caliper (Mitutoyo Corporation, Tokyo, Japan) was used to measure the thickness of the slices. The specimens were positioned on a metal base with a hole 2.0 mm in diameter. A cylindrical plunger tip (0.5 mm diameter) was adapted to the testing machine and positioned on the specimen such that it only was in contact with the GFP. The specimens were submitted to push-out testing using a universal testing machine (DL 2000, EMIC, São José dos Pinhais, PR, Brazil) at a crosshead speed of 0.5 mm/min. The results obtained were expressed in Newtons (N). To obtain the results in MPa, the adhesion area of each slice was calculated by using following equation: $A=((2\pi r + 2\pi R)*h)/2$, where π is 3.14, r and R are the smallest and largest radii of the GFP, respectively, and h is the slice thickness. The bond strength value was obtained by the equation $\sigma=T/A$, where T is load at failure of the specimen (N) and A is interfacial area (mm^2).

Failure Mode Analysis

Each specimen was evaluated using a stereomicroscope (EK3ST, Eikonal Equipamentos Ópticos e Analíticos, São Paulo, SP, Brazil) at 40x magnification to determine the failure modes: APC - adhesive failure between post and cement; ACD - adhesive failure between cement and dentin; CC - cohesive failure in cement; CD - cohesive failure in dentin; and M - mixed failure (post, cement, and dentin).

Statistical Analysis

Statistical analysis was performed using Kolmogorov-Smirnov and Levene tests for normality and homogeneity. The data were analyzed using 2-way ANOVA (different fiber post diameters and GFP thirds) followed by Tukey's test (α=0.05).

Results

According to Kolmogorov-Smirnov test, the push-out bond strength data are in normal distribution (p=0.274) and Levene test for equality of variances (p=0.169) confirmed the homogeneity of variances for the results. The statistical analyses showed no significant effect for an interaction between the two study factors (p = 0.297) nor for the GFP third in each group (p=0.247). Only the fiber post diameters presented a significant effect (p<0.001) (Table 1).

P2 and PC showed the highest bond strength values (p<0.05), which were not statistically different from each other. P5 and P1 were not statistically different and showed the lowest bond strength values (p<0.05).

A predominance of ACD failure was observed for P2, P5, and PC. On other hand, the predominant failure mode in P1 was APC (Fig. 1).

Discussion

The clinical procedure for luting GFPs in the root canal of endodontically treated teeth is sensitive to several

Table 1. Mean values and standard deviation (SD) of push-out bond strength (MPa) of different fiber posts and glass fiber post third (cervical, middle or apical)

Group	Cervical	Middle	Apical	Pool mean
P1	6.2 (3.4)	4.9 (2.8)	5.1 (2.8)	5.4 (3.0) b
P2	10.7 (3.0)	7.9 (2.0)	8.6 (5.9)	9.1 (4.0) a
P5	6.0 (2.1)	4.4 (1.8)	5.9 (3.7)	5.4 (2.7) b
PC	8.8 (2.7)	10.5 (3.6)	7.7 (2.6)	9.0 (3.1) a

Different letters indicate statistically significant difference for each fiber post (column) (p<0.05). Groups: P1: post number 1 (1.6 mm coronal diameter x 0.85 mm apical diameter); P2: post number 2 (1.8 mm coronal diameter x 1.05 mm apical diameter); P5: post number 0.5 (1.4 mm coronal diameter x 0.65 mm apical diameter); PC: post number 0.5 customized using composite resin.

factors that can decrease the bond strength, jeopardizing the longevity of restorations (4,7,11-14). The results of the present study showed that there was a difference in bond strength values among the groups tested. The groups with a greater adaptation to the root canal and GFP (P2 and PC) presented the highest bond strength results than the groups with less adaptation (P5 and P1). The PC restoration technique "individualized" the fiber post, leaving it with a shape similar to that of the root canal (3,5-7).

