Effect of Various Surface Treatment on the Push-out Bond Strength of Glass Fiber Posts Bonded to Human Root Dentin: An *in vitro* Study

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ABSTRACT

This *in vitro* study evaluated whether surface treatment for glass fiber posts has an effect on the push-out strength bonded to human root dentin. Fifty freshly extracted maxillary central incisors were endodontically treated and post-space preparation done. A total of 50 FRC Postec randomly divided into five groups (10 teeth each) were subjected to four different surface treatments: Silane only (II), cojet and silane (III), 10% sodium ethoxide and silane (IV), 10% hydrogen peroxide (V). The control group (I) did not receive any surface treatment. The root canals were treated with 37% phosphoric acid and Excite DSC and all the posts were luted with Variolink II dual cure resin. A push-out test was done to measure bond strength at different levels of the root. Data were analyzed with one-way ANOVA and post-hoc Tukey HSD test. The results showed no significant difference between control group and silane treatment. Cojet and silane (III) showed the highest bond strength of 15.50 ± 4.2 MPa, which was statistically significant than all the other group ($p < 0.001$). The coronal segment showed the highest mean bond strength of 13.74 ± 6.1 MPa ($p < 0.001$).

Keywords: Post, push-out bond strength, surface treatment

The challenge of restoring endodontically treated teeth has spawned a considerable diversity in foundation restorations and a plethora of publications in dental literature.[1] Pulpless teeth pose several challenges due to the loss of tooth structure by caries, defective restoration and endodontic access preparations.

Use of post system for the rehabilitation of endodontically treated teeth requires planning for restoring function of the tooth as well as structural and esthetic strategy. Currently, increasing demand for esthetic posts and cores has led to the development of zirconia and fiber posts.[2] These post systems have been developed to improve the optical effect of esthetic restorations.[3] Newer adhesive systems and resin-based luting agents create a genuine adhesive continuum between the tooth and the post-core complex. The use of these bondable materials allows the practitioner to unify the structure and morphology of root systems.[4]

Zirconium oxide posts demonstrate high fracture resistance due to high flexural strengths, which is comparable to that of cast gold and titanium posts. But the fracture of zirconium oxide posts often results in unrestorable damage to the tooth, whereas *in vitro* studies on fracture strength of fiber re-inforced composite (FRC) posts show more favorable mode of failure. The modulus of elasticity of FRC posts is closer to that of dentin and distributes stress evenly over a broad surface area.[5,6]

Fiber posts are bonded with resin luting cements, which allows the formation of a single unit where tooth, post and core function as a cohesive unit - monoblock configuration.[7] The clinical success of post retention depends on the bonding of post to the luting cement and luting cement with the dentin.[8] Surface treatments are methods by which general adhesive properties of a material are enhanced by facilitating chemical and micromechanical retention between different constituents.[9,10] Various methods of surface treatments for fiber posts are sand blasting, hydrogen

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peroxide (H_2O_2), silane, potassium permanganate, sodium ethoxide, etc.

Taking into consideration that the primary cause of failure of fiber posts is debonding, the objective of this study was to test the effect of various surface treatments on the push-out bond strength of glass fiber posts. The null hypotheses tested in this study were:

- The use of silane coupling agent alone does not have effect on the bond strengths of fiber posts
- There is no measurable difference in bond strength after different surface treatment
- There is no measurable difference in bond strength at different levels of root.

METHODOLOGY

Fifty freshly extracted single rooted human maxillary central incisors free of caries and fractures without any significant canal curvatures and with type 1 canal configuration were selected and stored in 0.9% physiologic saline until root canal treatment was performed. Crowns were decoronated to the level of cementoenamel junction for all samples using a diamond disc and pulp was extirpated using barbed broaches.

An initial 10 size K-file was passed in the canal till its tip could be seen at the apex and the length was measured. Working length was calculated by subtracting 1 mm from the measured length of the initial 10 size K-file. The coronal third of the canal was prepared using GG drills from sizes 4-1, while apical and middle third was prepared with K files manually using step back technique. Three percent sodium hypochlorite, 17% EDTA (ethylenediaminetetraacetic acid) and 0.9% physiological saline were the standard irrigants used in the study. Master apical size of #35 was standardized and obturation was done by lateral condensation technique with AH Plus sealer.

