Impact of Different Surface Treatments of CAD/CAM Fabricated Glass Fiber Posts on Push-Out Bond Strength to Root Canal Dentin

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Abstract

This study evaluated the impact of various surface treatments of CAD/CAM glass fiber posts on push-out bond strength to self-adhesive resin cement and root canal dentin. After endodontic treatment of forty human freshly extracted single-rooted premolars, post space was prepared to receive the post and core. According to the surface treatment of the post, the specimens were divided into 4 groups. After post cementation, three slices of 3-mm thickness were cut from each root and subjected to push-out test. There was a significant difference in push-out bond strength among surface treatment groups ($p<.001$), as well as among root thirds ($p<.001$). The interaction groups*root thirds was also significant ($p=.026$).

The different surface treatments of CAD/CAM fiber post and application of additional silane after etching with 24% H_2O_2 significantly increased the bond strength values. Significantly higher bond strength in the coronal third of the root dentin was recorded compared to the middle and apical thirds.

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Introduction

Endodontically treated teeth with a huge amount of missing coronal tooth structure, due to caries, old restorations or endodontic access cavity preparation are more susceptible to fracture resulting in higher failure rate of restorations after endodontic treatment. [1]

For endodontically treated teeth with a tremendous portion of lost coronal tooth structure, functional and aesthetic rehabilitation frequently require post preparation and placement inside the root canal system to retain a core for definitive restoration.[2]

According to the material of manufacture, posts are classified into: metals, ceramics, fiber reinforced composite and polyetherketoneketone (PEKK].[3] In addition, they also can be classified according to the fabrication technique into prefabricated and custom-made posts, that are fabricated by either lost wax or CAD-CAM technique.[4]

For teeth that are endodontically treated with fiber posts, clinical studies recorded success rates of 95 to 99 % without incidence of tooth fracture. This can be attributed to their favorable modulus of elasticity, closer to that of the root dentin, allowing for a better stress transmission to root canal walls. Further advantages are their superior biocompatibility, inherent low cost, mechanical strength, easy handling, corrosion resistance, easier removal, and aesthetics, as compared to metal posts.[5]

However, the root canal walls have to be prepared to conform to the post size when using prefabricated fiber post, which may further weaken the strength of the tooth. In addition, prefabricated fiberglass posts in non-circular or extremely tapered canals lead to decrease post adaptation to the dentin of the root canal, and hence compromising post retention.[6]

In order to overcome an unsatisfactory fiber post adaptation to root canal dentin, customized post was introduced. Such posts are obtained directly through relining the

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prefabricated post with resin composite prior cementation or through the indirect technique to produce the post in the laboratory.[7]

Today, CAD/CAM technology makes it possible to construct a one-piece fiber post and core as an alternative to the prefabricated fiber post with less thickness of the cement layer, greater retention, and increased resistance to fracture.[8]

The main cause of failure of endodontic treated teeth restored with fiber-reinforced posts was declared by previous studies not to be related to root fracture, as it happened with cast or metal posts. However, it is related to the pull out of the post and restoration, due to the lack of fiber post retention.[9]

The retention of the fiber post relies on bond strength between the fiber post and a luting agent, as well as bond strength between the luting cement and root canal dentin. Several factors affect the bond strength between the post-root dentin, including the influence of different root canal regions, length, diameter, luting cement and the surface treatment of the post.[10]

In order to improve glass fiber post retention characteristics, different surface treatment methods are reported in the literature such as application of 37% phosphoric acid,[10] application of alcohol, using air-borne particle abrasion for pre-treatment of the post surface, application of 10% hydrofluoric acid and 24% hydrogen peroxide. [11] Up to our knowledge, Optimum bonding cannot be ensured by a standardized protocol of neither surface treatment of the post nor for the post-space treatment.[12] Thus, the purpose of this study was to investigate the effect of various surface treatments of CAD/CAM fiberglass posts on the bond strength to root dentin. The hypotheses tested were that; i) bond strength of CAD/CAM glass fiber posts and resin cement differs according to surface treatment of the post; ii) bond strength of CAD/CAM glass fiber posts varies according to root level.

