Comparative evaluation of effects of different surface treatment methods on bond strength between fiber post and composite core

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PURPOSE. Debonding of a composite resin core of the fiber post often occurs at the interface between these two materials. The aim of this study was to evaluate the effects of different surface treatment methods on bond strength between fiber posts and composite core. **MATERIALS AND METHODS.** Sixty-four fiber posts were picked in two groups (Hetco and Exacto). Each group was further divided into four subgroups using different surface treatments: 1) silanization; 2) sandblasting; 3) Treatment with 24% H_2O_2, and 4) no treatment (control group). A cylindrical plexiglass matrix was placed around the post and filled with the core resin composite. Specimens were stored in 5000 thermal cycles between 5℃ and 55℃. Tensile bond strength (TBS) test and evaluation using stereomicroscope were performed on the specimen and the data were analyzed using two-way ANOVA, Post Hoc Scheffe tests and Fisher's Exact Test ($\alpha=.05$). **RESULTS.** There was a significant difference between the effect of different surface treatments on TBS ($P<.001$) but different brands of post ($P=.743$) and interaction between the brand of post and surface treatment ($P=.922$) had no significant effect on TBS. Both silanization and sandblasting improved the bonding strength of fiber posts to composite resin core, but there were not any significant differences between these groups and control group. **CONCLUSION.** There was not any significant difference between two brands of fiber posts that had been used in this study. Although silanization and sandblasting can improve the TBS, there was not any significant differences between surface treatments used. **[J Adv Prosthodont 2012;4:103-8]**

KEY WORDS: Composite resins; Fiber reinforced; Bond strengths; Post and core technique

INTRODUCTION

Endodontically treated teeth usually require using a post inside the root canal for retaining a coronal restoration.[1,2] Esthetic and strength demands are the most important factors that determine the type of a suitable restoration for these teeth.[3] In the case of large destruction of coronal tooth structure, the clinical choice may be an esthetic post and core restoration consisting of a composite resin core retained by a fiber post which has better stress distribution pattern and esthetic result.[2-7] Different factors are important in longevity of post and composite core restorations, such as: the core material, post type, and the bonding strength between the fiber post and the composite cement, and between post and the composite core restoration.[8-11] But the failure of these restorations mostly occurs at the junction between the composite resin core and fiber post.[4,6,12]

One of attempts that have been made to improve the bonding strength between composite resin core and fiber posts is the post surface treatment.[11] For this purpose, chemical or mechanical surface treatment procedures were used.[4,10,13] It is said that mechanical techniques (e.g. sandblasting) are more effective than chemical techniques (e.g. etching with hydrofluoric acid , potassium permanganate, silane and hydrogen peroxide).[2,4,10,14-16] Monticelli *et al*.[17] stated that the mechanical techniques are too aggressive for fiber posts and they can decrease the fiber posts fit in the root canals. However, Chemical treatments can also roughen the post surface and consequently increase its mechanical interlock with composite resin core.[10,18,19] On the other hand, it has been said that there is not any chemical interaction between composite resin and the epoxy resin matrix of fiber posts.[11,19] However, there are some surface treatments for enhancing resin bonding to the fiber posts

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(e.g. coating with priming solutions).[17]

It has been reported that etching with hydrogen peroxide can provide stronger adhesion between post surface and resin composite.[4,20-23] Some studies confirmed the benefit of silanization for enhancing the bond strength of a dual-cure resin core material to fiber posts[7,24] but there is a large controversy about silane application.[25,26]

There are many studies about the advantages of doing different surface treatments on fiber posts,[2,4,7,10,11,18,21,27-31] but there has not been any consensus about the most effective treatment for obtaining optimum bonding.

The aim of the present study was to evaluate the effects of some surface treatment methods on the tensile bond strength (TBS) between fiber post and composite core.

The first null hypothesis of this study was that the bond strength between fiber post and composite core with the various surface treatments are not significantly different and the second null hypothesis was that the fiber post brand had no significant effect on the tensile bond strength between fiber post and composite core.

MATERIALS AND METHODS

In this *in vitro* study, sixty four glass fiber posts (of two brands but with same composition) with maximum 1.6 mm diameter were selected. The materials used in this study are shown in Table 1. All of the fiber posts were placed in an ultrasonic bath cleaner (Biosonic UC300, Coltène/Whaledent, NV, USA) for two minutes at room temperature and then washed with ethanol 96% and were gently air dried. The posts in each group were randomly divided into 4 subgroups of 8 specimens each, according to surface treatments used:

Silane group. A single layer of a silane coupling agent (Ultradent Products Inc., South Jordan, UT, USA) was applied on the post surface for 60 seconds and then dried for 60 seconds with gentle air stream.

