Original Article

Push-out bond strength of a fiber post system with two resin cements

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ABSTRACT

Introduction: Debonding is a common cause of failure encountered with fiber-reinforced composite (FRC) posts, and usually occurs along the post space-dentin adhesive interface. The aim of this *in vitro* study is to evaluate the regional push-out bond strength of a fiber-reinforced post system, using two resin cements.

Materials and Methods: In this *in vitro* study 20 maxillary central incisors were decoronated and the roots were endodontically treated. Following post space preparation, the roots were divided into two groups of 10 specimens each. Fiber-reinforced composite posts were cemented with two resin cement systems: (a) Self-etch system (Panavia F2.0/ED-primer II) and (b) conventional system (Variolink II/Excite DSC). Three slices of each root, with a thickness of 3 mm, were prepared. The push-out test was performed with a universal testing machine at a crosshead speed of 1 mm/minute, and bond strength values were calculated. The data were analyzed with a two-way Analysis of variance (ANOVA) and Scheffe tests (α=.05).

Results: There were no significant differences between the mean push-out bond strengths of two experimental groups (Panavia F: 12.59±5.44, Variolink II: 12.49±4.52 MPa) (P=0.920), but there were significant differences between the mean push out bond strengths of the root dentin regions (P<0.001).

Conclusion: Under the conditions of this study, there was no significant difference between the mean push out bond strength of self-etching and the conventional resin cement systems. The coronal region of the root dentin showed a significantly higher bond strength than the apical region.

Key Words: Bond strength, composite resins, dental bonding, fiber reinforced, post and core technique, resin cements

INTRODUCTION

Endodontically treated teeth, with a large amount of coronal tooth structure missing, frequently require the placement of a post inside the root canal, to retain a core for definitive restoration.[1-3] The choice of appropriate restoration for these teeth is influenced by strength and esthetics.[4] Depending on the clinical parameters, the choice may be a metal or an esthetic post and core restoration.[5-7]

Clinical studies have reported success rates of 95 to 99% for teeth restored with fiber-reinforced posts, with no occurrence of root fracture during the study periods.[8,9] The most common cause of failure reported in these studies is not from the root fracture, as occurs with metal or cast posts, but rather from the pull out of the cement, post restoration assembly, as a result of lack of retention of the fiber posts.[7,10] The retention of fiber posts in the roots depends on the bond strength between the post material and a resin luting agent, as well as the bond strength between the resin luting agent and post space dentin.[11-14]

Many *in vitro* studies have investigated various factors that influence this bond strength. These factors include length, design, diameter, composition, surface treatment of the post, preparing the dentinal surface, the dentin bonding agent, luting cement, and

polymerization mode.[3,10,15] The effect of cement type on the retention of the post in endodontically treated teeth has been investigated extensively and it has been found that resin cements can significantly increase the retention of posts and fracture-resistance of the teeth, compared to other cements.[15-17]

Different resin luting agents and corresponding bonding systems have been proposed for cementing tooth-colored posts.[16,18] Several *in vitro* studies have reported controversial results regarding bond strengths of different luting agents to endodontic posts and root canal dentin.[19-26]

Selecting an appropriate adhesive and luting procedure for bonding posts to root dentin is an important challenge.[27-29] According to adhesive dentistry, two strategies can be used to allow the bonding agents to react with the dentin.[6] Some systems use etch-and-rinse with phosphoric acid to eliminate the smear layer and demineralize the underlying dentin. This step is followed by application of a hydrophilic monomer that penetrates the conditioned dentin surface. Other systems use self-etching primers, with no rinsing step, which cause less aggressive demineralization and are followed by the application of an adhesive resin.[30]

The bond strength of fiber posts to root canal dentin may be varied in different regions of the root canal.[18,30,31] This difference may arise from the difficulty of reaching the curing light to more apical parts of the root canal, difficulty of direct vision to the deeper regions of the root canal, and difficulty of moisture control and adhesive application in the apical region of the root canals.[16] The aim of the present study is to compare the push-out bond strength of a glass fiber reinforced composite post system, cemented with a self-etch and conventional resin cement systems, in different root canal regions.

The null hypotheses were: (1) Self etching and conventional resin cements provide the same bond strength for glass fiber reinforced composite post, and (2) there are no differences between the bond strengths of different post space regions.

