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The Influences of Various Matrices and Silanization on the Bond Strength between Resin Cores and Glass Fiber Posts

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Abstract

Purpose: The comparison of the influences of various matrices and silanization on the bond strength between resin cores and glass fiber posts.

Methods: In this study, 40 Rebilda Posts with methacrylate matrices and 40 Er Dentin Posts with epoxy resin matrices were utilized. Monobond N was used for silanization in half of the posts.

Three core materials, developed particularly for core build-up (Grandio Core, Rebilda Core, Build-It FR) and one hybrid composite (Filtek Z250) were administered to parallel parts of the posts. To perform the push-out test, three disks of 2 mm thickness were cut off from each post-core specimen. Surface morphology of the posts and cores was delineated following the push-out test by the scanning electron microscope (SEM). Univariate analysis of variance was performed for data analysis.

Results: The bond strength of Rebilda Posts was increased when compared to the bond strength of Er Dentin Post ($p<0.05$), and silanization augmented the push-out bond strength ($p<0.05$). The bond strengths of all core build-up materials were more when compared to Filtek Z250. The highest bond strength value was between Rebilda Posts with silane applied and the Rebilda Core (19,309 MPa) in all groups. A greater number of exposed fibers were present on the Rebilda Post surface, and gaps were observed on the fractured Filtek Z250 interface when SEM examination was performed.

Conclusion: The bond strength of post-core restorations can be influenced by the type of matrix in the fiber posts. The core materials, mainly designed for using in core build-up, and the silanization of posts can augment the push-out bond strength.

Keywords: Bond strength; Composite resin core; Fiber post; Push-out test; Silane coupling agent

Introduction

Teeth, deficient in coronal tooth structure due to severe damage caused by decay and treated endodontically, previously made restorations, or extreme wear are exposed to shearing chewing forces; they frequently require a post placement, in order to provide sufficient retention of a core foundation [1-4]. Since their introduction in the 1990's, fiber posts are increasingly becoming popular when compared to their zirconia or metal-based similitudes; fiber posts lead to greater bond strength to radicular dentin, they less frequently lead to vertical root fractures because of their stiffness and modulus of elasticity, similar to dentin [5]. Fiber posts, used following endodontic treatment, have extra superiorities such as biocompatibility, mechanical strength, resistance to corrosion, enhancement of light transmission, and the optical effects of esthetic restorations [6].

Using fiber posts in conjunction with direct resin composite build-ups can generate homogeneous integrity, together with similar modulus of elasticity (mono-block) [7]; post-core restorations can be placed in only one appointment, necessitating no additional laboratory costs [3,8].

Composites, particularly created for core build-ups, are usable for building up an abutment around the fiber post; however, hybrid composites have also been used in recent studies, even though they would not be the best choices [4,9].

The durability of a composite resin core restoration relies upon the generation of a strong bond between the core material and residual dentin, and between the core and post material; these allow the interface to transmit the stresses under functional loading, and they influence the success of the final esthetic restoration [10-13].

In a recently conducted *in vitro* study [14], it was shown that the interface between FRC posts and core materials was more fragile when compared to core materials and dentin; the failures occurring in these restorations are observed at the site of junction between the fiber post and composite resin core [14-16].

Fiber posts are usually constituted by embedding silanated glass or quartz fibers in a highly cross-linked polymer resin matrix based on epoxy or methacrylate resin. The chemical interaction between the organic matrix of the fiber post and the methacrylate of the core build-up material is deficient [17].

Various types of surface treatments have been suggested for ameliorating the bonding of composite resin cores to posts, regarding post-core restorations [2]. Extensive research has been done mainly for the applications of silane on post surfaces; however, their results were often contradictory [10,18].

In this study, our aim was to assess the bond strength between resin cores and glass fiber posts with various matrices, together with the

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effects of silanization. The null hypotheses tested in this study were as follows: (1) the bond strength of the fiber post with methacrylate matrix is greater when compared to fiber post with epoxy resin matrix; (2) the bond strengths of fiber posts are improved when a silane coupling agent is used; (3) the bond strengths of the core materials, mainly designed for core build-up, are greater than the restorative composite resin.

