Original Article

Effect of different surface treatments on the bond strength of fiber posts to various core materials

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Abstract

Objective: The present study evaluated the effect of different surface treatments of fiber posts on the micro-push-out force between posts and various composite core materials.

Methods: A total of 80 fiber posts were divided into 16 groups according to the surface treatment and core material. Four different surface treatments were applied on fiber posts including Al_2O_3 sandblasting, CoJet sandblasting, ytterbium-doped fiber (YbPL) laser roughening, and control (no surface treatment). The core materials were Bis Core, Core Flo, Clearfil DC Core, and Clearfil Photo Core, which were applied in a transparent mold on the surface-treated posts. The light was applied for a total period of 120 seconds. Four 1-mm sections were obtained from each post-core structure. The micro-push-out test was then performed and the results were recorded in Newtons and converted to megapascals (MPa).

Results: The type of surface treatment ($P<0.001$) and core material ($P<0.001$) significantly affected the bond strength. The highest bond strength was found in the combined application of Al_2O_3 sandblasting and Core Flo material (132.84 MPa) and the lowest was observed in YbPL laser-treated posts combined with Bis Core material (59.46 MPa).

Conclusions: Among the core materials, Clearfil Photo Core showed the highest bond strength with no significant difference from the Core Flo material. Clearfil Photo Core or Core Flo may be preferred for clinical use. Among the surface treatments, sandblasting with Al_2O_3 showed the highest bond strength. *(J Dent Mater Tech 2023;12(2): 61-67)*

Keywords: Bond strength, Fiber post, Laser, Post and core, Resin composite

Introduction

Investigations on post materials have gained popularity in recent decades due to the increasing demand for aesthetic restorations and the need to enhance fracture resistance of endodontically treated teeth (1-3). These post materials are available in various forms, including metal, zirconium, and fiber posts (4). Among these options, fiber posts are widely favored for the restoration of endodontically treated teeth (5). They offer numerous advantages, such as a close elastic modulus to dentin (approximately 20 GPa), proper stress distribution, high success rate, and reduced probability of root fracture (6, 7).

Fiber posts are composed of fibers, such as carbon, quartz, silica, zircon, or glass, embedded within a resin-based matrix. The connection between the fibers and the matrix is typically facilitated by a coupling agent, often silane. Notably, the silica-based fiber post, known as Snow Post, possesses uniform radio-opacity, providing an advantageous feature for radiographic evaluations (8).

Establishing a reliable bond at the post and core material interface is important to ensure the clinical success of the restoration (9). The adhesion of composite core materials to the prefabricated post is affected by several factors, including the surface treatment of the post, the head design of the post, and the type of composite core material (5, 10, 11).

Surface treatments have become widely employed to enhance the quality of material adhesion by enabling chemical and micromechanical interactions between different components (12). Various surface treatments have been proposed to improve the adhesion of posts to composite resins in post-core restorations (10, 13, 14). Nevertheless, it is widely believed that the bonding of composite resin cores to fiber posts falls short when compared to dentin or enamel (15, 16). This limitation

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arises from the highly cross-linked polymers present in the matrix of fiber posts, which lack reactive functional groups, thereby restricting the chemical reaction between the composite resin and the exposed fibers of the post (13, 17, 18).

No data is available on using a ytterbium-doped fiber laser (YbPL) to increase the coupling between the fiber post and the composite core material. The present study aimed to determine whether different surface treatments affect the micro-push-out bond strength of fiber posts to various composite resins. The null hypothesis was that the type of surface treatment and core material will not affect the bond strength between the post and composite core.

Materials and Methods

Experimental groups and preparation of samples

A fiber-reinforced post (Snow Post 1.6, Kuraray, Japan) was selected for this study. The core materials used were Bis Core (Bisco, USA), Core Flo (Bisco, USA), Clearfil DC Core (Kuraray, Japan), and Clearfil Photo Core (Kuraray, Japan). The surface treatments included Al2O3 sandblasting (Bego, Germany), CoJet sandblasting (3M ESPE, Germany), roughening with a YbPL laser, and a control group with no treatment. The posts were divided into four main groups based on the surface treatments (n=20). Each group was further divided into four subgroups based on the core materials (n=5).

