ORIGINAL ARTICLE

Influence of different surface treatments on push-out bond strengths of fiber-reinforced posts luted with dual-cure resin cement

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Abstract

Objectives: The objective was to evaluate whether fiber postsurface conditioning with air abrasion or erbium:yttrium-aluminum-garnet (Er:YAG) laser would influence the bond strength of dual-cure resin cement to the fiber-reinforced (FRC) posts.

Materials and Methods: Twenty-one FRC posts were divided into three groups according to surface treatment methods as follows: An untreated control group air abrasion with Al_2O_3 group, and Er:YAG laser treated group with 150 mJ parameter. Fiber posts were then built up to dual-cure resin cement. Eighteen specimens were set and sectioned perpendicularly along the long axis of the post using a saw. Two disks (thickness of 2 mm) were obtained from each specimen (n = 12). Remaining three posts were stored for scanning electron microscopic evaluation. Push out test was performed on the each specimen and the values were recorded as MPa. The data were analyzed using one-way analysis of variance and Tukey *post-hoc* tests ($P < 0.05$).

Results: The bond strength values for the groups were as follows: Control (15, 28 MPa), air abrasion group (19, 73 MPa), and Er:YAG group (17, 84 MPa). Air abrasion affected the bond strength significantly ($P < 0.05$).

Conclusion: Air abrasion attained higher bond strengths when FRC posts were luted to dual-cure resin cement. Additional studies should be designed with different types and parameters of laser devices to understand the effect of these devices on bond strength.

Key words: Air abrasion, erbium:yttrium-aluminum-garnet laser, fiber reinforced post, push-out

Date of Acceptance: 26-Jun-2015

Introduction

Posts are widely used to restore root canal treated teeth that have excessive loss of coronal tooth to obtain a core for the definitive restoration. Posts are selected as an alternative technique for casting metal post- and core-systems because of numerous superior advantages.[1,2] Reliable mechanical properties, such as lower modulus of elasticity similar to that of dentin, result in decreased incidence of root fractures.[3,4] Posttranslucence provides adequate polymerization between the post and the surrounding bonding material by allowing the light from the curing unit through the post and promotes high adhesion of the cementing system to the root dentin walls.[5] In addition, superior properties including biocompatibility, mechanical strength, resistance to corrosion, and optical effects allow more esthetic restorations using fiber-reinforced (FRC) posts.[6]

Despite all these advantages, fiber posts have several disadvantages. Debonding is one problem that causes

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Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/1119-3077.175962

failure at the post‑retained restorations.[7,8] Restorations performed with FRC posts fail due to displacement of the posts most frequently at the postadhesive junction.[9] FRC posts are composed of a polymer resin matrix that is usually epoxy resin that has a high degree of conversion and highly cross‑linked structures, reinforced by carbon, quartz, zirconia, glass, or silica fibers.[10,11] The polymer matrix in the structure of the FRC post is virtually unable to react with the monomers of resin cements.[12,13] Before the cementation process, optimal postsurface treatments could potentially improve the bond strength of the post and cement interface due to changes in the matrix of the fiber posts.[14]

Untreated fiber posts have a comparatively smooth surface area that restricts mechanical interlocking between the postsurface and the resin cement. Sandblasting with aluminum particles increases the surface roughness and surface area.[14] Air abrasion is used for FRC posts to remove the top layer of the resinous matrix. This technique creates micro‑retentive areas on the postsurfaces to improve the bond strength between the FRC posts and the resin cements.[15]

Another respected technique for surface treatment of dental materials is laser irradiation.[16] Lasers provide a relatively safe and easy means for altering the surface of materials, and change the wettability characteristics of ceramics and metals for improved adhesion and bonding.[17] During the past decade, the effectiveness of lasers has been investigated in the removal of tooth hard tissues and in the preparation of dental cavities.[18] Recently, among other laser systems, the erbium:yttrium‑aluminum‑garnet (Er:YAG) laser, emitted in a 2940 nm wavelength, has been frequently used in dental applications and to change the surface conditions of dental materials. However, there is no agreement in the literature that this system is the best surface conditioning method for obtaining optimal bond strength.[19] This laser system, associated with maximal absorption in water and well absorbed in hydroxyapatite, has been designed to remove dentin and the enamel structure effectively.[19]

The aim of this study was to investigate the effects of air abrasion and Er:YAG laser irradiation on the push‑out bond strengths of FRC posts and resin cement. The null hypothesis was that Er:YAG laser surface treatment and air abrasion method does not change the push‑out bond strengths of FRC posts and resin cement.

Materials and Methods

Twenty‑one radiopaque, translucent glass FRC composite posts (Rebilda Post, Voco, Cuxhaven, Germany) each with a 1.5 mm diameter were selected for this study. The surfaces of the fiber posts were cleaned with medicinal alcohol, dried according to the manufacturers' instructions, and distributed randomly into three groups, according to the type of surface treatment as follows:

- Group 1: No treatment
- Group 2: Air abrasion with 50 μm aluminum oxide was applied for 20 s at an operating distance of 10 mm from the postsurface, with 28 bar pressure. These specimens were washed with tap water for 10 s and air‑dried
- Group 3: 150 mJ, 10 Hz, 1.5 W Er:YAG laser irradiation for 60 s, 100 μs duration. The postsurfaces were treated using an Er:YAG laser (Doctor Smile Erbium and Diode laser, Lambda Scientifica S.r.l, Vicenza, Italy) at 2940 nm. The optical tip, which had a diameter of 400 μm, was used at an incidence angle of 45° under water cooling, 1 mm distant the postsurface. Eighteen posts were prepared for the push‑out test (n = 12). The remaining three posts were stored for the scanning electron microscopic evaluation.