Materials and Methods

In this study, two kinds of glass fiber-reinforced composite posts were used in various matrices: 40 Rebilda posts (Voco/Cuxhaven, Germany) and 40 Er Dentin posts (Komet Dental/Gebr Brasseler, Germany). The materials used in the study were shown in Table 1.

First, both kinds of posts were divided into two groups, being twenty in each group. Silane (Monobond N, Ivoclar Vivadent/Schaan, Liechtenstein) was applied to one group and was not applied to the other group. In the silane-applied group, the surface of the posts was smeared as one layer with silane by using a brush and was allowed to dry for 60 seconds at room temperature, in compliance with manufacturer's directions.

All posts with and without silane were divided into four subgroups, with each group consisting of five posts. The core build-up procedure was performed according to the method described by Goracci et al. [19] Post-core specimens were prepared around the cylindrical portion of the posts by using a Teflon mold 8 mm × 10 mm, together with Rebilda DC (Voco/Cuxhaven, Germany), Grandio Core DC (Voco/Cuxhaven, Germany), Build- It FR (Pentron/West Collins Clinical) and Filtek Z250 (3M ESPE/USA).

By the help of a parallelometer, posts were fixated perpendicularly on a glass plate with a drop of sticky wax (Figures 1A-1D). Composite core materials, which were deposited as 2 mm layers were polymerized 40 s by using a halogen light curing unit (HILUX, Benlioğlu Dental, Ankara, Türkey) with an output of 800 mw/cm^2. The material was polymerized directly from the open upper side of the mold and through the post. Additional 20-s irradiation was administered on the specimen side, which faced the glass plate. As the result of this procedure, a cylinder of resin composite was constituted around the fiber post.

The idle apical section of the post was left outside, and the constituted specimens were buried into autopolymerizing acrylic resin (Imicryl SC/Konya, Türkiye) with the help of parallelometer and teflon pipes, having a height of 18 mm and diameter of 14 mm. Following preparation of the post-core specimens, they were kept in drying oven for 24 hours at 37°C and then, they were sliced by using a diamond blade of 0.38 mm thickness (Norton Diamond Wheel) and a low-speed cutting device (Isomet 1000 Buehler/Lake, Bluff, IL)) under water cooling (Figures 1B and 2).

The apical section of the post outside the specimen was cut and removed; three discs, each with a thickness of 2 mm were obtained (Figures 1C and 2). Thus, 15 specimen discs belonging to each post-core group and a total of 240 specimens were acquired.

The push-out test

During the push-out test, to provide support for the specimens, a metal plate with holes 4 mm in diameter was used. An acrylic-structured set, covering the discs, was prepared on the plate, to prevent post- core slices from slipping.

Specimens were inserted into this set, and the push-out test was performed by the universal testing device (Instron Ltd., model 3344, USA), which had a header pace of 0.5 mm/min (Figure 1D and 2). The circular edge, used for the push-out test, was preferred to be 1 mm in diameter, to maintain the contact with the post only.

Measurements were made by the device (in Newton units) at the time that the post had left the post space, and they were recorded as the values of the related post-core slice. Since the post diameter was the same for all specimens at either the apical or the coronal side and was cylindrical-shaped, the formulation for measurement of the surface area of the cylinder was used (2πrh). The result obtained by dividing the recorded binding force (N) to the surface area was noted as MPa. The parallel allocation of the posts at their coronal sides facilitated the calculation.

SEM

Following the push-out test, eight specimens belonging to each one of four different composite resin cores and post groups with and without silane were prepared for SEM analysis. After separated surfaces of post-core discs had been sputter-coated with Au-Pd via Quorum (Judges Scientific plc, UK) plating unit, SEM images were taken at the magnification of 400 x by Inspect S50 device (FEI, Hilsbore Oregon).

Statistical analysis

The statistical analysis of the push-out bond strength values was performed by univariate analysis of variance (ANOVA), and Duncan multiple comparison tests compared composite resin cores.

