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Push-Out Bond Strength of Different Fiber Post Systems and Resin Cements: Experimental Study

Farklı Fiber Post Sistemleri ve Rezin Simanların Bağlanma Dayanımı: Deneysel Çalışma

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ABSTRACT Objective: The aim of this study was to compare the push-out bond strength (BS) of 2 different conventional fiber and glass fiber posts in the form of bundles by using 2 different resin cement and the fracture types formed accordingly. **Material and Methods:** Root canal treatment was applied to 48 extracted human premolars for the push-out test. The teeth were divided into 3 fiber post groups: Group 1: Biolight ST (conventional fiberpost), Group 2: RelyX (conventional fiberpost), Group 3: Biolight Plus (bundle post) according to the posts to be used for the push-out test. Each of the fiber post groups were divided into 2 subgroups according to adhesive cement [Core-X Flow, Build It FR] used in the cementation of posts (n=8). One mm sections were taken from the middle third of posts and the sections were subjected to a push-out test and the values were recorded. The samples were examined under a stereomicroscope and fracture types were determined. **Results:** No statistically significant difference was found between the groups according to the test results. When the fracture types were evaluated for all groups, there was no statistically significant difference in the result. **Conclusion:** The fiber post system in the form of bundles has similar properties with the conventional glass fiber post system in terms of BS.

Keywords: Fiber post; bond strength; push-out test; resin cements; root dentin

ÖZET Amaç: Bu çalışmada, iki farklı konvansiyonel fiber post ile demetler hâlindeki cam fiber postların 2 farklı rezin siman kullanılarak "push-out" bağlanma dayanımını ve buna bağlı olarak oluşan kırılma tiplerini karşılaştırmayı amaçladık. **Gereç ve Yöntemler:** Çalışmamızda çekilmiş 48 insan premolar dişine "push-out" testi için kanal tedavisi uygulandı. Dişler "push-out" testi için kullanılacak postlara göre Grup 1: Biolight ST (geleneksel fiber post), Grup 2: RelyX (geleneksel fiber post), Grup 3: Biolight Plus (demet post) olmak üzere 3 fiber post grubuna ayrıldı. Fiber post gruplarının her biri, postların simantasyonunda kullanılan adeziv simana [Core-X Flow, Build It FR] göre 2 alt gruba ayrıldı (n=8). Postların orta 1/3'lük kısmından 1 mm'lik kesitler alınarak kesitler "push-out" testine tabi tutularak değerler kaydedildi. Örnekler stereomikroskopta incelendi ve kırılma tipleri belirlendi. **Bulgular:** "Push-out" test sonuçlarına göre gruplar arasında istatistiksel olarak anlamlı fark bulunmadı (p>0,05). Tüm gruplar için kırık tipleri değerlendirildiğinde, sonuçta istatistiksel olarak anlamlı bir fark yoktu (p>0,05). **Sonuç:** Demetler hâlindeki fiber post sistemi, bağlanma dayanımı açısından geleneksel cam fiber post sistemi ile benzer özelliklere sahiptir.

Anahtar Kelimeler: Fiber post; bağlanma dayanımı; push-out test; rezin siman; kök dentini

Restoration of teeth with excess material loss and endodontically treated teeth is a major challenge in daily clinical practice. Fiber posts are commonly used materials among dentists in recent years due to their ease of use, absence of session loss for preparation, resistance to biochemical degradation and aesthetic properties.[1] A wide variety of fiber posts are used today and glass fiber posts are one of them. Glass fiber posts, which bond very well to the hard tissues of the tooth, composite and resin cement, are biocompatible and corrosion-resistant materials.[2]

In recent years, in addition to conventional single piece glass fiber posts, bundle-shaped posts consisting of newly developed rods that are more flexible

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than conventional glass fibers are used. Rebilda GT (Voco, Cuxhaven, Germany) and Biolight Plus (BP) (Bio Composants Medicaux, Tullins, France) are examples of these posts. According to the claims of the companies, these systems do not need extra root canal preparations with fiber post preparation drills. Due to their flexible structure, they are suitable for use in curved canals.

