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Research Article

Effect of Different Surface Treatments on Push-out Bond Strength of Glass Fiber Posts to Resin Composite Core Material

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Abstract

The aim of this study was to evaluate the effects of surface pretreatments of fiber-reinforced post on thin-slice puch-out bond strength to resin composite core material. Prefabricated glass fiber posts Parapost 1.4 mm diameter were divided into four groups; Group C: no pretreatment, Group A: air abraded using110 µm aluminum oxide, Group PH: phosphoric acid immersion, and group H: hydrogen peroxide immersion. Each group was then subdivided into two subgroups; Subgroup A: Silane coupling agent (EspeSil, 3M Espe) and Subgroup B: ONE-STEP adhesive system (ExciTE F DSC, Ivoclar Vivadent) applied to the treated post surfaces. A flowable dual-cured resin composite core material (Multicore Flow, Ivoclar Vivadent) was applied to each group for testing the adhesion using thin-slice push-out test. Data were analyzed using two-way ANOVA. The highest bond strengths was observed for H_2O_2 group after treatment with silane coupling agent (18.1± 2.3 MPa) followed by air abraded group (14.3 ± 1.8 MPa). The lowest bond strength was observed for phosphoric acid etching groups for both silane and adhesive treated subgroups (11.3 ± 1.6 MPa & 12.4 ± 1.9 MPa). When comparing bond strength (MPa) values dependent on the type of bonding used (silane vs. bonding), analysis of variance demonstrated no statistically significant differences (*p*<0.05).

Keywords: Bond strength; Glass fiber post; Push out test; Surface treatments

Introduction

Endodontically treated teeth often have substantial loss of tooth structure and its rehabilitation usually require a core buildup. However, if retention and resistance of the core are compromised, a post may also be necessary to retain the core [1-4]. Custom cast posts and cores or prefabricated metal posts were the standard for many years. Currently, increasing demand for esthetic posts and cores has led to the development of zirconia and fiber posts [5].

Nowadays, the restoration of endodontically treated teeth is based on the use of materials with a modulus of elasticity similar to that of dentine (18.6 GPa). Fiber posts, resin cements and some composite resins all have this characteristic [6]. With these materials, a mechanically homogeneous unit-monoblock can be created reducing fracture risk [7]. Unlike metallic posts, the most frequent failure of fiber post restoration was not due to fracture, but to debonding, which may occur between fiber post and resin or between resin and intraradicular dentin [8-10].

It should be noted that a reliable bond between fiber post and resin composite core also plays an important role in the post-core restoration of endodontically treated teeth. The retention and stability of the post systems and core build-up is an important factor for successful restoration [11]. The durability of a resin composite core restoration depends on the formation of a strong bond between the core material and residual dentin, as well as between the core and post material, enabling the interface to transfer stresses under functional loading [3,12].

Retention of resin composite core to the prefabricated post is influenced by several factors, including surface treatment of the post [13,14], the design of the post head, the post and the resincomposite core material [15,16]. The most commonly used core materials are glass ionomers, resin composites, amalgam, and cast metal alloys. Amongst which, resin composites are superior to glass ionomers and amalgam in that they enhance the retention and fracture resistance of the posts [17]. Moreover, resin composite core materials are aesthetically pleasing especially under all-ceramic crowns, performs as well as dental amalgam in strength, better than amalgam in bond strength to dentine, and similar to tooth structure in hardness and fracture toughness [18].

Different types of resin composites are available on the market that can be used to build-up a core onto the prefabricated posts [19,20].

A self-cure or dual-cure resin composite may be used rather than separate luting cement for cementation of the post and the subsequent buildup. These composites may be bulk-filled because they do not require deep penetration with a curing light. Self-cure and dual-cure composites polymerize more slowly than light-cure materials, allowing the material to flow during polymerization contraction, and placing less stress on the adhesive bond [20,21].

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Table 1: Mean ± SD of Bond Strength (MPa) of all groups.