Results

The mean values and standard deviations of data, together with their minimum and maximum values obtained from the push-out test were shown in Table 2.

When a preliminary statistical analysis was performed, the interactions of core-post, post-silane, core- silane, core-post-silane were determined as insignificant ($p>0.05$); hence, interactions were excluded, and analysis was performed concerning main factors. According to the results of variance analysis, the post types ($p<0.001$), the groups with and without silane ($p<0.05$), and composite resin cores ($p<0.05$) presented statistically significant differences when compared to each other (Table 3).

When the groups were compared concerning post types, it was found that Rebilda post (18.07 MPa) presented significantly more push-out bond strength values ($p<0.001$) than Er Dentin post (13.85 MPa) (Figure 3).

When the groups with and without silane were compared, statistically significant difference ($p<0.05$) was observed; higher bond strength values were acquired in the groups with silane (16.37 MPa) when compared to the groups without silane (15.56 MPa) (Figure 3).

Regarding all specimen groups, highest bond strength values belonged to the Rebilda cores and Rebilda posts with silane (19.30 MPa) (Figure 4). The Filtek Z250 and Er Dentin posts without silane, together, had the lowest bond strength (13.13 MPa) (Figure 5).

For multiple comparisons, Duncan test was performed among the composite resin cores with significant differences ($p<0.05$) (Table 4). According to the results of Duncan test, bond strength values of Grandio and Rebilda core material groups were similar to Build-It FR ($p>0.05$); however, the difference was statistically significant when compared to Filtek Z250 ($p<0.05$). No difference was found between bond strength values of Build-It FR and Filtek Z250 groups ($p>0.05$).

Product	Material	Composition	Lot number	Manufacturer
Rebilda Post	Fiber post	70% glass fiber, 10% filler,20% UDMA (2 mm in diameter, parallel in coronal 10 mm)	1419134	Voco/Cuxhaven
ER Dentin Post	Fiber post	60 % glass fiber embedded in epoxy resin (1.98 mm in diameter, parallel in coronal 8 mm)	226422	Komet Dental/Gebr Brasseler
Monobond N	Universal primer	Alcohol solution of silane methacrylate, phosphoric acid methacrylate and sulphide methacrylate.	S44405	Schaan, Liechtenstein
Grandio Core	Dual Cure Nano-hybrid composite core material	Matrix: Bis-GMA, UDMA resins Filler: silica/Ba-glass ceramics (77%, wt). Amines, benzoyl peroxide, BHT	1418125	Voco/Cuxhaven
Rebilda Core	Dual Cure Composite core material	Bis-GMA, diurethane dimethacrylate, BHT, benzoyl peroxide (71% wt. Inorganic filler)	1417287	Voco/Cuxhaven
Build-it FR	Dual Cure Fiber reinforced composite core material	Bis-GMA, UDMA, HDDMA, silanated barium borosilicate glass fillers (% 68 wt), chopped glass fibre, chemical/photoinitiator	L513149	Pentron/West Collins Clinical
Filtek Z 250	Light Cure Hybrid, universal restorative composite resin	Inorganic filler (zirconium/silica) loading is, 84.5% by weight with a particle size range of 0.01 to 3.5 microns. BIS-GMA, UDMA andBIS-EMA	N574383	3M ESPE
Bis-GMA: Bisphenol A Glycidyl Methacrylate; UDMA: Urethane Dimethacrylate; Bis-EMA: Ethoxylated Bisphenol A Glycidyl Methacrylate; Ba: Barium; BHT: Butylated Hydroxytoluene; HDDMA: Hexane Diol Dimethacrylate				

Table 1: Materials used in the study.