Sandblasted group The posts in this group were sandblasted with 50 μm aluminum oxide particles using an oral Microblaster (Dento-prep, Denmark) for ten seconds at 0.25 MPa pressure from a ten millimeter distance and then rinsed with ethanol 96% and were gently air dried.

H₂O₂ Group At first, the 30% hydrogen peroxide were diluted to 24% hydrogen peroxide and then the posts in this group were immersed in this solution for 10 minutes at room temperature and then rinsed under running water for 2 minutes and gently air dried.

Control group This was a control group without any surface treatment.

One layer of bonding resin agent (Voco GmbH, Germany) was applied on all of the prepared post surfaces and then was cured using a halogen light curing unit with 500 mW/cm² intensity (Coltolux 50, Coltene, Altstatten, Switzerland) for 20 seconds. Apical end of each post was maintained in a dental surveyor and positioned vertical to a glass slab. A transparent cylindrical Plexiglas mold 10 mm in diameter and 2 mm thick (equal to the length of non-tapered portion of the post) was placed around the post and manually adjusted so that the position of the post was exactly at the center. A core build up composite (Kuraray Medical Inc., Japan) was used to fill the cylinder around the post with an incremental technique and each layer was cured separately using the same halogen light curing unit. Before removing the matrix, a further 40 seconds curing was done on the other side of the cylinder to ensure complete polymerization of the core material. With this procedure a cylinder of resin composite around the fiber post is made. All of the procedures were performed by the same investigator. All of the specimens were subjected to thermocycling for 5000 cycles at temperatures alternating between 5 and 55℃ for 30 seconds each, with an intermediate pause of 15 seconds. The specimens were loaded in a universal testing machine (Electromechanical low-capacity testing Machines, walter + bai, AG, Switzerland) at a crosshead speed of 0.5 mm/min until failure occurred. Bond strength was expressed in Mega Pascal (MPa), by using the following formula:

$$\Gamma = \frac{F}{\pi R H}$$

where Γ is the tensile bond strength (MPa), R is the post diameter, H is the bonding height and F is the failure mode (N).

Each failed specimen was examined with a stereomicroscope at 15 magnifications (MBC, 10 Number: n 9116734 SF-100B, LOMO, Russia), in order to evaluate the mode of failure and classify it as adhesive between post and core, cohesive

Table 1. The materials used in this study

Material	Batch number	Product	Manufacturer
Fiber post	15912	Exacto Fiber Post	Angelus, Londrina, PR, Brazil
	786.917	Hetco Fiber Post	Hakim Tous, Mashhad, Iran
Surface treatment	B56TT	Ultradent Porcelain Silane	Ultradent Products Inc., South Jordan, UT, USA
	-	Dento-prep Microblaster	Dento-prep, Ronviga, Daugaord, Denmark
	107210	Hydrogen Peroxide 24% (H₂O₂)	Merck KGaA, Darmstadt, Germany
Bonding resin agent	1048032	Futurabond DC	Voco GmbH, Cuxhaven, Germany
Composite resin	2395AC	Clearfil Photo core Composite	Kuraray Medical Inc., Tokyo, Japan

within post, cohesive within core and mixed of both types.

The collected data were analyzed (SPSS/PC 16.0; SPSS Inc, Chicago, IL, USA) using Two-way analysis of variance (ANOVA), Post Hoc Scheffe tests and Fisher's Exact Test at $P<.05$ level of significance.

RESULTS

Tensile bond strength mean values and standard deviations for all experimental groups are presented in Table 2. As shown in Fig. 1, in both post brands the H_2O_2 group had the lowest TBS mean value. Analysis results on the effects of post types, surface treatments, and their interaction on TBS are shown in Table 3. The two-way ANOVA revealed that different surface treatments ($P<.001$) had a significant effect on TBS but different brands of post ($P=.743$) and interaction between the brand of post and surface treatment ($P=.922$) had no significant effect on TBS. Besides, Post Hoc Scheffe test showed that there were significant difference between H_2O_2 and Silane groups ($P<.001$) and between H_2O_2 and Sandblast groups ($P=.012$) but other groups had no significant differences ($P>.05$) (Table 4).