Materials and methods

Teeth selection and preparation

A total of forty human freshly extracted single-rooted premolars were selected for this study. The Selected teeth were free from caries, root cracks, severe root curvature. The root length was equal or more than 14 mm from root apex to cement-enamel junction. The teeth used in this study were obtained according to the protocol reviewed and approved by Ethical Committee, Faculty of Dentistry, Mansoura University, Mansoura, Egypt (protocol # A17080921). The collected premolars were extracted from healthy subjects due to orthodontic reasons after signing the consent form. The storage protocols followed international and institutional infection control guidelines. After removing all the external debris with ultrasonic scaler, distilled water was used as a storage medium for the specimens and was replaced every 2 days.

A low-speed diamond disc with a water coolant system was used for decoronation of all teeth below cement-enamel junction (CEJ) using to standardize all the root lengths to 13 mm and then stored in distilled water until the time of use.

All teeth were decoronated then endodontically treated by the same endodontist (AK). The working length was calculated by using K file #10 (Mani Inc., Japan) that was passed through the apical foramen so that the tip is just visible, then the file was withdrawn out of the root canal and the file length was recorded, then the working length was calculated by subtracting 0.5 mm from the previously recorded length.

ProTaper NEXT rotary files (Dentsply Maillefer, Ballaigues, Switzerland) were used for preparing all the root canals. The files were used in a brushing motion with rotational speed of 300 rpm and torque 2.0-5.2 (using X-Smart Plus electric motor), till X4 file (40/6). 3ml 5.25% Sodium hypochlorite (NaOCl) was used for irrigation of the prepared root canals between each file and other. The smear layer was removed by 1 ml of 17% Ethylenediamine Tetraacetic Acid (EDTA) (MD-cleanser, Meta Biomed). Finally, the root canal was rinsed with 5 ml distilled water, followed by drying with paper points.

Root canal filling and post space preparation

Root canals were obturated with Protaper Next matching single gutta percha cones corresponding to files (X4) and Adseal sealer (Meta Biomed Co, Cheongju, Korea) using single cone technique. After completion of obturation procedures, excess gutta-percha was removed using the EQ-V (Meta Biomed Co, Cheongju, Korea) Pack Tip and then the gutta-percha was condensed with a hand plugger. Glass ionomer cement (Fuji, GC, Tokyo, Japan) was used for sealing the coronal orifices of the canals.

For complete setting of the root canal sealers, all teeth were stored in an incubator at 37° C and 100% humidity. After one week storage of the specimen, Peeso reamer (Mani Inc., Japan) was used to remove 9-mm depth of the root canal filling, keeping 4 mm gutta-percha for the apical seal.

Fabrication of CAD/CAM glass fiber post and surface treatment

The post space was scanned using Medit i500 scanner (MEDIT corp, Seongbuk-gu, Seoul, Korea). The data were processed using Dental CAD 3.0 Galway software (exocad GmbH, Darmstadt, Germany) (Figure 1). Then the custom glass fiber post and core (Trilor Bioloren, Saronno, VA, Italy) was manufactured by a Ceramill Motion 2 (Amann Girrbach, Koblach, Austria) CAM milling machine.

According to the post surface treatment, the specimens were divided into 4 equal groups (n=10) as follows:

Group (1) control: the post surface was not treated.

Group (2) Silane group: A microbrush (cavibrush, FGM) moistened with silane (Ultradent Silane, Ultradent Products Inc, USA) was applied on the surface for 1 minute and then dried.

Group (3) Sandblasting and silane: the post surface was exposed to air abrasion with 50 µm aluminium oxide (JNBP-2, Jianian Futong, Medical Equipment Co. Ltd., Tianjin, China) at 2.5 bar pressure for 10 sec at a 10 mm distance, then rinsed, and air-dried for 20 sec, then application of silane as in group (2).