Silane	Resin Core	Post Type	Minimum	Maximum	Mean value-SD
Treated	Grandio	Er Dentin	10.4	17.55	14.25 ± 2.259
		Rebilda	14.13	23.4	18.99 ± 2.306
	Rebilda Core	Er Dentin	10.46	18.94	14.63 ± 2.640
		Rebilda	16.97	21.5	19.30 ± 1.662
	Build-It FR	Er Dentin	9.05	20.8	14.11 ± 3.904
		Rebilda	14.75	24.11	18.47 ± 2.328
	Filtek Z250	Er Dentin	8.84	16.37	13.57 ± 2.180
		Rebilda	13.95	21.9	17.62 ± 2.371
Untreated	Grandio	Er Dentin	10.34	17.95	13.31 ± 2.093
		Rebilda	12.61	21.76	18.24 ± 2.554
	Rebilda Core	Er Dentin	6.94	19.67	14.21 ± 3.506
		Rebilda	11.57	21.78	18.04 ± 3.186
	Build-It FR	Er Dentin	11.48	15.17	13.62 ± 1.146
		Rebilda	11.35	22.32	17.41 ± 2.878
	Filtek Z250	Er Dentin	10.35	15.82	13.13 ± 1.616
		Rebilda	11.79	19.55	16.48 ± 2.411

Table 2: Minimum, maximum, mean values and standard deviations (MPa) (n=15, N=240).

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Core	58.584	3	19.528	3.045	0.03
Post	1066.606	1	1066.606	166.336	0
Silane	39.715	1	39.715	6.194	0.014
Core * Post	9.944	3	3.315	0.517	0.671
Core * Silane	0.056	3	0.019	0.003	1
Post * Silane	3.425	1	3.425	0.534	0.466
Core * Post * Silane	2.419	3	0.806	0.126	0.945
Error	1436.37	224	6.412	-	-

Table 3: ANOVA of the push-out test.

Rebilda Core presented the highest bond strength value (16.54 MPa) among composite resin cores; Grandio (16.20 MPa), Build-It FR (15.90 MPa), and Filtek Z250 (15.20 MPa) had the second and third rows, regarding bond strength.

The results of SEM analysis

The SEM images of both posts were analyzed, and it Rebilda posts were determined to have more numbers of exposed fibers (Figures 6A-6D) when compared to Er Dentin posts (Figures 6A and 6B).

Accumulation of composite resin particles on the surfaces of Rebilda Posts (Figure 6D) following silane application, together with increasing number of exposed fibers on the silane-treated surfaces of Er Dentin Posts (Figure 6B) were remarkable findings.

Composite Resin Cores	N	Subset	
		1	2
Filtek Z250	60	15.20[b]	-
Build_It FR	60	15.90[ab]	15.90[ab]
Grandio	60	-	16.20[a]
Rebilda Core	60	-	16.54[a]
Level of Significance	-	0.125	0.185
(*: values that represented by the same letter are similar)			

Table 4: Duncan multiple comparison tests of composite resin cores.

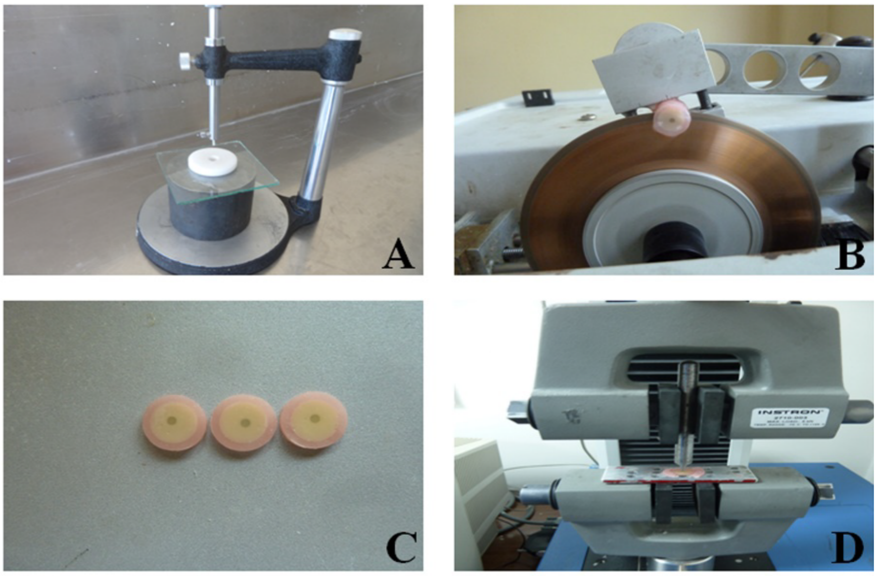

Figure 1: Specimen preparation and the push-out test.