MATERIALS AND METHODS

In this *in vitro* study, 20 human maxillary central incisors with 15 mm length (from 1 mm above the cementoenamel junction to the apex), extracted for periodontal reasons, were selected. The specimens were free of cracks, carious lesions, fractures, and resorption, with fully developed apices and without previous endodontic treatments, posts, or crowns. They were cleaned off soft tissues and calculus, and placed in 2.5% sodium hypochlorite for two hours, for surface disinfection, and then stored in 0.1% NaN3 solution until use.

The coronal part of each tooth was removed 1 mm above the cementoenamel junction with diamond disks (Ref.070, D and Z, Berlin, Germany), mounted on a dental lathe machine (KaVo Polishing Unit. EWL 80, Leutkrich, Germany) at low speed, under constant water irrigation, to achieve a uniform length of 15 mm. The canal working length was established 1 mm short of the apical foramen. The step-back technique was used for canal instrumentation. Obturation was performed using AH26 (Dentsply Caulk, Milford, Germany) and gutta-percha (Aria Dent, Asia Chemi Teb Co., Tehran, Iran), with the vertical condensation method. After completion of endodontic treatment, the coronal root canal openings were filled with a provisional restorative material (GC Caviton; GC Dental Products Corp., Tokyo, Japan), and the teeth were stored in 100% humidity for one week at 37°C, to allow the sealer to set. After one week, the gutta-percha was removed from the coronal aspect of each root with a Gates Glidden drill #3 (Dentsply-Maillefer, Ballaigues, Switzerland) leaving 4 mm gutta percha in the apices, to preserve the apical seal. The post spaces were prepared to a depth of 10 mm with the appropriate drills (Fibio, Anthogyr, Sallanches, France). A new drill was used for every five specimens.

Post size 3 was tried, to ensure that the posts would reach the bottom of the post space. All posts were marked at a distance of 10 mm from the apical end, and were cut to that size with diamond disks. The shortened posts were cleaned with 70% ethanol for 60 seconds, rinsed with distilled water, and air dried. Before the cementation procedures, the post surfaces did not undergo any pretreatment.

The prepared roots were randomly divided into two groups of 10 specimens each for cementation procedures [Table 1].

In group 1, the posts were luted with Panavia F 2.0 (Kuraray Medical, Inc., Okayama, Japan) after conditioning the dentin with ED-Primer (A and B liquid mixture, Kuraray) for 60 seconds, using a

Table 1: Materials tested

Group	Material	Manufacturer	Composition	
			Composite resins	Primers
1	Panavia F Ed Primer	Kuraray Co. Ltd.	Barium glass powder, sodium fluoride, dimethacrylate, MDP, silica, benzoyl peroxide, amine, sodium aromatic sulfinate	10-MDP, HEMA, N methacryl 5 aminosalicylic, sodium benzene sulfinate, N,N9diethanol p toluidine, water
2	Variolink II Excite DSC	Ivoclar Vivadent	Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacylate, ytterbium trifluoride barium glass, silica	HEMA, bis-GMA, glycerine dimethacrylate, phosphoric acid acrylate, highly dispersed silica, ethanol

DSC: Dual cure single component, MDP: 10-Methacryloyloxydecyl dihydrogen phosphate, GMA: Glycidyl methacrylate, HEMA: Hydroxyethyl methacrylate

microbrush. The post space was gently air-dried and the excess primer was removed with paper points (Aria Dent).

In group 2, Variolink II (Ivoclar Vivadent, Schaan, Liechtenstein) was used as the luting agent. The canals were etched using 35% phosphoric acid (Ultra-Etch, Ultradent, South Jordan, UT, USA) for 15 seconds and rinsed with distilled water. Excess water was removed from the post spaces with a gentle stream of air and paper points. The Excite DSC (Ivoclar Vivadent), dual-polymerizing, single-bottle bonding agent was applied for 10 seconds with a microbrush coated with chemical initiators and the excess bonding agent was removed with paper points and gently air-dried. The bonding agent was polymerized with a halogen light unit, with 500-mW/cm^2 intensity (Coltolux 50, Coltene, Altstatten, Switzerland), for 20 seconds, with the tip of the light unit directly in contact with the canal orifice.