The results of fracture mode after TBS testing as observed with a stereomicroscope (at $\times 15$ magnification) showed that in this study there were only two types of fracture mode: one as adhesive between post and core and another as cohesive in the core material (Fig. 1). None of the test groups demonstrated cohesive failure within the post material. In the Silane
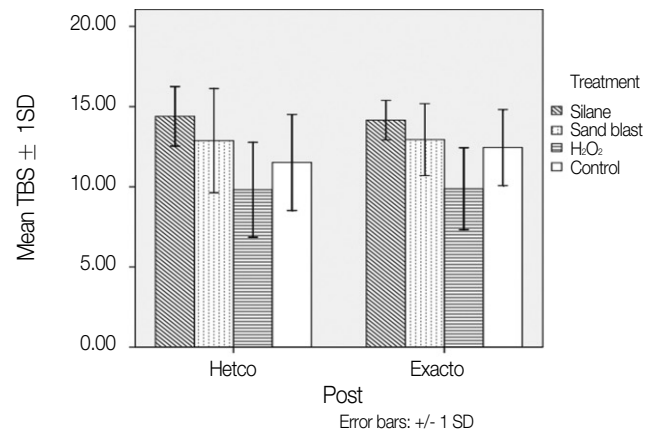

Fig. 1. Tensile bond strength mean values (MPa) and standard deviations for the eight experimental groups.

and Sandblast groups most of the fractures were cohesive but in the other two groups (H_2O_2 and control groups) the predominant fracture pattern was adhesive failure (Table 5). Fisher's Exact Test showed significant differences between different surface treatments in the case of two types of fractures. Besides, significant differences were seen between Sandblast and Control groups ($P=.01$) and between Silane and Control groups ($P=.003$) by using Fisher's Exact Test.

Table 2. Tensile bond strength mean values (MPa) and standard deviations for the eight experimental groups ($n = 8$)

Post	Treatment	n	Mean	SD	95% Confidence interval	
					Lower bound	Upper bound
Hetco Fiber Post	Silane	8	14.3875	1.85568	12.8361	15.9389
	Sandblast	8	12.8762	3.24750	10.1613	15.5912
	H_2O_2	8	9.8150	2.95970	7.3406	12.2894
	Control	8	11.5138	2.99125	9.0130	14.0145
Exacto Fiber Post	Silane	8	14.1550	1.23472	13.1227	15.1873
	Sandblast	8	12.9400	2.24293	11.0649	14.8151
	H_2O_2	8	9.8800	2.55286	7.7458	12.0142
	Control	8	12.4450	2.37187	10.4621	14.4279

Table 3. Results of two-way analysis of variance for surface conditioning methods

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected Model	169.539[a]	7	24.220	3.845	.002
Intercept	9606.450	1	9606.450	1524.973	.000
Post	.685	1	.685	.109	.743
Treatment	165.821	3	55.274	8.774	.000
Post * Treatment	3.034	3	1.011	.161	.922
Error	352.768	56	6.299		
Total	10128.757	64			
Corrected Total	522.307	63			

a. R Squared = .325 (Adjusted R Squared = .240)

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Table 4. Post hoc test (Scheffe) for comparing surface treatments

Treatment	Subset	
	1	2
H_2O_2	9.8475	
Control	11.9794	11.9794
Sand Blast		12.9081
Silane		14.2713
Sig.	.136	.095

Table 5. The results of fracture mode after TBS testing

Fracture type	Treatment			
	Silane	Sandblast	H_2O_2	Control
Adhesive	2	3	7	11
	12.50%	18.80%	43.80%	68.80%
Cohesive	14	13	9	5
	87.50%	81.20%	56.20%	31.20%

DISCUSSION

The results of this *in vitro* study rejected the first null hypothesis that the bond strength between fiber post and composite core with the various surface treatments are not significantly different. However, the hypothesis that the fiber post brand had no significant effect on the tensile bond strength between fiber post and composite core is accepted.

In this study the composite core material was directly applied on the prepared fiber post surface in a way that was similar to the method used in some other studies.[4,32,33] Preparing the specimens and then sectioning them (that is used in most microtensile tests) has some disadvantages like high premature failure rate that can occur during specimen preparation and large data distribution.[28,34] However, one of the advantages of using the "thin slice" microtensile tests is retrieving multiple specimens from a single fiber post and composite core complex.[5]

In the present study, the highest tensile bond strength was seen in the Silane group in both brands of post (Table 2) but there was not a statistical significant difference between this group and control group (P=.003). This is not in accordance with the results of some other studies.[24,25,34,35] Increasing the TBS with silane application is due to this fact that silane can increase the surface wettability and creates covalent bonds with hydroxyl-OH groups of inorganic substrates, such as glass.[17,36] But some authors stated that there is not any chemical bonding between resin composites and epoxy resin matrix of fiber posts, because epoxy polymers have a highly cross-linked structure.[37] Amino-silane coupling agents are generally used for increasing the bonding epoxy resin polymers to composite core materials,[34,38] and some authors believe that the chemical bond may be achieved only by using silane between the resin composite and the exposed glass fibers or filler particles of the post.[17,26,34] Also, some studies claimed that silane did not increase the bond strength of fiber posts.[4,13,23,30,39,40] However, there is a large controversy about the efficiency of post silanization in improving TBS.[17,24,25,30,34,35,37,39-41] This inconsistency in the results of the studies may be explained by the differences in the composition of the post and the core materials used and the mode of testing.