Group (4) Hydrogen peroxide and silane: 24% hydrogen peroxide (Luna for Perfumes and Cosmetics, Egypt) was used for post immersion for 1 minute, then washed for 1 minute and dried, followed by application of silane as in group (2).

Post cementation

After the surface treatment, cementation procedure of the post was performed in the same way for all groups according to manufacturer instructions using dual-cure self-adhesive resin cement (G-CEM LinkAceTM, GC Corp., Tokyo, Japan). A brush was used to apply cement on the post surface and a paste carrier tip was used to apply it inside the post space. Finger pressure slowly fixed all the posts, removing any excess cement by a brush. Immediately on cementing the post, light-cure was directed from the top of the post using a LED-curing unit (BlueLEX LD-105, Monitex Industrial Co., LTD. Taiwan, light output: 1100 mW/cm^2) for 60 seconds. The light curing output was checked by a radiometer (Demetron/Kerr, CT-100, Danbury, USA). Finally, distilled water of 37° C was used to store specimens for 24 hours.

Push-out Bond Strength Test

Chemical cured acrylic resin was used for immersion of all the roots with the posts. Afterwards, they were sectioned transversally under water cooling by IsoMet 4000 microsaw (Buehler USA) mounting diamond disk of 0.6 mm thickness at speed 2500 rpm and feeding rate 10 mm/min. A diamond disk at low speed and under constant distilled water cooling was utilized to section the root at 90-degree angle to the long axis, creating 3.0 mm-thick slices. Hence; three post/dentin sections (coronal, middle, and apical) from each root were attained. Ten specimens were selected per root thirds group to yield 95% power in the results of this study based on those of Mosharraf *et al* study, in which the authors found a significant difference in push-out bond strength between four different surface treatment materials using a similar study design (effect size=0.70, Pooled SD=6.62, alpha(α)=.05).

Since the fiber posts have tapered design, their diameters were measured on each surface of the post/dentin sections by digital calipers (Electronic digital caliper, Minova Co, Japan), with 0.01 mm accuracy.

The universal testing machine (Instron universal testing machine model 3345 England data recorded using computer software Bluehill 3 version 3.3) was used to perform the push-out test at f 1 mm/minute crosshead speed. This was accomplished by using a Pin on the center of the post surface in an apical to coronal direction thus avoiding interference with any constrictions. Newton (N) was the unit of measuring the maximum failure load and was converted into MPa by dividing the applied load by the bonded area, which was calculated by the formula:

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

Where π was the constant 3.14, r1 was the coronal post radius, r2 was the apical post radius, and h was the thickness of the slice in millimeters.

A stereomicroscope (Olympus SZ61, Tokyo, Japan) at 20 x magnification was utilized to examine the debonded specimens to evaluate the fracture pattern. The modes of failure were classified as follows: 1) adhesive between post and resin cement (no resin cement visible around the post); 2) adhesive between resin cement and root dentin (resin cement covering the post); 3) mainly cohesive within the resin cement; 4) mixed.

Scanning electron microscopy (SEM) evaluation

The surface topography of each pretreatment group was examined under a Scanning Electron Microscopy (SEM) (JSM-6510LV, Jeol, Tokyo, Japan). Accordingly, for each group, two additional fiber posts were cleansed using ultrasonic scalar for 3 min with deionized water, then immersed in 96% ethanol for 2 minutes and air-dried. Each specimen was fixed on metallic stubs then gold sputter-coated (SPI-MODULE^{TM}, SPI Supplies, USA) and evaluated under SEM at 500x magnification to evaluate any alterations in surface topography that might have occurred due to surface treatment.

Statistical analysis

SPSS program (SPSS v25.0; SPSS Inc) was selected to analyze the obtained data. Test of normality was performed using Shapiro Wilk test and homogeneity of variances by the Levene's test. The Push-out bond strength data were normally distributed and presented as mean ± standard deviation for descriptive statistics. Two-way ANOVA was used to compare Push-out bond strength data between groups and tooth thirds followed by Tukey's multiple comparisons if significant differences detected. P was significant at 5%.