For cementation of fiber posts, equal amounts of luting pastes (Panavia F 2.0 and Variolink II) were mixed and applied onto the surface of the posts and into the root canals with a Lentulo spiral instrument (Dentsply/Maillefer). The posts were inserted into the canal, to a full depth, by using gentle finger pressure, and the excess was immediately removed with a disposable brush. For Panavia F 2.0 the remaining cement around the post was protected with oxygen-inhibiting gel (Oxyguard II, Kuraray). For Variolink II, after the initial chemical polymerization, light curing was performed for 60 seconds in such a way that the tip of the light unit was directly in contact with the coronal end of the posts. The light output was monitored to ensure accurate light intensity before each exposure by using the light meter (Coltolux, Coltene).

After the cementation procedures, all specimens were stored in sterile saline in a light-proof box for one week at 37°C. Next, each root was sectioned perpendicular to the long axis with a diamond disk at low speed under constant distilled water cooling to create 3 mm-thick slices. In this manner; from each root, three post/dentin sections (coronal, middle, and apical) were obtained. Due to the tapered design of the fiber posts, post diameters were measured on each surface of the post/dentin sections, using digital calipers (Electronic digital caliper, Minova Co, Japan), with 0.01 mm accuracy.

The push-out test was performed by using the universal testing machine (TLCLO, Dartec Ltd., Stourbridge, England) at a crosshead speed of 1 mm/minute, using a pin (diameter, 1.0 mm) on the center of the apical aspect of the post surface in an apical-coronal direction, without stressing the surrounding post space walls. The peak force (N) required to extrude the post from the root slice was recorded. To express the bond strength in MPa, the load at failure (N) was divided by the area of the bonded interface, which was calculated with the following formula:

$$A = \pi(r_1 + r_2)\sqrt{(r_1 - r_2)^2 + h^2}$$

where π was the constant 3.14, r_1 was the coronal post radius, r_2 was the apical post radius, and h was the thickness of the slice in millimeters.

The collected data were analyzed (SPSS/PC 16.0; Statistical package for the social sciences (SPSS) Inc, Chicago, Ill) using two-way analysis of variance (ANOVA) and Post Hoc Scheffe tests at $P<0.05$ levels of significance.

RESULTS

The mean push-out bond strength values (MPa) of the test groups in different root canal regions are shown in Table 2. The two-way ANOVA showed no significant differences between the mean push-out bond strength values recorded for two experimental groups (two types of cement systems) and there was no interaction between the type of resin cement system and different root canal regions ($P=0.920$ and $P=0.731$, respectively) [Table 3]. Otherwise, significant differences were

observed among the bond strength values of the root dentin regions ($P<0.001$). The lowest bond strength values were obtained in the apical regions. The Post Hoc Scheffe test revealed that in both resin cement systems, there were significant differences between the coronal and apical regions [Table 4].

DISCUSSION

The results of this *in vitro* study support the first

Table 2: Descriptive statistics of push-out bond strength values (MPa) of two groups in different root canal regions

Cement	Root canal region	Mean	Std. deviation	95% confidence interval	
				Lower bound	Upper bound
Panavia F	Coronal	17.12	5.37	14.789	19.451
	Middle	12.87	3.31	10.539	15.201
	Apical	7.78	2.60	5.447	10.109
Variolink II	Coronal	16.20	3.49	13.869	18.531
	Middle	12.60	4.06	10.269	14.931
	Apical	8.68	2.39	6.349	11.011

Table 3: Two-way ANOVA

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	720.607[a]	5	144.121	10.664	0.000
Intercept	9437.103	1	9437.103	698.297	0.000
Type of resin cement	0.138	1	0.138	0.010	0.920
Root canal regions	711.943	2	355.971	26.340	0.000
Resin cement * Root regions	8.526	2	4.263	.315	0.731
Error	729.781	54	13.514	–	–
Total	10887.490	60	–	–	–
Corrected total	1450.388	59	–	–	–

ANOVA: Analysis of variance, [a]R Squared = .497 (Adjusted R Squared = .450), Sig.: Significant

Table 4: Scheffe test for push-out bond strength values (MPa) of two groups in different root canal regions

Cement	Root canal region	Subset for alpha=0.05	
		1	2
Panavia F	Apical	7.7780	–
Variolink II	Apical	8.6800	–
Variolink II	Middle	12.6000	12.6000
Panavia F	Middle	12.8700	12.8700
Variolink II	Coronal	–	16.2000
Panavia F	Coronal	–	17.1200
	Sig.	0.106	0.202

Sig.: Significant

hypothesis that self-etching and conventional resin cements provide the same bond strength of a glass fiber reinforced composite post. However, the hypothesis that there are no differences between the bond strengths in different post space regions has been rejected.