Group	Post surface treatment	Mean ± SD of bond Strength (MPa) of silane subgroups	Mean ± SD of bond Strength (MPa) of bond subgroups
Group C	No Treatment (Control)	10.9 ± 1.3	11.6 ± 1.5
Group PH	37% Phosphoric Acid Etching	11.3 ± 1.6	12.4 ± 1.9
Group A	Air abraded	14.3 ± 1.8	17.3 ± 0.8
Group H	H2O2 treatment	18.1 ± 2.3	20 ± 2.6

Group A Air abraded 14.3 ± 1.8 17.3 ± 0.8
Group H H_2O_2 treatment 18.1 ± 2.3 20 ± 2.6

Table 2: Summary of 2-way ANOVA for representation of interactions between fiber post surface treatment and type bonding system applied.

	Sum of Squares	df	Mean Square	F value	P
Corrected Model	873.95	7	124.85	37.26	0.001
Intercept	16776.52	1	16776.52	5006.98	0.001
Bonding system	61.77	1	61.77	18.43	0.001
Surface Treatment	793.30	3	264.43	78.92	0.001
Bonding System * TREATMEN	18.87	3	6.29	1.87	0.14
Error	241.24	72	3.35		
Total	17891.73	80			
Corrected Total	1115.20	79			

A number of studies particularly focused on the possibility of improving adhesion at the fiber post-composite interface through various treatments of the post surface [13,22]. Certain mechanical and chemical treatments of post surface such as sandblasting, airborne-particle abrasion and silane coupling have shown favorable results in terms of improving the bond strength between fiber posts and core resins [14,23,24]. Chemical treatments of the post-surface such as etching with 10% hydrogen peroxide for 20min or 24% hydrogen peroxide for 10min also proved to be effective in promoting adhesion between the post and composite core [20,25]. Additionally, adhesion of dual-cure resin composite to epoxy resin-based fiber posts was claimed to be improved when the post surface was treated with a dual cured bonding agent or was silanized [12]. Although, sandblasting and phosphoric acid etching are used to improve the bonding of fiber posts to resin composite core material, these surface pretreatments can damage the glass fibers and affect the post integrity. Hydrogen peroxide is one of the materials that can selectively dissolve the epoxy matrix without interfering with the glass fibers and can expose the fibers to be silanated.

The purpose of this in vitro study was to evaluate the push-out bond strength of a flowable resin composite core material to fiber post treated with different conditioning methods followed by either application of silane coupling agent or an adhesive system. The null hypothesis tested was that post surface conditioning protocols and the type bonding system used would not affect the interfacial bond strength between fiber posts and resin composite core material.

Materials and Methods

Forty Prefabricated glass fiber posts Parapost (Coltène AG 9450 Altstatten/ Switzerland) with a diameter of 1.4 mm were used in the study. Posts were divided into four groups, ten specimens each, according to the surface pretreatment performed.

Group C: no pretreatment was performed.

Group A: posts were air abraded using110 µm aluminum oxide particles for 5 s at 2.8 bar (0.28 MPa) from a distance of 1 cm.

Group PH: posts were immersed in 37% phosphoric acid gel for 60 s and rinsed with deionized water for 2 min.

Group H: posts were immersed in 24% hydrogen peroxide for 10 min.

All protocols were performed at room temperature. After treating the surfaces, the posts were rinsed with water for 30 s and air-dried.

Each group was then subdivided into two subgroups, five specimens each;

Subgroup A; Silane coupling agent (EspeSil; 3M Espe) was applied for 60 s. to the treated post surfaces.

Subgroup B; ONE-STEP adhesive system (ExciTE F DSC, Ivoclar Vivadent) was applied to the treated post surfaces.