Results

Two-way ANOVA of the effect of surface treatment groups, root thirds, and their interaction on the Push-out bond strength is demonstrated in Table 1. There was a significant difference in Push-out bond strength between groups (p<.001), root thirds (p<.001), and also the interaction groups*root thirds was significant (p=.026).

	Type III Sum of Squares	df	Mean Square	F	P value
Corrected Model	250.22	11	22.74	27.29	<.001*
Intercept	1186.01	1	1186.01	1422.87	<.001*
Groups	118.72	3	39.57	47.47	<.001*
Root thirds	118.25	2	59.12	70.93	<.001*
Groups*root third	13.23	6	2.20	2.64	.026*
Error	40.00	48	0.83		
Total	1476.24	60			
Corrected Total	290.23	59			

Table 1. Two-way ANOVA of the effect of group, third, and their interaction on the Push-out bond strength (MPa).

	(J) group	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Control	Silane	-.148	.333	1.000	-1.065	.769
	Sandblast and Silane	-.654	.333	.334	-1.571	.263
	H_2O_2 and Silane	-3.467*	.333	.000*	-4.385	-2.550
Silane	Control	.148	.333	1.000	-.769	1.065
	Sandblast and Silane	-.506	.333	.814	-1.423	.411
	H_2O_2 and Silane	-3.319*	.333	.000*	-4.237	-2.402
Sandblast and Silane	Control	.654	.333	.334	-.263	1.571
	Silane	.506	.333	.814	-.411	1.423
	H_2O_2 and Silane	-2.813*	.333	.000*	-3.731	-1.896
H_2O_2 and Silane	Control	3.467*	.333	.000*	2.550	4.385
	Silane	3.319*	.333	.000*	2.402	4.237
	Sandblast and Silane	2.813*	.333	.000*	1.896	3.731

*. The mean difference is significant at the .05 level.

Table 2. Post hoc test (Tukey) comparing Push-out bond strength (MPa) between surface treatment groups.

Post-hoc test for comparing total Push-out bond strength between groups is presented in Table 2. The highest total push-out bond strength was noted with Group 4 (H_2O_2 + silane treatment), followed by Group 3 (sandblast + silane treatment), then Group 2 (silane), while the lowest strength was recorded with control group. There was a significant difference in total push-out bond strength between H_2O_2 and silane group and other groups (control, silane, sandblast and silane). However, there was no significant difference in total push-out bond strength between control, silane, sandblast and silane groups.

Post-hoc test for comparing total Push-out bond strength between root thirds is presented in Table 3. The highest total push-out bond strength was noted with coronal third, then middle third and the lowest strength was noted with apical third. A significant difference was obtained in total bond strength between each two thirds.

	(J) third	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Coronal	Middle	1.430*	.289	.000*	.714	2.147
	Apical	3.424*	.289	.000*	2.707	4.140
Middle	Coronal	-1.430*	.289	.000*	-2.147	-.714
	Apical	1.993*	.289	.000*	1.277	2.709
Apical	Coronal	-3.424*	.289	.000*	-4.140	-2.707
	Middle	-1.993*	.289	.000*	-2.709	-1.277

*. The mean difference is significant at the .05 level.

Table 3. Post hoc test (Tukey) comparing Push-out bond strength (MPa) between root thirds.

	Coronal		Middle		Apical		ANOVA P value
	X	***SD***	***X***	***SD***	***X***	***SD***	
Control	4.63 A,a	0.946	3.5 A,b	0.83	2.01 A,c	0.52	<.001*
Silane	4.35 A,a	0.82	4.028 A,a	0.68	2.19 A,b	0.67	.001
Sandblast and Silane	5.99 B,a	1.21	4.048 A,b	1.37	2.05 A,c	0.47	<.001*
H_2O_2 and Silane	9.27 C,a	1.12	6.958 B,b	1.11	4.30 B,c	0.63	<.001*
ANOVA P value	<.001*		<.001*		<.001*		

Table 4. Comparison of Push-out bond strength (MPa) between levels of surface treatment groups and root thirds.