Retention of posts depends on the bond strength (BS) among root dentin/cement/post. The attachment of fiber posts to the root canal is directly related with adhesive cementation, and these posts are used in combination with resin cements during restoration of endodontically treated teeth.[3] Resin cements show similar properties to restorative composites in terms of content and characteristics. Besides their high physical and mechanical strength, their solubility is low.[4] While they can chemically bond to dental tissues, they can also adhere to many dental materials. Resin cements could be divided as in 2 main groups *"conventional"* and *"self-adhesive"*. Conventional resin cements are divided into 2 subgroups as *"total-etch"* and *"self-etch"* resin cements.[5] With the resin and various production methods used; studies that planned to increase bonding between fiber materials and the resin matrix are ongoing.[6]

In this study; it was aimed to compare the push-out BS of 2 different conventional fiber posts and the bundle-shaped glass fiber posts -a newly developed post system-, using 2 different total-etch resin cement.

MATERIAL AND METHODS

Present study was approved by Clinical Research Ethic Committee (decision date: January 15, 2020; decision number: 2020/22). The methodology of present study was in accordance with the Helsinki Declaration. Forty eight mature mandibular premolar teeth with single root and canal were used. All teeth were extracted for periodontal and/or orthodontic reasons at Erciyes University Oral and Maxillofacial Surgery Clinic. Only teeth without caries, cracks or any restoration were included in the study. Radiographs were taken from mesiodistal and buccolingual sides and root canal morphology was evaluated and we exclude teeth with resorption, calcified, curved or additional canals, anatomic anomalies or endodontically treated teeth. Teeth with same root lengths and same crown lengths were chosen (±0.5 mm). Calculus, soft tissue residues, and calcified deposits on the teeth were mechanically cleaned using a hand scaler, samples were kept in 37 °C distilled water up to the time they would be used.

Access cavities were opened with a round diamond bur (Hicare, Ponyu District, Guangzhou, China) under continuously water cooling high-speed handpiece instrument. After verifying the canal opening of the teeth with an ISO #15 K type file (Mani, Tochigi-Ken, Japan), the tip of file was positioned visible through the apical foramen, and the length of the file was measured. Working length was determined 1 mm shorter than the visually determined length. As similar to the study of Carrillo et al. root canals were cleaned and prepared with EdgeFile X7 (EdgeEndo, Albuquerque, NM) files #20/04, #25/04, #30/04 and #35/04 respectively.[7] Each canal file was replaced with a new one after being used on 5 teeth. During each file change, irrigation was done with 2.5 mL 2.5% NaOCl (Wizard, Rehber Kimya; İstanbul, Türkiye). Final irrigation was done with 17% EDTA (Wizard, Rehber Kimya; İstanbul, Türkiye) and 2.5 mL distilled water, and then canals were dried with ISO #35 paper points (Pearl Endo, Ho Chi Minh, Vietnam). Filling of root canals were performed with cold lateral compaction technique using a resin-based root canal sealer (ADSeal; Meta Biomed, Cheongju, South Korea) with the master cone number 35/04 gutta-percha (Pearl Endo). Filling quality of the canals were checked with mesio-distally and bucco-lingually taken periapical radiographs. Access cavities were sealed with a temporary filling material (Coltosol F; Coltene/Whaledent Inc. Altstätten Switzerland). Samples were kept in a 100% humid environment at 37 °C for 1 week to harden the resin sealer. Before proceeding to the fiber post application, the teeth were decoronated 2 mm above the cementoenamel junction. In all samples, root lengths were adjusted to 17 mm, and the length of the fiber post inserted into root canal was adjusted to 12 mm and apical 5 mm of the filled root canal left untouched. The filled material in the canal at specified lengths was removed with a #3 Gates-Glidden

(Dentsply Maillefer, Ballaigues, Switzerland) bur. The same total-etch adhesive system (Adper Single Bond2; 3M ESPE, Saint Paul, USA) was used for all the posts. The adhesive system application protocol of the posts and cements to be used according to the manufacturer's instructions is as follows:

For RelyX (RX) and Biolight ST (BST), post spaces were opened on the teeth with the post drill recommended by the manufacturer, and no extra post space was prepared for BP. Post spaces were irrigated with 2.5 mL 96% ethyl alcohol and dried with paper cones. Post spaces was treated with 37% phosphoric acid for 15 sec and rinsed with distilled water (10 mL) for 30 sec. Post spaces were dried with paper cones. Then, two layers of Adper Single Bond2 (3M ESPE) were applied to the post spaces for primer and bond application, air dried lightly and polymerized for 10 sec.