Dual‑polymerizing resin‑based luting material (Variolink II; Ivoclar Vivadent AG) was then applied to the exposed postsurfaces using a stock metal ring for a standardized bonding area. Specimens were then light polymerized for 40 s with a light‑curing unit (Elipar FreeLight LED II, 3M ESPE Dental Products, St. Paul, MN) according to the manufacturer's instructions. An additional 40 s of light polymerization was performed to ensure optimal polymerization of the luting agent. After 24 h of storage in distilled water, each specimen was mounted on the holding device of a low‑speed saw (Isomet, Buehler, Lake Bluff, IL) and cut perpendicular to the long axis of the pos. Fiber posts have double tapers at the middle and apical parts of their design. The parallel sections of the posts were used to simplify calculation of the surface area. Two disks (2 mm thick) were obtained from each sample, and each group therefore consisted of a 12‑disk sample. Slices were examined with a stereomicroscope (Novex, Arnhem, Holland) at ×20 magnification to determine the surface area of the inner part of the slices.

Each specimen was subjected to a push‑out bond strength test using a universal materials tester (MicroTester, Instron, Norwood, MA). The test was performed at a cross‑head speed of 0.5 mm/min, with the load applied in the apical‑coronal direction until the post was dislodged [Figure 1]. The maximum load at failure was recorded in Newtons (N) and was converted to MPa by dividing the applied load by A, the bonded area. Because of the tapered postshape, the bonded area was calculated using the following formula:

$$\pi\ (R + r)\ h^2 + (R - r)^2$$

R and r represent the smallest and largest diameters, respectively, of the cross‑sectioned tapered post, and h represents the thickness of the section. The data were analyzed using one‑way analysis of variance and Tukey *post‑hoc* tests (P = 0.05).

The remaining posts from each group were mounted on a metallic stub, sputter coated with gold (Polaron Range SC7620; Quorum Technology, Newhaven, UK), and observed under a scanning electron microscope (EVO LS10, Zeiss, Oberkochen, Germany) at ×3000 magnification.

Results

The means and standard deviations of the push-out bond strength values are presented in Table 1. The highest push-out bond strength was observed in the air abrasion group (19.73 ± 2.72 MPa), and there was a significant difference when the group was compared to the untreated group (15.28 ± 3.39 MPa) ($P = 0.005$). In the Er:YAG laser group (17.8 ± 3.42 MPa), a higher bond strength value was observed than in the control group, but statistical analysis did not reveal any significant differences ($P = 0.144$). Standard error of the mean evaluation revealed that after air abrasion, the surface topography of the FRC posts appeared to be significantly more micro-retentive [Figure 2].

Table 1: Mean push-out bond strength values (MPa) and SDs

Groups	Mean±SDs	Statistical group*
Control	$15.28^{a}\pm3.39$	a
Air abrasion	$19.73^{b}\pm2.72$	b
Er:YAG 150 mJ	$17.84^{ab}\pm3.42$	ab

Same letters mean that the differences were not statistically significant. SDs=Standard deviations; Er:YAG=Erbium: Yttrium-aluminum-garnet

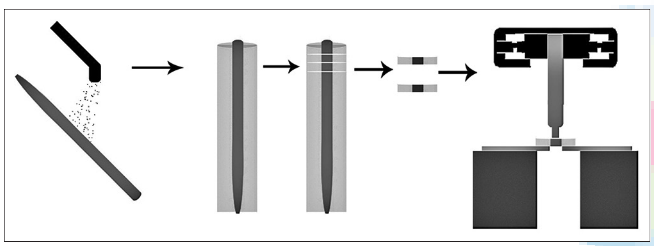

Figure 1: Schematic representation of the test procedure

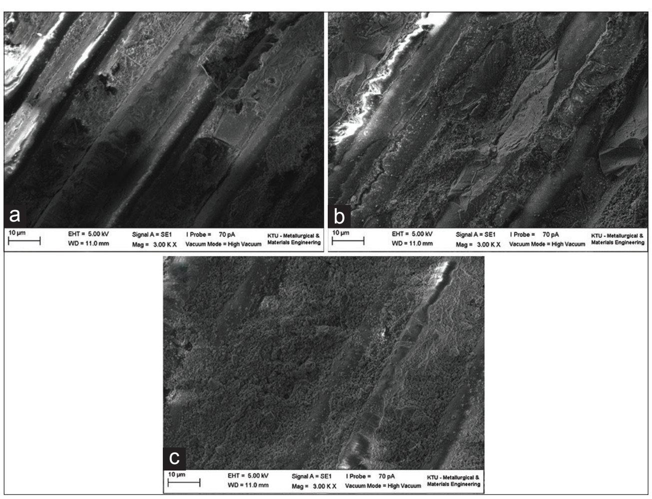

Figure 2: Scanning electron microscope images of the fiber postsurfaces after different treatments at a magnification of ×3000. (a) Untreated fiber postsurface. The postsurface appeared smooth with small porosities. (b) Fiber postsurface after air abrasion treatment. The postsurface appeared significantly rougher than that in the control group. (c) After 150 mJ erbium:yttrium-aluminum-garnet laser application on fiber postsurfaces which has slight differences