In the case of the first hypothesis, our result was in agreement with some previous studies.[6,12,13,31-34] Noirrit *et al*.[6] stated that the hybrid layer and resin tags that resulted from both bonding systems (self-etch and total-etch) were nearly the same, although the conditioning of the canal walls was different. Micromorphological investigations showed that etching the dentin with phosphoric acid (PH≈2) (as used in the 'etch-and-rinse' systems) completely dissolved the smear layer and exposed the tubule apertures, collagen fibrils, and interfibrillar spaces, while the use of self-etch bonding systems had a variable effect on the smear layer.[6,11,18,28] These facts might be able to demonstrate the first hypothesis.

Bitter *et al*.[18] found a significant difference between these two types of luting agents when used as luting glass fiber reinforced composite posts on root canal dentin. They noted that the hybrid layer appeared thinner with the 'self-etch' system, than with the 'etch-and-rinse' system. They concluded that demineralization by phosphoric acid led to a deeper penetration of the adhesive than did a self-etch system, which could not completely penetrate the smear layer. Akgungor and Akkayan[11] and Yoshiyama *et al*.[35] stated that a system with a self-etching primer and light-polymerized bonding agent provided a significantly higher bond strength to root canal dentin than the self-etching bonding agents and the strength of this bond was not dependent on the hybrid layer thickness. In contrast, some authors[19,28,36] stated that simplified self-etch and self-adhesive resin cements, such as Panavia 21, exhibited an etching potential insufficient (even with a PH of ≈ 2.0) to dissolve the thick smear layers created in the post-space preparation, with slow-speed drills. They stated that this fact yielded to the high shrinkage stress in the thin cement layer and the consequent opening of interfacial gaps might account for the relatively low push-out strength recorded for ED Primer/Panavia 21 as compared to the results obtained with the use of the total-etch system, Excite DSC/Variolink II. However, they proposed the use of self-adhesive resin cements for intra-canal posts, because of their simple luting procedure.[37]

In the case of the second hypothesis, our result was in agreement with the previous studies that reported higher bond strength for coronal dentin than values for the middle and apical sections of the root.[4,6,23,33,34,38-40] According to Akgungor and Akkayan,[11] the self-etching primer Clearfil Liner Bond 2V did not show regional differences in post-space bonding, unlike the single bottle adhesive Excite, which exhibited significantly lower strength at the apical level. Goracci *et al*.[19] observed a higher bond strength in the coronal sections for Excite/Variolink II, but similar values for RelyX Unicem.

It has been shown that tubule density is greater in the coronal and middle thirds than in the apical region of the root canal,[41] and the diameter of the tubules decreases in the apical direction.[29] The difference in the number of tubules may explain why the strongest adhesion is achieved in the most coronal regions. In the presence of a greater number of tubules per mm^2 a stronger bond will be expected, because the adhesion may be enhanced by the penetration of the resin into the tubules.[42] Furthermore, it is shown that dentin hybridization is not uniform in the apical region of the root canal dentin and the lateral branches of the resin tags are not observed in the apical part of the interface post-adhesive system.[41]

Some methodological factors might have contributed to the discrepancies in bond strength values, such as, better accessibility of the coronal portion of the root canal, which made it easier to etch and apply the adhesive agents.[33,39] In addition, a reduction of light energy during transmission would decrease polymerization of the bonding agent at the medium and apical regions.[29]

However, some other studies[7,31,43] found no significant differences in the bond strengths between the different regions of the bonded posts to root canal dentin.

In this study, the mode of pushing out fiber posts was not evaluated. The specimens were prepared with no coronal tooth structure. However, it was suggested that the amount of remaining coronal tooth structure played a major role in the longevity of the restoration of endodontically treated teeth.[44]

In the present study, the influences of fatigue loading and thermal cycling on the push-out bond strength of the glass fiber reinforced composite post system were not investigated.

CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions were drawn:

1. There was no significant difference between the push-out bond strengths of glass fiber reinforced composite posts for self-etching and conventional resin cements
2. The coronal region of the root dentin showed a significantly higher bond strength of the glass fiber reinforced composite post than the apical region.

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