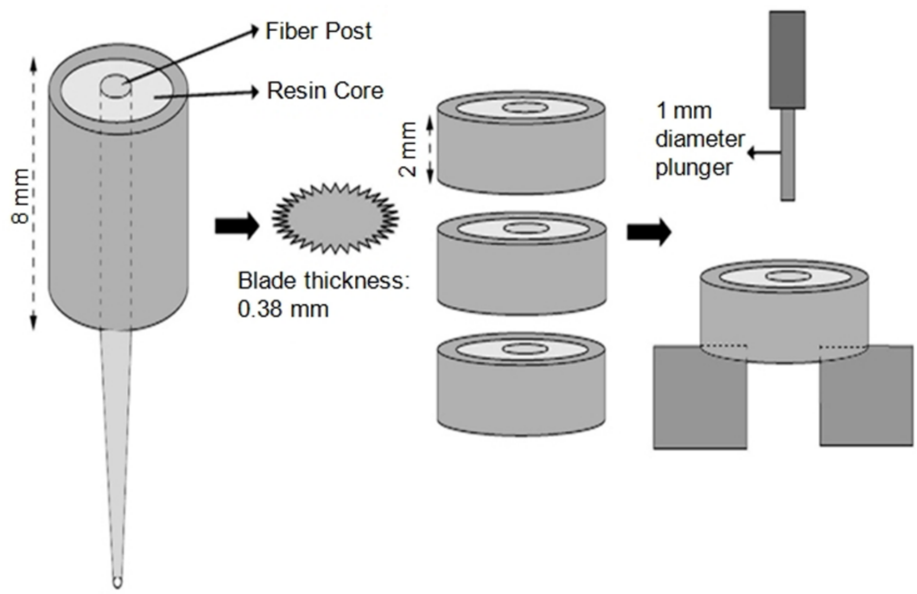

Figure 2: Schematic representation of specimen preparation and the push-out test.

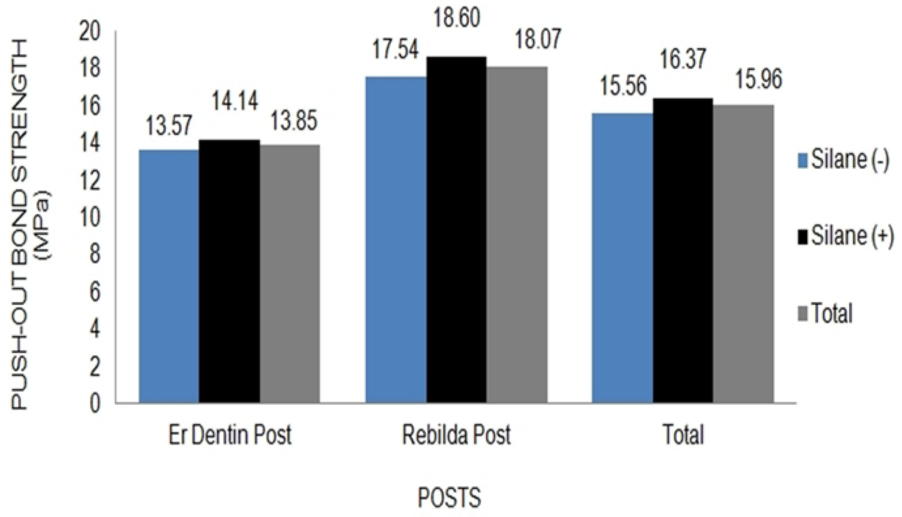

Figure 3: Bond strength of posts with and without silane (MPa).