*p is significant at 5%. X; mean, SD standard deviation. Different capital letters in the same column showed significant difference between groups (Tukey, p<.05). Different small letters in the same raw indicate significant difference between teeth thirds (Tukey, p<.05). The same letters showed no significant difference.

Figure 1. Post & core design with CAD-CAM system.

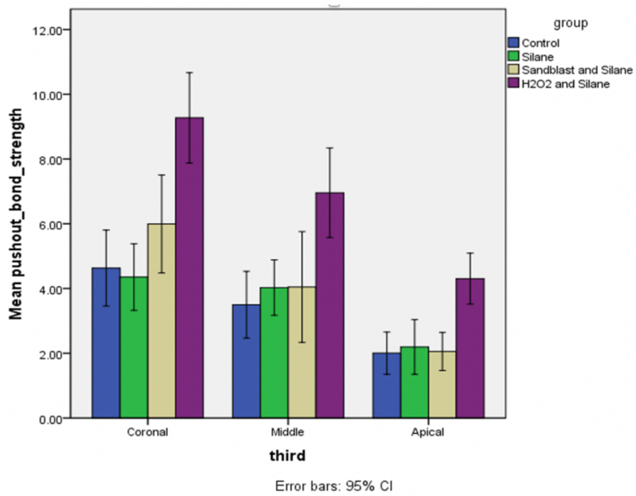

Figure 2. Multiple comparison of Push-out bond strength (MPa) between surface treatment groups for each root third.

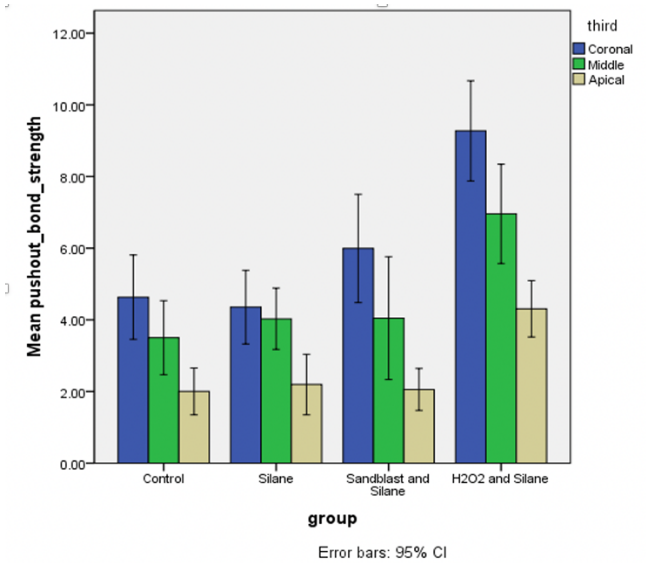

Figure 3. Multiple comparison of Push-out bond strength (Mpa) between root thirds for each surface treatment group.

Comparison of Push-out bond strength between levels of groups and root thirds is presented in Table 4 and Figure 1, 2. For all root thirds, there was a significant difference in push-out bond strength between groups. The highest push-out bond strength was noted with H2O2 and Silane group, followed by Sandblast and Silane, then Silane and the lowest strength was noted with control group.

Multiple comparison of Push-out bond strength between groups is presented in Table 4 and Figure 3. For coronal third, no significant difference was observed between control and Silane groups. For middle and apical group, no significant difference was noted between control, Silane and sandblast and Silane groups. For all root thirds, H_2O_2 and Silane group showed significant higher strength than other groups.

For all groups, there was a significant difference in Push-out bond strength between tooth thirds. The highest strength was noted with coronal third, followed by middle third and the lowest strength was observed with apical third.