Surface treatments

The following surface treatments were applied to the posts:

Group 1 (Al_2O_3 sandblasting): Twenty posts were sandblasted for 10 seconds using 50 µm Al2O3 particles at a distance of 10 mm and a pressure of 2.8 bar. Sandblasting was performed perpendicular to the post surface. The posts were then washed for 10 seconds and dried for another 10 seconds (3).

Group 2 (CoJet sandblasting): In this group, twenty posts were sandblasted using an intraoral sandblasting device (Dento-Prep Microblaster; Ronvig Dental Mfg, Daugaard, Denmark) with 30 µm silica-modified Al2O3 particles. Sandblasting was applied perpendicular to the surface with a pressure of 3 bars from a distance of 10 mm for 15 seconds. The post surfaces were subsequently coated with a silane coupling agent (ESPE-Sil, Germany) and air-dried for 5 minutes.

Group 3 (YbPL laser): The posts were roughened using a YbPL laser (1,064 nm; Vision, Neukirchen, Germany) with 40 kHz frequency, 1 mJ pulse energy, and 100 ns pulse duration (ultra-short pulse). The laser was applied in non-contact mode with vertical and horizontal scanning of the post surfaces. The laser had an air-cooling system and was operated at a working distance of 17.8 mm.

Group 4 (Control): No treatment was applied to the post surfaces in the control group.

Application of core material

After each surface treatment, the core materials were bonded to the posts. A transparent plastic mold with a diameter of 6 mm and a height of 5 mm was used to form the core material around the post surface. The diameter of the embedded fiber post was the same in all groups. Each post was positioned vertically in the center of the circular plastic mold. Following the manufacturer's instructions, the core materials were applied in three incremental layers and polymerized with a light curing device (Castellini, Italy) after each layer, for a total period of 120 seconds. Once the process was completed, the transparent mold was removed.

From each sample, four disc-shaped sections with a thickness of approximately 1 mm were obtained using a rotary cutting disc (Diatech 910D; Coltene/Whaledent AG) under running water. A total of 20 sections were obtained from five posts per subgroup. The thickness of each section was measured using a digital caliper (Mitutoyo, Tokyo, Japan).

Push-out test

Push-out testing was performed using a universal testing device (Testometric Micro 5000, High Wycombe, UK). Each section was placed on a custom-made stainless-steel base in the lower part of the device. A push pin with a diameter of 0.8 mm was installed in the loading cell of the test machine. The pin was placed at the center of the post so that the force was applied to the post without forcing the core material. A constant load was applied to each section at a speed of 1 mm/min. The peak force value was measured during post-segment extrusion from the section. The force was recorded in Newtons (N) and converted to megapascals (MPa).

Statistical analysis

The obtained data were analyzed using MedCalc statistical software version 12.7.7 (MedCalc, Ostend, Belgium). The ample size was calculated as 320 for the total sample (G-Power, version 3.1.9.4) using the following parameters: effect size = 0.25, $\alpha = 0.05$, power = 0.80, and the number of groups = 16.

As the variables did not show a normal distribution according to the Shapiro-Wilk test (p>0.05), the Kruskal-Wallis test was used to assess the effects of surface treatment and core material on the bond strength to fiber posts. Dunn's multiple comparisons test was performed to determine differences between groups. A level of p<0.05 was considered statistically significant.

Results

Evaluation of micro-push-out results

The micro-push-out test results revealed notable variations in bond strength (Table 1). The combined application of Al2O3 sandblasting and Core Flo material exhibited the highest bond strength (132.84 MPa), whereas the lowest bond strength was observed with the use of YbPL laser and Bis-Core material (59.46 MPa).