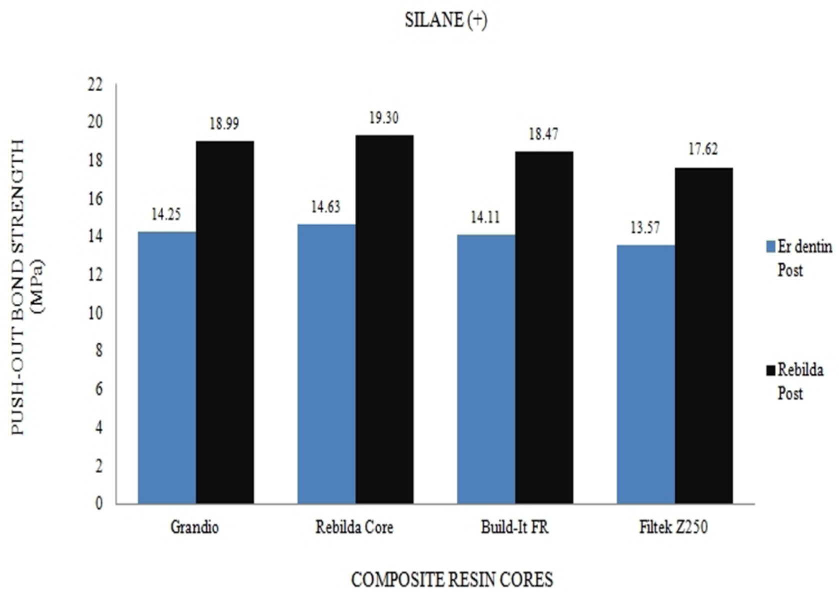

Figure 4: Bond strength between resin cores and silane-applied posts (MPa).

When SEM images of composite resin cores were analyzed, bubble-cavity formation was not observed on the surfaces of core materials particularly developed for core build-up (Figures 7A-7C); however, the universal restorative Filtek Z250 (Figure 7D) was observed to have gaps in 400x magnification.

Discussion

Our study results supported the tested null hypotheses. Silane application significantly increased the bond strength between the posts and resin cores, fiber posts with methacrylate matrix exhibited significantly higher bond strength when compared to fiber posts with the epoxy matrix, and resin cores, particularly designed for core build-up, exhibited significantly higher bond strength when compared to restorative composite resin.

The low-bonding of polymerized epoxy resin matrices of fiber posts to the methacrylate-based resins of the build-up composite has been considered the consequence of discrepancies in chemical structure [3] together with the extremely cross-linked structure of the epoxy resin [4]. Additionally, the chemical compatibility of the resinous matrix of the Rebilda post with the composite cores (both containing methacrylate resin) might be a factor for higher bonding strengths of Rebilda post, particularly with Grandio Core and with Rebilda core, both manufactured by the same producer [20].

Although producers keep a significant amount of information confidential, we can suppose that additional factors, such as size, density, distribution of the fibers, texture of the surface, and manufacturing process might also have affected the push-out strength [3]. Nagas et al. [21] conducted a study for assessment of the bond strengths of

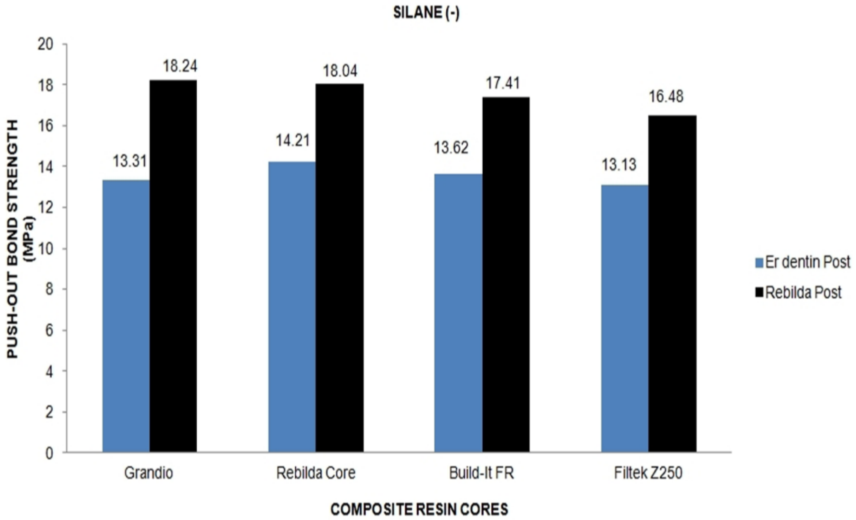

Figure 5: Bond strength between resin cores and untreated posts (MPa).