For the core build-up procedure, the post was placed into the plastic tube; the remaining part of the tube was removed by the cutting machine (to obtain a standardized central position of the post). Multicore Flow (Ivoclar Vivadent) flowable dual-cured, core build-up resin composite was applied to the tube, and light-cured for 40s at 500mW/cm2 according to the manufacturer's instructions, using a halogen light curing unit (Optilux501;Kerr).The resin was always irradiated directly from the open upper side of the tube, through the post. All specimens were stored in distilled water for 24 hat 37 C. The non-tapered 5-mm portion of the posts were sectioned with the cutting machine (Isomet 4000; Buehler, USA) resulting in 5 specimens, each 1mm thick discs. Thickness of each disc with a digital caliper (Liaoning MEC Group, Mainland, China) for the micro push-out test, the specimens were mounted in a universal testing machine (Lloyd LRX; Lloyd Instruments, Fareham Hants, UK) with a custom made jig. The discs were loaded with a flat ended cylindrical plunger, 1.1mm in diameter, centered on the disc avoiding contact with the surrounding core surface, with a cross-head speed of 1.0mm/min. The maximum failure load was recorded in Newton (N) and converted into megapascals (MPa). Push-out bond strengths were calculated for each section by using the following formula: Deboned stress = debonding force (N)/A where: A= area of post/cement interface. Debond stress values were converted to megapascals. (MPa).

Statistical Analysis

Statistical analysis was performed using SPSS 11.0 software for Windows (SPSS Inc., Chicago, IL, USA). Bond strength data (MPa) were submitted to two-way ANOVA with the bond strength as the dependent variable and the bonding type (2 levels; silane and one step adhesive) and the corresponding surface treatments as the independent variables (4 levels; c, A, PH, H). Multiple comparisons were made using Tukey's post-hoc test. p-values less than 0.05 were considered to be statistically significant in all tests.

Results

The mean bond strengths, standard deviations, and group differences for the four different surface- treatment groups are shown in Table 1. In the study groups, the lowest bond strength was observed for phosphoric acid etching groups for both silane and adhesive treated subgroups (11.3 ± 1.6 MPa and 12.4 ± 1.9 MPa). No statistically significant difference was observed between the control groups and phosphoric acid etching groups where bond strength values were (10.9 ± 1.3 MPa and 11.6 ± 1.5 MPa) respectively. The highest bond strengths was observed for H_2O_2 treated group (18.1 ± 2.3 and 20 ± 2.6 MPa) for both silane and adhesive treated subgroups respectively. Air abraded group showed signification difference in bond strength values compared to H_2O_2 treated group for both silane and adhesive treated subgroups (14.3 ± 1.8 and17.3 ±.8 MPa). The 2-way ANOVA revealed a significant influence of fiber reinforced post surface treatment on the push out pond strength to resin composite core (Table 2). For C, PH, A and H groups, there were significant differences between the different surface treatments for two types of bonding used (p<0.05). Regarding the C and etched groups, there was no significant difference in bond strength (p< 0.05). When comparing bond strength (MPa) values dependent on the type of bonding used (silane vs. bonding), analysis of variance demonstrated no statistically significant differences (p< 0.05). The SEM studies revealed that the surface irregularities of the fiber root canal post corresponded to the results of the bond-strength study. The surface topography of posts was modified following treatment with H_2O_2, phosphoric acid etching and air abrasion compared to control group (Figure 1). The surface treatments with H_2O_2 dissolved the resin matrix of the posts and exposed the glass fibers of the posts. In addition, the exposed glass fibers were not damaged or fractured by the surface treatments. Post surface treatment with air abrasion increase surface area avialble for bonding compared to phosphoric acid and control group (Figure 1).

Discussion

In light of the thin-slice push-out bond strength results, the null hypothesis that there wouldn't be a significant difference between coupling agent and adhesive system in improving bond strength was rejected, while that for the core material to the fiber post bond strength using different conditioning protocols was accepted.

Push-out technique used in this study for testing the adhesion of fiber posts to composite resin core material was designed as a "thin-slice push-out test", since the specimens dimension was reduced for achieving a more uniform stress distribution. This method provides a better estimation of bond strength than the conventional shear test, as fracture occurs parallel with the bonding interface, which simulates the clinical conditions and therefore this test has been generally accepted for bond strength evaluation. Furthermore, this test method offered the opportunity to test five disc-shaped specimens from one Post [27].

To enhance the adhesion of resin composite to fiber reinforced composite post, many post surface treatment methods have been suggested. Among the methods, silanization is controversial about the efficiency of increasing bond strength. Silanization on FRC Postec Plus was significantly effective on the increase of bond Strength [27].