The higher bond strength results for P2 and PC could be explained by the lower volume of resin cement required to fill the spaces between the GFP and root dentin, compared to P5 and P1. The fact that the GFPs are more adapted to the root canal reduces the amount of resin cement used, thus minimizing the polymerization shrinkage of the material and generating less stress at the adhesive interfaces, corroborating with other studies (11,17). Different results found in other studies (13-16) are most likely due to different materials (cements) and/or tests used (microtensile and pull-out bond strength tests). Resin cements have different physicochemical properties related to bond strength, such as viscosity and flow. A resin cement with greater flow fills the root canal better, providing an intimate contact between the GFP and root dentin, improving adhesion (7). The push-out test was used in the present study because it is the most reliable test for evaluating the GFP bond strength to root dentin, since the fracture pattern occurs parallel to the cement/root dentin interface. Moreover, the premature loss index is lower, the variance is more acceptable, and the standard deviation tends to be lower when comparing this test to other tests (18).

Among P2 and PC, the amount of cement used was similar, justifying the lack of difference in the bond strength values. It is of clinical relevance that the use of the customized post technique with a light-curing composite resin in teeth with a very broad root canal diameter is an efficient technique for improving the adaptation of GFPs to roots, increasing the bond strength (19). In addition, the lower bond strength values for P5 and P1 groups could be explained by the presence of bubbles and pores formed in thick cement layers (higher volume of resin cement). Furthermore, it is likely that there is no statistically significant difference between P5 and P1 because the polymerization shrinkage does not influence the bond strength at the GFP/resin cement/root dentin interface (8-9,11-12), when using a certain resin cement volume, due to the large number of bubbles and pores (9,11). It is important to emphasize that henolic compounds of eugenol present in Endofill release free radicals and leave an oily