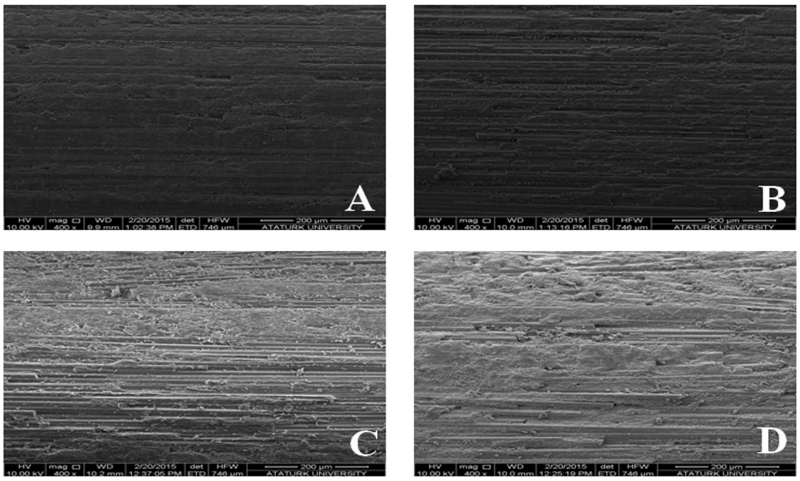

Figure 6: SEM image of the post surfaces after the push-out test (magnification 400x).

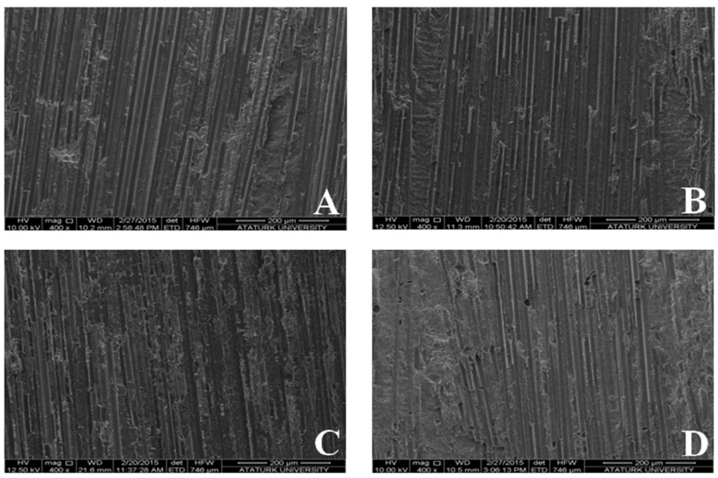

Figure 7: SEM image of the composite resin cores after the push-out test (magnification 400x).

fiber posts and composite cores following various surface treatments; the bond strength values of FRC Postec and DT Light posts were determined to be higher when compared to Everstick. They suggested that this result might have originated from higher fiber concentration of the posts.

Exposed fibers on the post surface were found to be less in number (compliant with the lower fiber concentration of the post), and SEM results confirmed this finding. Therefore, another explanation can be made for the study results in which Er Dentin post showed less fiber concentration (60%) and had lower bond strength values than Rebilda post with higher fiber concentration (70%).

Silane coupling is a sensitive step, regarding the technique. During silane application, dimers, trimers, and oligomers of silane may be created when water within the air humidity enters the bottle, and consequently reduces the effectivity of the solution. The occurrence of such an effect was shown to be more improbable with two component silane agents [3].