Discussion

In most clinical cases that include endodontically treated teeth restored with posts, cementation failure of the posts is observed.[20,21] Therefore, the bonding failure of FRC posts and dual-cure resin cement was evaluated in this study. We used a metal ring as the mold and posts with the same diameter to standardize the bonding surface area. Therefore, we intended to obtain adequate push-out bond strength values that may be clinically beneficial.

The aim of the current study was to investigate the effect of the Er:YAG laser on the bond strength of FRC posts to dual-cure resin cement. This study revealed that the Er:YAG laser used as postsurface treatment did not significantly affect the push-out bond strength at the present power setting. Therefore, the null hypothesis is rejected.

FRC posts are preferred compared to cast posts for esthetic coloration and favorable biomechanical properties in order to restore endodontically treated teeth.[22,23] Because of the modulus of elasticity is almost similar to that of dentin and resinous materials, optimal stress distribution and decreased risk of root fracture can be obtained.[22]

Various testing methods were advanced to assess the retention of adhesive posts. The push-out test used in the present study reflects clinical conditions compared with the pull-out test.[24] When compared with the Microtensile test, the push-out test has demonstrated more reliable values in measuring the bond strength of the adhered fiber posts. No premature failure occurred with the push-out test; however, in the microtensile technique, premature failures occurred frequently.[25] More homogenous stress distribution and lower data variability have been observed compared with the Microtensile test.[25,26] In addition, preparing the specimens and performing the test are easy; regional differences between root dentin levels can be evaluated with this method.[25,27] The push-out test is an important tool for evaluating fiber postbonding. Thus, we chose this method.

Epoxy resin is the main surface material covering the surface of FRC posts. Surface treatments that have been improved for natural substrates and restorative materials change the surface energy characteristics of posts, expose the fibers, and increase the surface area available for chemical bonding.[28,29] The spaces between these fibers provide additional places for micromechanical retention of resinous materials. This enhances the bond strength values.[14]

In previous studies, the authors reported that airborne-particle abrasion with aluminum oxide particles increased the surface area and the mechanical interlocking between the cement and the post.[30,31] In this study, the air abrasion technique produced significantly higher bond strength between the cement and the FRC post when compared with the untreated group without silanization.

Laser irradiation is the other technique for surface treatment of dental materials.[32] This system causes a rough and irregular surface similar to the effects that occur in acid etching.[33] Among the various laser types, the Er:YAG laser is highly recommended for application on the surfaces of dental materials.[34] In a previous study, the effects of different surface treatments in enhancing porcelain zirconia bonding were evaluated. According to the results of this study, sandblasting and laser irradiation methods increased the porcelain zirconia bond strength. The authors concluded that laser pretreatment might be an alternative to sandblasting for improving zirconia porcelain bonding.[35] An another study reveals that sandblasting and Er:YAG laser irradiation of the surface of the quartz fiber post before cementation provided a significant increase in bond strength between quartz fiber posts and resin cement.[36] Arslan *et al*.[16] investigated the effects of Er:YAG laser irradiation at different parameters and the sandblasting method on the push-out bond strength of FRC posts to composite resin cores. For artificial aging, the specimens were subjected to thermal cycling. They showed that irradiation by the Er:YAG laser at 450 mJ significantly affected bond strength. The other surface treatments did not reveal a significant difference. An another study demonstrate that surface treatments to the fiber posts; silica coating modified with Al_2O_3 particles, hydrofluoric acid etching and Er:YAG laser irradiation significantly affected the tensile bond strength of glass fiber posts to resin cement.[37] Tuncdemir *et al.*[38] evaluated the influence of postsurface treatments on the push-out bond strength of adhesively luted quartz fiber posts. The authors reported that the push-out test values did not vary significantly according to the surface treatments applied. In this study, Er:YAG irradiation did not affect the push-out bond strength values. However, the air abrasion technique significantly increased the bond strength values.

Further investigations conducted in different laser types and different parameters are required to evaluate the bond strength values of FRC posts.

In the limitations of this study, the 1.5 W Er:YAG laser irradiation did not increase the bond strength values significantly. Surface treatment with air abrasion resulted in significantly higher bond strength of the dual-cure resin cement to the FRC post.

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How to cite this article: Arslan H, Ayranci LB, Kurklu D, Topçuoglu HS, Barutcigil C. Influence of different surface treatments on push-out bond strengths of fiber-reinforced posts luted with dual-cure resin cement. Niger J Clin Pract 2016;19:218-22.

Source of Support: Nil, **Conflict of Interest:** None declared.