Generally, sandblasting is used for pretreating acid-resistant materials.[42] It can roughen the restoration surface and preparing it for micro-retention.[43] According to the results of the present study, sandblasting increased the bonding between fiber post and composite resin core but there was not any statistical significant difference between this group with control group (P<.001). Some other studies concluded that sandblasting can improve the bonding strength of fiber post to composite core.[2,15,19,21,23,31,44-46] Several reasons were introduced for this finding. The sandblasting roughens the fiber post surface and produces a mechanical retention for the composite resin. The composition of the glass-fiber surface is composed of the resin matrix, inorganic filler particles and the glass fibers.[2] Some authors believed that sandblasting modifies the epoxy resin matrix and creates a larger surface area for bonding.[2,19,21,47] However, sandblasting is considered as an aggressive pretreatment for fiber posts, because it significantly modifies the post shape.[21,29,48] For this reason it is said that Al_2O_3 particle size, as well as the application time and distance, may influence the bonding strength between fiber post and composite core. Radovic *et al.*[45] concluded that sandblasting can improve fiber post-composite resin bond but water aging significantly reduced the bond strength of sandblasted specimens.

Surprisingly, in this study the H_2O_2 group had the least TBS mean value even in comparison with the control group. In the present study, there were significant differences between H_2O_2 and Silane groups (P<.001) and between H_2O_2 and Sandblast groups (P=.012). This can be due to this fact that in the present study (like the study by Mazzitelli *et al.*[19]) the bonding agent was used immediately after H_2O_2 application (without silane coupling agent as a mediator). Although this type of surface conditioning roughens the post surface and increases the bonding surface area, it may, however, produce substantial damage to fiber post substructure. In some other studies, the researchers used the H_2O_2 as a pretreatment for using silane coupling agent. They concluded that surface treatment of quartz and glass fiber posts with hydrogen peroxide significantly enhance the bond strength due to its ability to remove the surface layer of the epoxy resin matrix of post and creating a better chemical bonding between silane and fiber post.[4,20,22,23,34] One can conclude that using H_2O_2 alone had no benefits to increasing TBS, because bonding between exposed post fibers and composite resin cannot be achieved adequately with-

out a mediator.

In a study by Khamverdi *et al.*[10] the bond strength values of hydrogen-peroxide-treated posts were higher than the sandblasted posts. However, in some studies application of H_2O_2 had no significant effect on bonding strength between fiber post and composite core material.[49,50] Also, some authors claimed that pretreatments are not necessary before silane application.[29] Although, the rationale for conditioning the surface of fiber post is creating a surface layer of epoxy resin and producing more quartz fibers available for silanization.[19]

Each failed specimen was examined microscopically at 15 magnifications in order to classify the mode of failure as adhesive between post and core, cohesive within post, cohesive within core and mixed of both types. But the observation of the tested specimens in this study revealed only two failure modes: one as adhesive between post and core and the other as cohesive in the core material (Table 5). In the Silane and Sandblast groups the predominant mode of failure was cohesive in the core material but in the two other groups (H_2O_2 and control) the failure mode was primarily adhesive between fiber post and core material. Such a result was seen in the study by Balbosh and Kern,[2] Wrbas *et al.*[13] stated that higher failure rate of adhesive failure is a sign of lack of chemical bonding between fiber post and composite core material. In the present study, it can be said that in the groups with higher TBS the failure mode was primarily cohesive.

Thermocycling and water aging may significantly decrease the bond strength between post and core, although bond strength after prolonged storage in water was not significantly different between some surface treated groups.[10] This has been attributed to degradation of the fibers or the matrix and to the difference in thermal expansion coefficients between the two. In this way Sahafi and Peutzfeldt,[12] and Bitter *et al.*[34] stated that bonding strength between post and core depends more on the post material and the surface treatment of posts than on the storage duration and condition.

One of the limitations of the present study is that only one core composite resin and three surface treatments of the posts were evaluated in the *in vitro* conditions. Using a combination of pretreatments can lead to different results. Another limitation of this study is the pre-treatment of the post immediately followed by the application of the bonding resin and composite core material. Further, the surface characteristics of the dislodged posts were analyzed under stereomicroscope and not by using scanning electron microscope.

CONCLUSION

Within the limitations of this study, the tensile bond strength of core resin to fiber posts was affected by the surface treatments applied to the post surface. Sandblasting and silanization of the post surface could result in a slight improvement of

the bonding strength of core resin to fiber posts. However, there were significant differences between H_2O_2 and silane groups and between H_2O_2 and sandblast groups but other groups had no significant differences. There was not any significant difference between two brands of fiber posts that had been used in this study.

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