DETERMINATION OF EXPERIMENTAL GROUPS

Forty eight teeth were divided into 6 groups according to 3 different post brands (BST, BP, RX) and 2 different resin cements [Core-X Flow (CXF); (Dentsply DeTrey), Build It FR (BFR); (Pentron, USA)] to be used for bonding resistance tests (n=8) (The ingredients of adhesive cements and resin cents are given in Table 1).

Before cementation, BST and BP fiber posts were applied with a thin layer of silane (Ultradent Silane, South Jordan, UT, USA) for 60 sec. According to manufacturer RX post does not need silanization procedure because of its micro mechanically prepared surface modification. After then resin cements were applied to root canal spaces, fiber posts were inserted into the root canals and the samples were cured with LED light (Valo, Ultradent, South Jordan, UT, USA) for polymerization of luting cements.

Each specimen was cut perpendicularly to long axis of the root with the help of a saw (Minitom, Struer, Denmark) under water cooling.

In the experimental groups, a root slice (1±0.05 mm height) was taken from the 6th mm of coronal side of root, and a total of 48 discs were obtained with fiber post in the middle root section. The height, large

TABLE 1: List of the composition of tested cements and adhesive.

Build-It® FR™ Core Build-up Material (base)	Build-It® FR™ Core Build-up Material (catalyst)	Core-X® flow Dual Cure Core Build-Up Material and Cement for Endodontic Posts	3M™ Adper™ Single Bond 2
(1-methylethylidene) bis (4,1-phenyleneoxy (2-hydroxy-3,1- propanediyl)) ester	(1-methylethylidene) bis (4,1-phenyleneoxy (2-hydroxy-3,1- propanediyl)) ester	Urethane dimethacrylate	Ethanol
1,6-Hexanediol dimethacrylate	1,6-Hexanediol dimethacrylate	Di- & tri-functional methacrylates	(1-methylethylidene) bis [4,1- phenyleneoxy (2-hydroxy-3,1-propanediyl)] bismethacrylate
7,7,9(or 7,9,9)-trimethyl-4,13-dioxo-3,14-dioxa-5,12-diazahexadecane-1,16-diyl-bis-methacrylate	7,7,9(or 7,9,9)-trimethyl-4,13-dioxo-3,14 dioxa-5,12- diazahexadecane-1,16-diyl bismethacrylate	Barium boron fluoroaluminosilicate glass	Silane treated silica
Silicon dioxide	Dibenzoyl peroxide, benzoyl peroxide	Camphorquinone photoinitiator	2-Hydroxyethyl methacrylate
Aluminium oxide		Photoaccelerators	Copolymer of acrylic and itaconic acids
Calcium oxide		Silicon dioxide	Glycerol 1,3 dimethacrylate
Fluorides		Benzoyl peroxide	Diurethane dimethacrylate
Phosphorus pentoxide			Water
Sodium oxide			Diphenyliodonium hexafluorophosphate

and small diameters of the fiber posts on each disc were measured and recorded with an electronic caliper (Mitutoyo, Tokyo, Japan) with an accuracy of 0.01 mm.

Push-out testing of the sections was performed with a universal test machine (Instron Corp., Canton, MA, USA) by applying to the sections at a speed of 1 mm/min^{-1} with metal plunger (0.6 mm-0.8 mm in size) suitable for the diameters of the posts in the center of the sections. The plunger only contacted the fiber post (center of the obturated canal lumen) during loading. Sections were placed with the apical surface upwards position. The maximum strength value in the universal tester at the time of dislodgement was recorded in Newton (N). Samples were examined under a stereomicroscope. Failure types in sections; *Type 1* adhesive failure: failure between test material and dentin, *Type 2* cohesive failure: failure that occurs within the test material itself, *Type 3* mixed failure: grouped as seeing both failures together.