Post-space preparation was done using the corresponding drill supplied by the manufacturer leaving 5 mm of apical gutta-percha for all the samples. The canals were then irrigated with distilled water and dried with paper points. The canal walls of all the experimental samples were then etched with 37% orthophosphoric acid gel for 15 seconds using an applicator tip.

The canal walls were then irrigated with distilled water to remove the excess etchant from the canal and dried with paper points. The bonding agent Excite DSC (Ivoclar Vivadent) was applied with the Microbrush all over the prepared post-space of the root canal and light cured for 20 seconds from the orifice. All the samples were randomly assigned into five experimental groups of 10 teeth each.

Box 1. Surface Treatment of Posts

- Group I (n = 10): No surface treatment
- Group II (n = 10): Silane treatment only (The posts were surface-treated with silane coupling agent (Monobond-S) for 60 seconds and then gently air-dried)
- Group III (n = 10): Cojet and silane treatment (The posts were sandblasted (Cojet) for 30 seconds and then treated with silane coupling agent for 60 seconds and then gently air-dried)
- Group IV (n = 10): 10% H_2O_2 and silane treatment (The posts were immersed in 10% H_2O_2 for 5 minutes, washed with distilled water and treated with silane solution for 60 seconds and then gently air-dried)
- Group V (n = 10): Sodium ethoxide and silane treatment (The posts were immersed in freshly prepared solution of sodium ethoxide for 5 minutes, washed with distilled water and treated with silane solution (Monobond-S) for 60 seconds and then gently air-dried).

The fiber post-FRC Postec (Ivoclar Vivadent) - 1.0 mm diameter (Tip) (n = 50) was grouped as shown in Box 1.

All the posts were then luted with Variolink II (Ivoclar Vivadent) dual cure resin cement. After luting the samples were stored in 100% humidity at 37°C and were subjected to a temperature of 45°C for 3 minutes, 5 times a day for 15 days.

Push-out Bond Strength Testing

The apical 5 mm of the samples containing gutta-percha was cut down with a diamond disc. From the remaining coronal segment of the samples, 3 cross sections of 2 mm thickness from apical area were obtained and the thickness was checked with a digital vernier calipers.

The specimens were then placed in an acrylic mold of 2 mm diameter and then subjected to push-out bond strength testing. Each section was attached to the acrylic mold with cyanoacrylate adhesive ensuring that the coronal surface faces the mold and the post was centered over the hole of 2 mm diameter in the mold

The push-out mold was then placed in Lloyds Instron universal testing machine. The cross head was lowered at a speed of 1 mm/min until the post was dislodged. Push-out bond strengths were calculated for each section. All the values obtained were tabulated and subjected to statistical analysis.

RESULTS

The highest mean push-out strength values were recorded in Group III (Cojet and Silane treatment) 15.50 ± 4.2 MPa followed by Group V (Sodium ethoxide and Silane treatment) 12.04 ± 3.9 MPa and Group IV (10% H_2O_2 and Silane treatment) 11.9 ± 3.5 MPa as shown in Table 1. These results were analyzed using one-way-ANOVA and post-hoc Tukey HSD test. Group III (Cojet and Silane treatment) was significant with all the other groups at $p < 0.001$ level. There was no significant difference between Group I (No surface treatment) 10.43 ± 3.8 MPa and Group II (Silane treatment) 10.73 ± 3.5 MPa at $p < 0.05$ proving that there was no increase in bond strength of fiber posts that had undergone silane treatment only.

In all the experimental groups, the coronal segment showed the highest mean bond strength of 13.74 ± 6.1 MPa. The lowest bond strength was observed with the apical segments (10.58 ± 5.1 MPa). Coronal segments show a statistical significance ($p < 0.001$) when compared with the apical and middle segments.