In a recently conducted *in vitro* study [22], it was determined that the formation of a multilayer surface can reduce the effectiveness of the silane-coupling agent when the number of free methacrylate groups is reduced. Regarding its effectiveness, solvent evaporation plays a significant role. A small amount of solvent may be helpful in boosting silane wetting; however, an incomplete removal may compromise the coupling process [23]. Therefore, in the current study, the silane was applied in a single layer and was dried for 60 seconds at room temperature, following the instructions of the manufacturer.

Chemical and micromechanical interactions are required for the development of strong bonds between the resin composite and the post [24]. Since silane has a low viscosity, it facilitates substrate wetting and provides a more intimate contact between the interfacing materials. After that, the forces of Van der Waals might become effective. When a physical adhesion develops, it also promotes the chemical reactions [19,24,25]. Therefore, in the present study, silane-applied fiber posts showed higher bond strength. The surface wetting theory confirms the key role of silane wetting capacity regarding increased adhesion.

Silane-coupling agents were suggested to have other advantages during interfacial adhesion. They were suggested to increase the resistance to chemical dissolution, particularly in the presence of water [26]. Additionally, since differences are present between thermal expansion coefficients of materials, silane might be able to absorb the stress developing at the interface of fiber post/composite core [19]. However, when data was compared, the difference, determined between the silanized and non-silanized groups, was 0,8 MPa. Thus, the statistical significance might be related to the high number of samples [27].

In the study, composite resins, particularly designed for core built-up, and a hybrid composite were utilized. In the study conducted by Sadek et al. [4], highly filled low-viscosity core materials and hybrid composites were determined to be better alternatives when compared to flowable composites for building-up the core. They stated that core materials were performing slightly better than the other tested materials and were showing the highest bond strength due to the combination of filler content and flowable consistency. Hence, the bond strengths of composites, in which core build-up was made, were higher than Filtek Z250 in the present study.

As Vano et al. [22] have reported, low-viscosity composite resins can penetrate excellently within the irregularities of the post surface and can constitute a good structural integrity around the fiber post, thereby, increasing the size [22,24].

Regarding the filler percentage of used composite resins, Built-it FR has the lowest filler content; it is followed by Rebilda Core, Grandio Core, and Filtek Z250, consecutively. Although Built-it FR had the lowest filler content, the bond strength of Built-it FR was lower than Rebilda Core and Grandio Core, and higher than Filtek Z250. We can suggest that the decreasing amount of resin and the increase in viscosity due to its fiber content leads to this result.

We can indicate that Built-it FR, with its fiber content and chemical compatibility, does not have any advantage in bonding to fiber post, since the cross-linked matrix of fiber post contains no free radicals to react with fibers of Built-it FR [3,28].

The presence of voids/bubbles inside the resin cores and the gaps at the interface with the post can negatively affect the strength of the abutment [24]. Therefore, for obtaining homogeneous and bubble-free cores, dual-polymerized composite resins were used in cartridges and syringes. SEM investigation showed that only Filtek Z250 had some voids that could have acted as raisers of stress and could have initiated mechanical failure.

The push-out test, which has been considered widely for assessment of bond strength [2,4,21,29] provides considerable advantages; (I) fracture develops not transversely, but parallel to the bonding interface, with the clinical conditions being simulated; (II) it is possible to fetch multiple specimens from a single bonded fiber post-composite core; (III) uniform stress distribution is produced due to the reduced dimension of specimens; (IV) technical meticulousness of specimen preparation is less than that of microtensile test method [2,21,30].

These enduring stresses, together with storage temperature and time following the polymerization, might also have altered the push-out bond strength of the posts and the core materials [16]. Further *in vitro* studies, in which intraoral environment should be simulated by considering the effects of thermal cycling or artificial aging, are required.

Conclusion

The following conclusions were made within the limitations of this *in vitro* study: (i) the bond to core material may be significantly affected by the matrix type of the used fiber post; (ii) Using a silane-coupling agent may lead to increased bond strength between the composite cores and the fiber posts; (iii) Composite resins, particularly designed for core build-up, may be better than universal restorative resins for core foundation around fiber posts.

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