CALCULATION OF BS

In order to convert the BS to MPa, the bonding surface areas of the discs were calculated in mm^2. The formula given below was used for calculation.[8] Bonding surface area (mm^2) = π (R + r) (h^2 + (R - r) ^{2}) $^{1/2}$

(π: 3.14, R: coronal post diameter, r: apical post diameter, h: height of the disc)

Later;

BS (MPa)= Maximum applied force (N)/Bonding surface area (mm^2)

STATISTICAL ANALYSIS

The normality of data was evaluated by histogram and Shapiro-Wilk test and Q-Q graphs, and data. Nonparametric analyzes were applied to quantitative variables as the data did not provide the normal distribution assumption. In comparison of groups with more than two Kruskal-Wallis analysis, Mann-Whitney U test was used for pair comparison. Dunn's test was used as multiple comparison analysis. Pearson c^2 analysis was used to evaluate the relationships between categorical variables. Data analysis was performed in Turcosa Cloud (Turcosa Ltd Co, www.turcosa.com.tr, Türkiye), statistics software. Significance level was accepted as $p<0.05$.

RESULTS

There was no significant difference between the posts used and in means of push out BS values (p=0.305) (Table 2). There was no statistically significant difference between the push out BS values of the resin cement groups (p=0.132) (Table 3).

No statistically significant difference was found in the comparison of the median push-out values of the resin cement groups (CXF and BFR) in all tested fiber post groups [the BST group (p=0.294), RX group (p=0.345), BP group (p=0.248)]. No statistically significant difference was found in the comparison of the median push-out values of the posts (BST, RX and BP) in both CXF group (p=0.357) and BFR group (p=0.733) (Table 4).

When the fracture types were evaluated among the fiber posts, it was understood that there was no statistically significant difference between posts and fracture types (p=0.228) (Table 5). Also, there was no statistically significant relationship between the cement used and the fracture types (p=0.589) (Table 6).

TABLE 2: Push-out bond strength (MPa) values according to the posts.

	Fiber posts			
	Biolight ST (n=16)	RelyX (n=16)	Biolight Plus (n=16)	
	Median (minimum-maximum)	Median (minimum-maximum)	Median (minimum-maximum)	p value
Push-out bond strength values	2.89 (0.22-6.85)	3.50 (0.54-7.35)	3.88 (2.13-6.08)	0.305

Kruskal-Wallis test

TABLE 3: Push-out bond strength (MPa) values according to the cements.

	Adhesive cements		
	Core-X Flow (n=24)	Build It FR (n=24)	
Variables	Median (minimum-maximum)	Median (minimum-maximum)	p value
Push-out	3.26 (0.22-5.54)	4.13 (0.54-7.35)	0.132

Mann-Whitney U test

TABLE 4: Push-out bond strength (MPa) values according to the cements and posts.

	Post			
	Biolight ST	RelyX	Biolight Plus	
Cements	Median (minimum-maximum)	Median (minimum-maximum)	Median (minimum-maximum)	P#
Core-X Flow	2.50 (0.22-5.01)	3.32 (2.32-4.32)	3.62 (2.13-5.53)	0.357
Build It FR	3.42 (1.30-6.85)	4.26 (0.54-7.35)	4.18 (2.69-6.08)	0.733
P*	0.294	0.345	0.248	

Dunn's test

P*: It is the p value in which the push out values are compared between cement groups within each sub-level of the posts; P#: It is the p value in which the push-out bond strength values of the posts are compared within the cement sublevels.

TABLE 5: Fracture types according to the posts.

	Fiber post groups								
	RelyX		Biolight ST		Biolight Plus		Total		
Fracture types	n	%	n	%	n	%	n	%	p value
Adhesive	8	50	3	18.75	6	37.5	17	35.42	0.228
Cohesive	0	0.00	0	0.00	1	6.25	1	2.08	
Mixed	8	50	13	81.25	9	56.25	30	62.5	
Total	16	100.00	16	100.00	16	100.00	48	100.00	

Chi-square test

TABLE 6: Fracture types according to adhesive cements.