In the current study, higher mean bond strength values regarding the silane treated subgroups was measured for etching the epoxy resin surfaces of the post with hydrogen peroxide, The surface treatment of glass fiber posts with 24% hydrogen peroxide for 10 min significantly enhanced the bond strength due to its ability to dissolve the epoxy resin matrix used in each post, it also increased the surface roughness and exposed the fibers thus creating a better chemical bonding between silane and fiber post [29,30].The etching effect of hydrogen peroxide depends on its capacity to partially dissolve the resin matrix, breaking epoxy resin bonds through a mechanism of substrate oxidation [31].

In a study by Khamverdi et al. [32] the bond strength values of hydrogen-peroxide-treated posts were higher than the sandblasted posts. However, in other studies application of H_2O_2 had no significant effect on bonding strength between fiber post and composite core material [33,34].

Silanization of glass fibers with the silane and infiltration with a low-viscosity flowable resin composite, significantly enhanced the interfacial micromechanical bond strength. Silane improve the bonding of composite resins to porcelain by 25%. The use of silane solutions to improve the bond between new composite resin and existing composite is controversial. There are not many studies testing the use of silane solutions for bonding posts to root canal dentin. Silane improved the bonding between new composite and an existing fiber-reinforced composite framework, similar to the structure used in fiber posts [35].

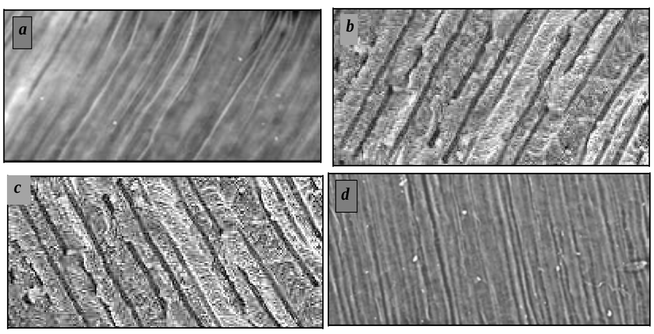

Figure 1: Scanning Electron micrographs showing the surface of fiber posts with different surface treatments. a) Control, b) Phosphoric acid etching, c) Air-blasted and d) H_2O_2 immersion.

In this study the surfaces of the fiber posts were airborne-particle abraded with 110-μm alumina particles at 2.8-bar pressure for only 5 seconds from a distance of 1 cm. This regimen did not produce visible changes in the form of the posts. Nevertheless, this mild form of airborne-particle abrasion resulted in a statistically significant increase the bonding strength of fiber post to composite core [37]. In another study, airborne-particle abrasion of the smooth post surface more than doubled its retentive strength [36].

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 [14]. Some authors believed that sandblasting modifies the epoxy resin matrix and creates a larger surface area for bonding [14,38,39].

However, sandblasting is considered as an aggressive pretreatment for fiber posts, because it significantly modifies the post shape [40].

For this reason it is claimed 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.

The result of this study is consistent with those of previous studies that reported that airborne-particle abrasion with alumina particles increased the surface area and enhanced the mechanical interlocking between the cement and the roughened surface of a post [41].

Phosphoric acid has been used for etching the tooth surfaces in concentrations ranging from 30 to50%. Generally, 37% phosphoric acid is preferred for acid etching the tooth surface [42]. In this study also, 37% phosphoric acid was used for conditioning the post surface. Acidic treatment of the post surface produced higher retention values than those recorded for the no-treatment controls. A similar result was reported in a previous study [14], in which a minimal increase in retention was achieved when the glass-fiber post surface was conditioned with the self-etching primer the roughness of the post surface produced by the acidic treatment may have been insufficient to attain strong mechanical interlocking between the cement and the post surface [31].

The bond strength values obtained with the surface pretreatment of fiber post with phosphoric acid was the least among the experimental groups, even though higher than the control group. This may be due to less removal of superficial layer of epoxy resin thereby leading to small amount of micromechanical retention.

Conclusion

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

1. Thin slice push-out bond strength of resin composite core material to fiber posts was affected by the surface treatments applied to the post surface.
2. Application of H_2O_2 before silanization increased the bond strength of resin composite core material to the fiber posts.
3. Silanization of the post surface could result in a slight improvement of the bonding strength of resin composite core material to fiber posts.

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