DISCUSSION

The restoration of endodontically treated teeth is one of the extensively studied topics in endodontics and yet remains controversial from many perspectives. There are varieties of posts that are available today which may vary in composition, mechanical properties and structural geometry (Custom made cast post, prefabricated post, titanium post, zirconia and fiber posts).[11] Fiber-reinforced technology is already used for a wide range of applications in dentistry - splints, complete dentures, fixed dentures, retainers, etc. Fibers have also been used for endodontic post build-up restorations to reinforce composite resins.

Surface treatments are methods by which general adhesive properties of a material are enhanced by facilitating chemical and micromechanical retention between different constituents. As it has been hypothesized that the primary mode of failure of fiber posts is debonding, various surface treatment methods have been suggested to improve the bond between the post and the luting cement like sand blasting, silanization, H_2O_2, sodium ethoxide etching, etc.[12,13]

Silanes are hybrid organic-inorganic compounds that can mediate adhesion between matrices through their intrinsic dual reactivity. Although the use of silane coupling agents as adhesion promoters in fiber reinforced materials is well-established, their use in pre-treatment of fiber posts still remains controversial.[14,15] Bond integrity is challenged by the limited capacity to dissipate polymerization shrinkage stresses (C factor) in long narrow post-spaces that exhibit highly unfavorable cavity geometry.[16-18]

The efficacy of one step (self-etch) adhesives in forming a durable bond with root dentin is questioned.[19] It was shown that the hybrid layers created by self-etch adhesives are not uniform and contain nanovoids that are permeable to water. This may adversely affect the longevity of bonded root canal fillings and posts. The increased collagenolytic activity in root dentin due to the less acidic primers of self-etch adhesives have also been demonstrated recently.[20] Therefore, a total etch technique was followed in this study.

Excite DSC, dual polymerizing single bottle agent was used as the bonding agent. The uniform formation of hybrid layer lies in the wetting of the adhesive entirely over the etched surfaces. The importance of microbrush in reaching the narrowest and deepest portion of root canal preparations has been shown by Vichi et al[21] and Ferrari et al.[8] This results in a deep diffusion of resin into the tubules and the formation of uniform hybrid layer and lateral branches. In an attempt to simulate the oral condition, a thermocycling protocol was done to all the test samples.

In a recent study of the bonding of resin cements to fiber posts, it was found that the strength of the bond depended on the post material, the surface treatment of the post and the resin cement.[22] The role of silane

Table 1. Push-out Bond Strength of Coronal, Middle and Apical Specimens

Groups Subgroups	I (MPa)	II (MPa)	III (MPa)	IV (MPa)	V (MPa)
Coronal	11.9 ± 6.3	12.5 ± 7.2	17.1 ± 7.0	13.5 ± 4.9	13.7 ± 5.5
Middle	10.5 ± 5.5	10.7 ± 6.9	15.2 ± 5.8	11.9 ± 5.2	12.0 ± 7.2
Apical	8.9 ± 7.3	9.0 ± 6.8	14.2 ± 4.9	10.3 ± 6.6	10.5 ± 7.3
Mean	10.43 ± 3.8	10.73 ± 3.5	15.5 ± 4.2	11.9 ± 3.5	12.04 ± 3.9

in the bonding of ceramics and composites has been established but its role in fiber post adhesion yet remains controversial. Silane due to its low viscosity would assist substrate wetting, and once an intimate contact between the interfacing materials is established, the Van der Waals forces would become effective providing physical adhesion, which may lead to a tertiary monoblock structure from the existing secondary monoblock.

The results showed no significant difference in Group I and II (No surface treatment and silane (10.43 ± 3.8 MPa and 10.73 ± 3.5) proving no increase in bond strength of fiber posts that had undergone only silane treatment. Hence, the first null hypothesis tested holds good. These results were in accordance with the study by Perdigao et al[23] and Newman et al.[24] The highest mean push-out strength values were recorded in Group III (Cojet and Silane) 15.50 ± 4.2 MPa followed by Group V (Sodium ethoxide and Silane) 12.04 ± 3.9 MPa and Group IV (10% H_2O_2 and Silane) 11.9 ± 3.5 MPa. The results show a statistically significant difference at $p < 0.001$ levels.