	Adhesive cement						
	Core-X Flow		Build It FR		Total		
Fracture types	n	%	n	%	n	%	p value
Adhesive	8	33.33	9	37.50	17	35.42	0.589
Cohesive	1	4.17	0	0.00	1	2.08	
Mixed	15	62.50	15	62.50	30	62.50	
Total	24	100.00	24	100.00	48	100.00	

Chi-square test

DISCUSSION

The aim of the present study was to compare the push out BS of 2 different resin cements and 3 different fiber post systems (2 conventional and a bundle-shaped fiber post systems). The use of natural human premolars to test the BS of posts in vitro is a reliable method and has been used in many studies. Additionally, premolars are highly susceptible to load that can cause fracture, therefore they should be restored with crowns.[9,10] By the way using different type of teeth group such as molar or anterior teeth in the present study may yield different results.

Glass fiber posts, which bond very well to the hard tissues of the tooth, composite and resin cement, are biocompatible and corrosion-resistant materials.[2] Ferrari et al. reported that the failure seen in fiber posts was 3.2% in a 6 years of follow-up retrospective study.[11] In another retrospective study, the success rate of fiber posts was reported as 95%.[12] Therefore, fiber posts were selected in our study due to their high success rate, elasticity properties close to dentin and their ability to be used under aesthetic restorations.[13]

The adhesion of fiber posts and the root canal is based on adhesive cementation. Cekic-Nagas et al. investigated the bonding of BFR and Rebilda DC to dentin using different adhesive systems showed that the use of dual-cured resin cements and etch-rinse adhesive systems in core construction is more preferable than self-etch adhesive systems.[14] At the same time, it was suggested that it is necessary to create a homogeneous and monoblock structure in order to seal and increase durability in restorations of root canal treated teeth.[15] For this reason, in our study we prefer total-etch resin cements of 2 different brands, which can be used in both post-cementation and core construction.[16]

As a result of the push-out test in our study, regardless of the post type used, BFR gave a higher BS value than CXF cement, but this result is not statistically significant (Table 2) (p>0.05). Likewise, there was no significant difference between adhesive, cohesive and mixed failure types in the push-out test, regardless of the posts used between cements (Table 5) (p>0.05). This situation can be attributed to the fact that both CXF and BFR resin cements applied with the same cementation procedures which has prevented bonding problems that may arise from different application protocols. In addition, our study is the only study in the literature that compares CXF and BFR cements in terms of BS values and related failure types. Further BS comparison studies are needed in of these 2 cements with other self-etch or self-adhesive cements, which will provide ease of use due to the number of steps to be applied.

Many different methods such as shear, tension, and microtensile tests have been used in the literature in measurement of BS values of dental materials to root dentin. In the literature, the results of the push-out test among these tests are found to be more effective and reliable. Goracci et al. reported that push-out tests are a more convenient and reliable method than traditional shear, tension and microtensile tests due to the application of parallel force to the dentin-cement interface, and they allow the measurement of low BS values in the root canal system.[16] It has been stated that dentin slices to be tested are thicker than 1 mm, causing the BS values to be measured more than they are due to the increase of the friction surface. For this reason, dentin slices were prepared with a thickness of 1 mm while performing the push-out test in our study.[17]

In the literature; regardless of the post type used, it has been stated that coronal root thirds have the highest BS and apical root thirds have lowest BS.[18] The slices for the push-out test in our study were taken only from middle third of the root. In the BP group, due to the bundle structure of the post opening towards the coronal, the number of fiber rods and the amount of cement between the fibers are different in different parts of the root; the BS values can be expected to vary in different parts of the root. Further investigations including BS values at different root thirds are recommended to complement the present study.

Although there was no statistically significant difference (p>0.05), regardless of which cement was used, BP gave the highest BS value, followed by RX and BST posts (Table 1).

CONCLUSION

No significant difference was observed in BS and fracture strength values between conventional posts and bundle-shaped posts made of fiber rods. The results of our study show that CXF and BFR could be used in bundle-shaped posts cementation as well as fiber-containing conventional posts.

Source of Finance

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Yakup Üstün; **Design:** Yakup Üstün;**Control/Supervision:** Yakup Üstün, Eda Biricik; **Data Collection and/or Processing:** Eda Biricik; **Analysis and/or Interpretation:** Eda Biricik; **Literature Review:** Eda Biricik; **Writing the Article:** Eda Biricik; **Critical Review:** Yakup Üstün; **References and Fundings:** Yakup Üstün; **Materials:** Eda Biricik; **Other:** Eda Biricik.*

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