Statistical analysis demonstrated a significant difference among the groups regarding the surface treatment method (P<0.001; Table 2). The median bond strength of the Al2O3 Sandblasting group (124.55 MPa) was the highest among the surface treatment groups (Table 2). Dunn's pairwise comparisons revealed significant differences between Al2O3 sandblasting and CoJet sandblasting (P=0.019), Al2O3 sandblasting and control (P=0.009), as well as Al2O3 sandblasting and YbPL laser (P<0.001) groups.

Table 1. Mean, standard deviation (SD), median (Med), minimum (Min), and maximum (Max) values obtained as a result of the micro-push-out test in the study groups

Core materials	Surface treatment	Mean±SD	Med	Min-Max
Bis Core	Control (No surface treatment)	104.68±26.3	100.14	63.3-162.69
Bis Core	Al_2O_3 sandblasting	112.77±35.37	113.11	55.62-196.24
Bis Core	CoJet sandblasting	99.24±31.61	110.4	48.13-170.79
Bis Core	YbPL laser	68.4±23.65	59.46	35.58-119.84
Core Flo	Control (No surface treatment)	114.28±32.98	112.41	62.55-182.31
Core Flo	Al_2O_3 sandblasting	133.37±28.45	132.84	51.97-175.66
Core Flo	CoJet sandblasting	122.35±25.79	119.45	72.61-194.25
Core Flo	YbPL laser	106.62±25.44	106.29	50.14-153.11
Clearfil DC Core	Control (No surface treatment)	109.45±24.14	109.64	64.86-152.08
Clearfil DC Core	Al_2O_3 sandblasting	116.21±25.86	116.53	63.04-177.13
Clearfil DC Core	CoJet sandblasting	103.35±23.79	100.55	53.44-146.4
Clearfil DC Core	YbPL laser	107.05±31.65	101.07	51.47-175.61
Clearfil Photo Core	Control (No surface treatment)	120.34±34.95	119.76	57.06-208.87
Clearfil Photo Core	Al_2O_3 sandblasting	135.51±41.74	128.41	80-258.33
Clearfil Photo Core	CoJet sandblasting	123.11±30.22	125.33	67.37-188.29
Clearfil Photo Core	YbPL laser	130.53±30.36	132.07	62.59-166.21

Table 2. Mean, standard deviation (SD), median (Med), minimum (Min), and maximum (Max) values of micro-push out test as a result of different surface treatments

Surface treatment	Mean±SD	Med	Min-Max
Al_2O_3 sandblasting	124.47 ± 34.32	124.55^b	51.97-258.33
CoJet sandblasting	112.01 ± 29.58	113.53^a	48.13-194.25
YbPL laser	103.15 ± 35.43	101.83^a	35.58-175.61
Control (no surface treatment)	112.19 ± 29.93	109.64^a	57.06-208.87
P-value	<0.001		

*The groups that have been defined by different letters indicate statistically significant differences at P<0.05.

Table 3. Mean, standard deviation (SD), median (Med), minimum (Min), and maximum (Max) values of micro-push out test as a result of different core materials

Surface treatment	Mean±SD	Med	Min-Max
Bis Core	96.27 ± 33.58	93.53^{a}	35.58-196.24
Core Flo	119.16 ± 29.52	$118.27^{c,d}$	50.14-194.25
Clearfil DC Core	109.02 ± 26.46	107.21^{b}	51.47-177.13
Clearfil Photo Core	127.37 ± 34.5	125.13^{d}	57.06-258.33
P-value	<0.001		

*The groups that have been defined by different letters indicate statistically significant differences at P<0.05.

The Kruskal-Wallis test confirmed that the type of core material significantly influenced the bond strength (P<0.001; Table 3). Clearfil Photo Core exhibited the highest median bond strength (125.13 MPa), whereas Bis Core had the lowest median bond strength (93.53 MPa) among the core materials (Table 3). Dunn's pairwise comparisons highlighted statistically significant differences between Bis Core and Clearfil DC Core (P=0.022), Bis Core and Core Flo (P<0.001), Bis Core and Clearfil Photo Core (P<0.001), Clearfil DC Core and Core Flo (P=0.031), as well as Clearfil DC Core and Clearfil Photo Core (P<0.001). No statistically significant difference was found between Clearfil Photo Core and Core Flo (P=0.162).