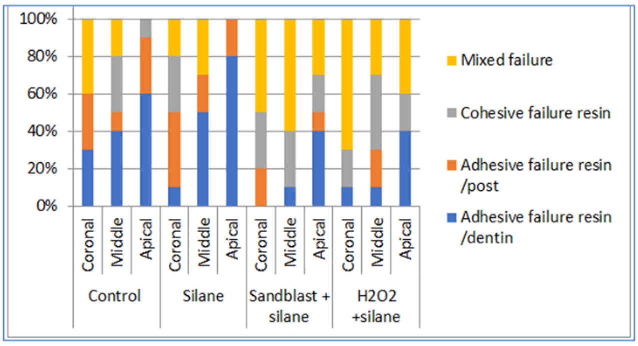

Figure 4. Failure mode distribution.

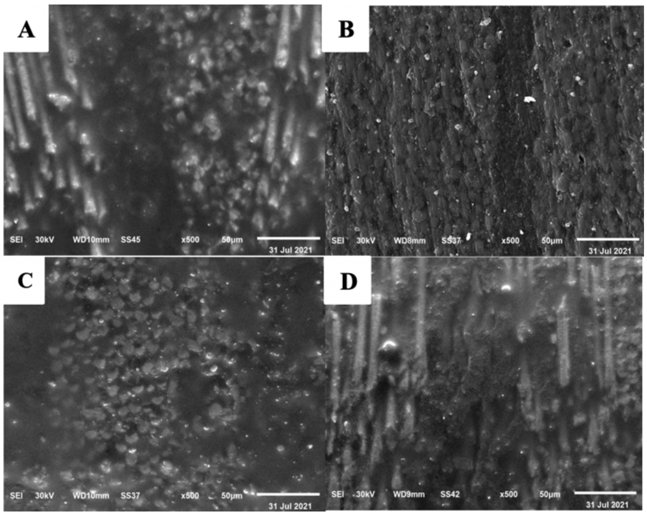

Figure 5. SE-micrographs of non-treated and treated specimens of CAD/CAM fiber post at 500x magnification. A: Non-treated, B: Silanization, C: Silanization after 50 µm sandblasting treatment, and D: Silanization after H2O2 treatment.

Examination by stereomicroscopic at the debonded area showed four modes of failure; adhesive failure when no resin luting agent residue is left on the root dentin or post surface, cohesive failure within resin luting agent, and mixed failure when resin luting agent remnants were partially left on dentin or post surface. There was a variation in modes of failures between the tested groups as shown in Figure 4, where more adhesive failure was showed in Group 1 (non-treated) and Group 2 (silane treatment), while cohesive and mixed ones were showed in Group 3 (silanization after sandblasting) and Group 4 (silanization after H_2O_2).

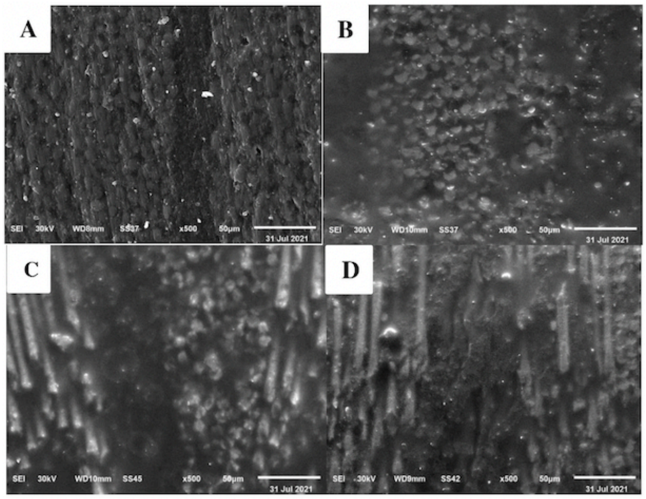

Figure 6. Scanning electron photomicrographs of non-treated and treated specimens of CAD/CAM fiber posts (FP) at 500x.