The highly cross-linked polymers of the matrix of the glass FRC posts used in this study do not have any free functional group for reaction.[22,23] This could be the possible reason for insignificant effect of the silane when no surface treatment was done. Etching solutions such as sodium ethoxide, hydrogen peroxide, potassium permanganate have been commonly employed for partially removing the resinous superficial layer of the fiber posts containing epoxy resin matrix. Increased bond strength has been observed after the combined etching and silanization coupling from various studies than silane treatment alone.

In the present study, mechanical roughening using cojet followed by silane treatment achieved the highest bond strength of 15.5 MPa compared to chemical etching (10% H_2O_2, sodium ethoxide) and silane treatment. These were significant to $p < 0.001$ level. In addition to that findings, etching with chemical solutions yielded higher bond strength values than Group I and II (Silane and Non-Silane). Thus, second null hypothesis tested has been proven to be false.

The coronal segment showed the highest mean bond strength of 13.47 ± 6.1 MPa. The lowest bond strength was observed with the apical segments. Coronal segments show a statistical significance ($p < 0.001$) when compared with the apical and middle group. But no statistical difference was observed between the middle and apical segments ($p > 0.001$). These results were consistent with the studies of Boff et al,[6] Kalkan et al[16] and Perdiago et al.[23] But these were in contrary with those of Teixeira et al in which apical segments revealed the highest bond strength which may be due to the fact that bond strength was related more to the area of solid dentin than the density of tubules.

Adhesion to root dentin is a viable procedure but structural differences exist between coronal and radicular dentin. Tubule density is greatest in the coronal and middle third than the apical third of the root. As adhesion is enhanced by the penetration of resin into the tubules, if there were a greater number of tubules per mm^2, a stronger bond would be expected. Additionally, the coronal portion of the canal is the most accessible part for the canal space, making it easier for thorough application of the adhesive and therefore formation of resin tags is more uniform than the deeper areas of the canal. Hence, the third null hypothesis tested has been proven to be false. Thus, mechanical roughening of the post (Cojet) and silanization has proven to be more effective than the use of the etching solutions and silane.

CONCLUSION

Within the limitations of the present study it has been found that:

- Silanization without any surface treatment has negligible effect on the bond strength of fiber post.
- Cojet with silane treatment has proven to be more effective than silanization done along with etching solutions.
- There is a marginal increase in bond strength when the posts were silanated after etching with 10% H_2O_2 and sodium ethoxide.
- Highest push-out strength was achieved at the coronal third of the root when compared with the middle and apical third.

Further studies on these fiber post systems are required to validate the results of the present study. More parameters like microleakage, flexural strength, modulus of elasticity, etc. needs to be evaluated.

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Safe Driving Limit

The legal permissible limit of blood alcohol content (BAC) is 0.03% or 30 μL alcohol in 100 mL blood alcohol as detected in a test by a Breath Analyzer.

- Two pegs in the first hour and one per every 1 hour after that will give a blood alcohol concentration of 0.05 (g/100 mL).

"Blood-alcohol maximum-per-drink" number

If you divide the number 3.8 by your body weight in pounds, you should obtain a number between 0.015 and 0.40. This is your personal "blood-alcohol maximum-per-drink" number. This is the maximum percentage alcohol that will be added to your blood with each "drink" you take.

For the purposes of this calculation, a "drink" is a 12-ounce, 4% alcohol, bottle of beer or a 4-ounce glass (a small wine glass) of 12% alcohol wine, or a one-ounce shot glass of 100 proof liquor (most bars's mixed drinks have this amount of alcohol). (Microbrewery beer, malt liquor, pint bottles of beer, large [6 oz.] wine glasses, 20% alcohol ["fortified"] wines and very stiff or large mixed drinks should be counted as "1½" drinks.)