Examining different surface treatments within each core material revealed no significant difference when Clearfil DC Core or Clearfil Photo Core were utilized. However, for Bis Core and Core Flo materials, the type of surface treatment significantly impacted bond strength (P<0.05). Dunn's pairwise comparison tests indicated that the combination of Bis Core and YbPL laser-treated posts (59.46 MPa) exhibited significantly lower bond strength than other Bis Core groups (P<0.05). Furthermore, the bond strength of Core Flo material bonded to Al2O3 Sandblasted posts (132.84 MPa) was significantly higher than the bond strength of Core Flo specimens bonded to YbPL laser-treated or control posts.

Evaluation of scanning electron microscope (SEM) images

The SEM image of the untreated, control sample is presented in Figure 1A. The CoJet application showed the least damage on the post surface (Fig 1B). Comparatively, the Al2O3-treated post surface displayed increased roughness and fiber destruction (Figure 1C). On the YbPL laser-treated post surface, there were evident fiber breaks and deep resin losses (Figure 1D).

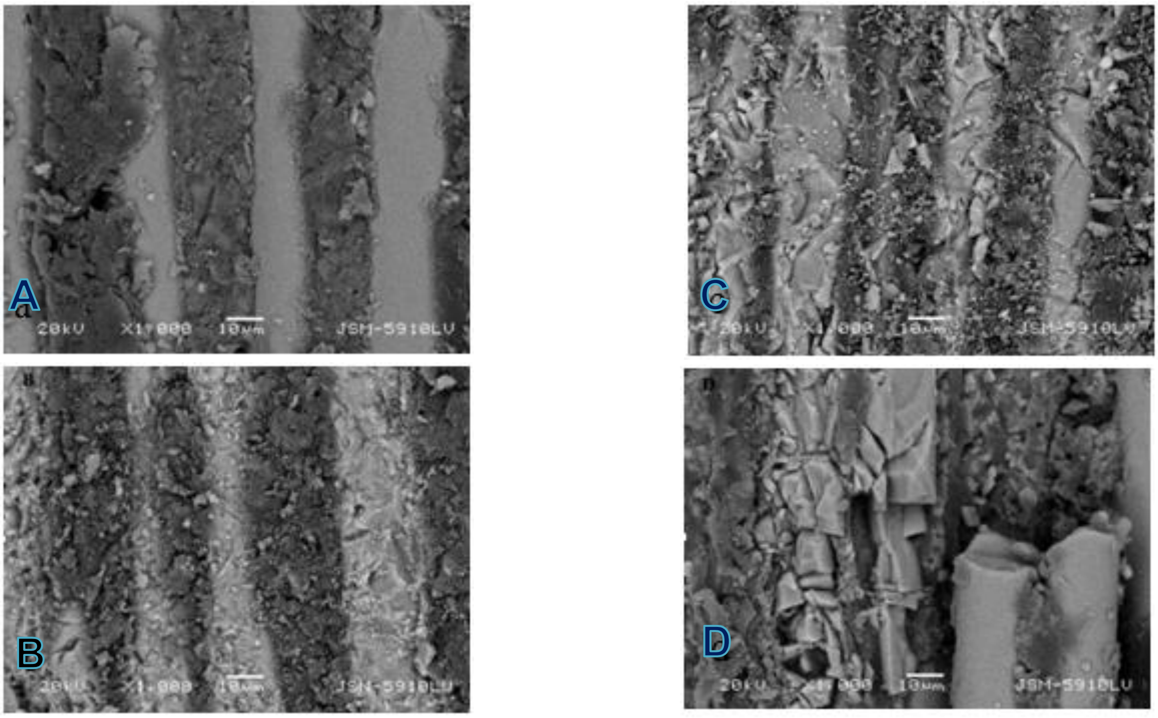

Figure 1. SEM images of post surfaces after surface treatment at X1000 magnification A= Control group, B= CoJet Sandblasting, C= Al_2O_3 Sandblasting, and D=YbPL Laser

Discussion

Although the connection between the post and dentin in the root canal is believed to be the weakest point of the restoration, the connection between the post and the resin core system is also important to provide long-term success (19). This study aimed to investigate the influence of different surface treatments on the micro-push-out bond strength between the posts and various core materials. The null hypothesis that "the type of surface treatment and core material will not affect the bond strength between the post and the composite core" was rejected due to significant differences between the groups.