Figure 6 displays the scanning electron photomicrographs of non-treated and treated specimens of CAD/CAM fiber posts (FP) at 500x magnification. Figure 5 (A) displays a SE-photomicrograph of a non-treated specimen; the topography of the untreated fiber post surface displays micropores and grooves with superficial glass fibers entirely covered by epoxy resin matrix. Figure 5 (B) displays a SE-photomicrograph of a specimen treated with silane; the topography of the surface exhibits impregnated micromechanical features of the fiber posts by silane. Figure 5 (C) displays a SE-photomicrograph of a specimen treated with airborne abrasive particle (50 µm Al_2O_3) followed by silanization; the topography of the surface exhibits a roughness with exposed and intact superficial glass fibers. Figure 5 (D) displays a SE photomicrograph of a specimen treated H2O2 followed by silanization; the topography of the surface shows dissolved matrix with undamaged glass fibers.

Discussion

Based on the results of this investigation, there is acceptance of the null hypothesis that different surface treatments have significant effect on the bond strength between fiber post and resin cement.

Several customization techniques have been suggested to improve post-adaptation. The most common technique is to use a composite resin covering a prefabricated fiberglass post. Unfortunately, this technique creates a different adhesive interface between the resin and the composite, increasing the possibility of failure. In addition, contamination may occur between composite resin increments or between the Post / resin interface. [13]

In this study, CAD/CAM post was used, the advantages of using CAD/CAM fiber post is the fabrication of the post and core in a one piece, without creating an interface between fiber post and composite resin. [13]

Fiber posts are comprised of glass fibers embedded in a matrix of epoxy resin. The epoxy resin matrix cannot chemically bond with resin cements, since they are highly cross-linked structure.[14] It was assumed that the bond strength between the fiber post and resin cement can increase by applying silane coupling agent on the fiber post surface. However, there is no definite consensus on this topic.[15]

As a result, the post-surface treatment is required, as it will partially dissolve the epoxy resin matrix, expose the glass fibers and allow them to be silanated. various surface treatments, such as chemical, mechanical, and chemical-mechanical, have been reported in the literature. [13, 16]

Three surface treatments (silane, hydrogen peroxide and sandblasting) were used in this study. Hydrogen peroxide treatment affects adhesion by oxidizing the post surface, permitting partial removal of the epoxy resin and exposure of the glass fibers so that the silanization can take place. [17]

Air abrasion is a technique intended to change the topography of a post's surface by removing the top layer of resin matrix, generating retention gaps and exposing the glass fiber for chemical interaction. [18]

Silane coupling agents are organic–inorganic molecules with an inherent dual reactivity that can facilitate adhesion between the resin composite and the glass component of the fiber post. [19]

In this study, the push-out test was used, as it has been assumed as one of the most appropriate methods to evaluate the bond strength of fiber posts to root canal dentin. [14] Push-out test has a number of advantages including fewer pre-test failures, lower standard deviation and creating shear stress at the interface between post and cement resembling the stresses detected in clinical condition.[20]

In the present study, the result showed that silane alone was ineffective in increasing the tensile bond strength of fiber posts to resin cements. Our findings agreed with previous studies [21], who observed no significant effect of silanization.

Insufficient chemical bonding between the posts that have little exposed glass fibers could justify the inefficacy of salinization. [16] Another explanation might be the resin matrix composition of fiber posts. According to reports, the methacrylate matrix binds to silane solution better than epoxy resin containing fiber-reinforced posts. [12] However, Goracii et al. [22] recorded significant increase in bond strength after silane application. The contradiction of the results can be attributed to the silane composition (that may differ in pH, solvent concentration, molecule size), as well as the application technique.[23]

In this study, a significant increase was noticed in total push-out bond strength when using H_2O_2 before silanization compared to other groups (control, silane, sandblast and silane), which is in agreement with some other research. [17, 20, 24,25]

In this study, 24% hydrogen peroxide was used for 1 minute. Previous studies reported that this technique, with its concentration and duration, can partially remove the epoxy resin layer of the post and expose the glass fibers without damaging the post structure. [25] as shown in SEM observation (Figure 6D). On the contrary, Elsaka SE [21] applied various concentrations (10%, 30%) of H_2O_2 to the post surface over varying periods of time (5 and 10 min). The result showed that 30 percent H_2O_2 for 5- or 10-minutes enhanced bond strength, but that 10 % H_2O_2 was insufficient to improve post/core complex bond strength. The incompatibility of the results might be due to the various testing techniques and materials used.