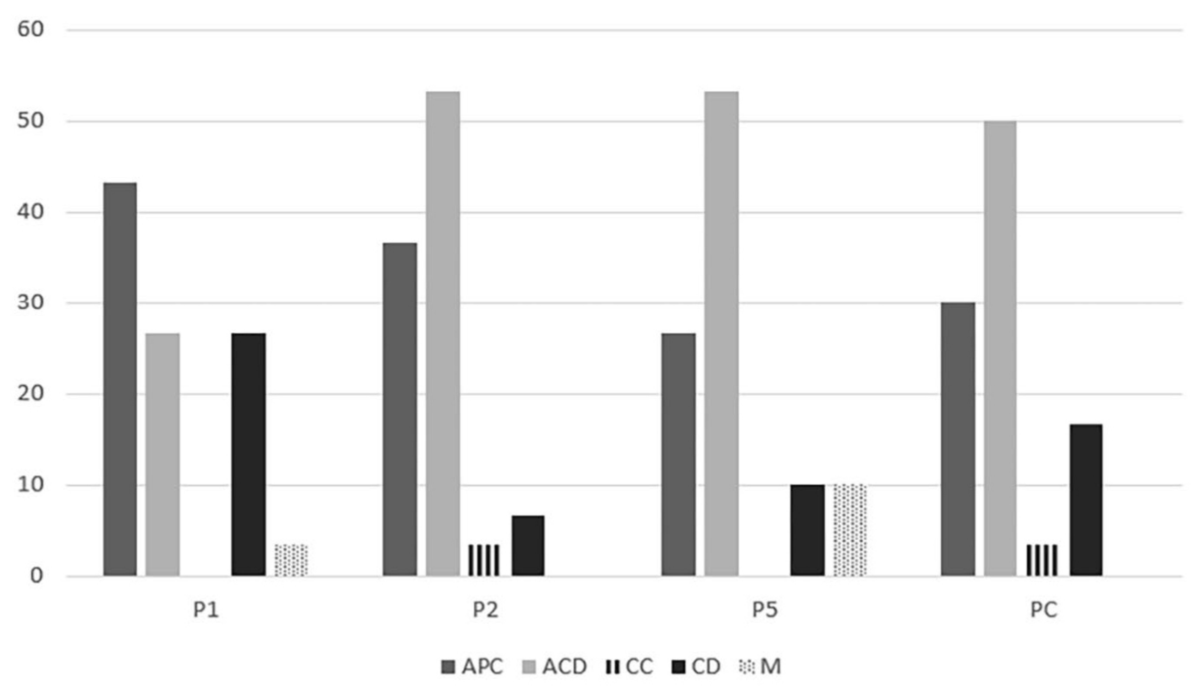

Figure 1. Failure mode (APC, ACD, CC, CD, and M) analysis for each type of glass fiber post (P1, P2, P5, and PC). Groups: P1: post number 1 (1.6 mm coronal diameter x 0.85 mm apical diameter); P2: post number 2 (1.8 mm coronal diameter x 1.05 mm apical diameter); P5: post number 0.5 (1.4 mm coronal diameter x 0.65 mm apical diameter); PC: post number 0.5 customized using composite resin. Failure modes: APC: adhesive failure between post and cement; ACD: adhesive failure between cement and dentin; CC: cohesive failure in cement; CD: cohesive failure in dentin; M - mixed failure (post, cement, and dentin).

layer of debris that hamper the polymerization of luting composites (20,21).

No difference was found with regards to the bond strength values among the different GFP thirds. In the present study, the root canal was prepared with a 1.8 mm drill in the cervical third and 1.05 mm in the apical third. This diameter allowed easy access to the middle and apical thirds of the root canal, allowing the adequate removal of any remnants of sealing material (gutta-percha and endodontic cement). Additionally, proper acid etching on dentin maintained a standardized thickness of the hybrid layer throughout the dentin (22-23). The differences in the bond strength among the root thirds could be explained by the different preparations of the root canal (24). Additionally, the differences in bond strength in the GFP thirds can be explained by the materials, as self-etching resin cements do not require the application of an adhesive system for dentin bonding, thus reducing the sensitivity of the technique because it does not depend directly on access to the middle and apical thirds (4,7-8).

For P2, P5, and PC, a predominance of ACD failures was observed. This result corroborates other studies (2,13) and shows the effectiveness of the cementation technique and the push-out test, since the bond strength occured at the resin cement/root dentin adhesive interface. Moreover, this result shows that the most critical adhesive interface is between the resin cement and root dentin and that the surface treatments on the GFP promoted a satisfactory resin cement/GFB bond strength.

Some methodological limitations allow a limited interpretation of the results. The non-standardization of root length allowed for the ability to work in different root dentin regions that present histological differences. Therefore, more studies are needed to evaluate the relation between fitting the GFP to root dentin (canal walls).

It is concluded that the cementation techniques for GFPs that provide a more intimate contact with the root canal walls presented better push-out bond strength to root dentin without differences among GFP thirds. The most common adhesion failure occurred at the interface between the resin cement and the root dentin.

Resumo

O objetivo neste estudo foi avaliar o impacto de diferentes diâmetros de pinos de fibra de vidro (PFVs) na resistência de união à dentina. Quarenta dentes humanos unirradiculares foram tratados endodonticamente e utilizados para cimentação de PFVs (White Post DC, FGM) com diferentes diâmetros (n=10): P1 - ø 1,6 mm coronal x 0,85 mm apical; P2 - ø 1,8 mm coronal x 1,05 mm apical; P5 - ø 1,4 mm coronal x 0,65 mm apical; e PC - pino número 0,5 individualizado com resina composta (Tetric Ceram A2, Ivoclair Vivadent). Todos os PFVs foram cimentados no canal radicular usando cimento resinoso dual (Variolink II, Ivoclar Vivadent). As raízes foram seccionadas em três secções (cervical, média e apical) e submetidas ao teste push-out. Os modos de falha de todos os espécimes foram classificados em falha adesiva entre o cimento resinoso e pino, falha adesiva entre dentina e cimento resinoso, falha coesiva no cimento resinoso, pino ou dentina e falha mista. Os dados foram analisados com ANOVA two-way e teste de Tukey (α=0,05). Os maiores valores de resistência da união foram apresentados para os grupos P2 e PC. Não houve diferença estatisticamente significante entre os terços dos PFVs cimentados na raiz para cada grupo. Os grupos P2, P5 e PC apresentaram predominantemente falha adesiva entre a dentina e o cimento resinoso. Para o grupo P1, o tipo de falha mais prevalente foi a adesiva entre cimento resinoso e pino. Pode-se concluir que o pino de fibra de vidro bem adaptado ao canal radicular apresentou os maiores valores de resistência da união, independentemente do terço dos PFVs.

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