In the present study, according to statistical analysis, surface treatment with sandblasting before silanization revealed higher values of bond strength which is statistically significant in the coronal third but not significant in middle and apical third when compared to untreated control group, and silane group. These results are consistent with the results of previous studies.[24, 17, 26, 27] Such result is supported by the SEM observations that show an increase in the roughness of the surface and exposure of the glass fibers, which led to greater micromechanical and chemical adhesion between the resin cement and the fiber post.

However, another study found a significantly lower push-out bond strength of the air-abrasion surface treatment when compared to the control group in the coronal and middle thirds of the root.[16] The heterogeneity in the results could be related to the differences in used material and different methodology.

Sandblasting with Al_2O_3 causes roughening of the fiber post for better bonding, however it may initiate cracks in the post.[16] Previous researches recommended the reduction of exposure time and gentle sandblasting so as to minimize the dimensional changes of the fiber post.[28] Therefore, in our study, Al_2O_3 particles at 2.5 bar pressure for 10 sec from a distance of 10 mm, were used for sandblasting of the fiber posts, as suggested in previous studies.[24,28]

The second hypothesis of this study was accepted, since our results showed that there was a significant difference in bond strength among the root canal thirds, with higher bond strength in the coronal third when compared to the middle and apical thirds. These results are in compatible with other studies.[13, 16, 29]

The high bond strength in coronal region could have resulted from various factors, including larger diameter, and consequently greater surface area available for bonding as compared to apical region and the difference in dentinal tubule densities and orientation toward the apical portion of the root canal. On the contrary, many factors hinder the bond strength apically including: the complexity in visualization and access to the apical region and the restrictions of the material flow which forms extra bubbles and voids in the luting agent. In addition to the continuous risk of the presence of remnants of gutta-percha and endodontic sealer, which weaken the adhesion.[30] Furthermore, the thick smear layer that is formed as a result of the post space preparation could not be conditioned by the adhesive luting agent or eliminated by EDTA/NaOCl irrigation for optimal bonding.[29]

Failure modes have been categorized as adhesive, cohesive, and mixed. Previous researches reported that the adhesive failure between adherent and bonding system occurs in low bond strength value, on the contrary, the cohesive failure occurs within the strong system. In the current study, the fracture analysis showed that modes of failures were adhesive, mixed, and cohesive for all adhesive tested groups. It was found that the adhesive failure was more frequently seen in the non-treated group, which supports the result of push-out bond strength as it has found the lower shear bond strength value. On the other hand, cohesive failure was found more frequently in group 4 (H_2O_2 + Silane treatment), which supports the result of push-out bond strength as it has found the highest push-out bond strength value. Thereby, the detected mode of failure supports the achieved result values of the bond strength in this study. Furthermore, the appearance of mixed failures might be attributed to the unequal stress distribution at the bonded area at the time of the loading procedure.

There were several limitations in this study. For example, there was only one type of CAD/CAM post, a single type of resin cement was tested, and the effects of fatigue loading on the specimens' push-out bond strength were not investigated.

Conclusions

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

1. The mean push-out bond strength values of CAD/CAM fiber post were significantly affected by different surface treatments and root canal region
2. The use of hydrogen peroxide before silanization significantly improved the bond strength of CAD/CAM fiber post to resin cement and radicular dentin.
3. The mean bond strength values in the coronal third of the root canal were greater than the middle and apical thirds.

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Declaration of Interest

The authors deny any conflict of interest. They have no financial interest in the companies whose materials are included in this article.

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