The micro-push-out test was employed to evaluate the bond strength between the post and core materials. This method allows force application parallel to the post-core connection, providing more accurate results that reflect clinical conditions (10, 20). Additionally, this test enables obtaining multiple samples in 1- or 2-mm-thick sections from a post (10). In the micro-push-out test, micro bonding is achieved due to surface roughness, and macro bonding results from friction (21). In this study, 1 mm sections were obtained to eliminate the influence of macro bonding due to friction and find only the bonding due to surface treatment and core material.

Regarding the surface treatments, sandblasting with Al2O3 particles yielded the highest bond strength among the tested methods. Similarly, Cekic-Nagaş et al. (10) reported that Al2O3 sandblasting and surface treatment with hydrofluoric acid (HF) significantly improved the micro-push-out values of fiber posts. Archana et al. (17) found that sandblasting has a superior effect than silanization in increasing the bond strength of the glass fiber post to the core material. Moreover, it has been observed that sandblasting can restore the bond strength between the fiber post and resin composite after saliva contamination (22). Alshahrani et al. (23) found that both sandblasting and HF acid resulted in significantly higher bond strength of glass-fiber posts to composite resin core material as compared to hydrogen peroxide and control (no treatment) groups. However, there remains controversy regarding the efficacy of surface treatments in enhancing bond strength and clinical performance of fixed prostheses, as some in vitro studies reported no alterations in fixed prosthesis strength with silane, HF acid, sandblasting, and hydrogen peroxide compared to no surface treatment (24-26).

In the present study, the YbPL laser showed significantly lower micro-push-out bond strength than other groups. This finding is supported by the SEM images, which demonstrated severe damage to the post surface and resin matrix caused by the YbPL laser. Similarly, a meta-analysis study conducted by Davoudi et al. (24) reported that Er:YAG and Er, Cr:YSGG laser-irradiated fiber posts did not exhibit superior bond strength values compared to control groups.

Different types of composite resins that are currently available on the market can be used to form the core of the fiber post. Relatively hard self-cure resins will have the advantage of providing stable support for the restoration. On the other hand, more elastic composites, such as fluid and light-activated materials, are typically simpler to work with and better integrated with the fiber post surface, resulting in fewer bubbles or gaps in the abutment (27,28). In the literature, it is seen that there are not enough studies with different composite core materials, and all of the composites used as core materials were not specially produced for build-up (10, 24). We used four different composite resins in this study that were specially produced for core production. Clearfil Photo Core material showed the highest bond strength value in this study. It has been demonstrated that silane application to the post surface increases the bond strength between the post and core material (29). The higher bond strength of Clearfil Photo Core may be attributed to the fact that it is a hybrid composite core material containing silanized silica and silanized barium glass fillers (30). Furthermore, Clearfil Photo Core has a heavy consistency whereas other core materials used in this study are in fluid consistency. This may also play a role in the higher bond strength values observed in the Clearfil Photo Core material.

Although no significant difference was found among the subgroups of Clearfil Photo Core (control, Al2O3 sandblasting, CoJet sandblasting, and YbPL laser), it exhibited an overall higher bond strength than other core materials (Bis Core, Core Flo, and Clearfil DC Core). Therefore, we can conclude that the type of core material is more important than the surface treatment in terms of achieving optimal bond strength. Further studies investigating different core materials and examining the clinical durability of posts after surface treatments are recommended.

Conclusions

Based on the findings of the present study, the following conclusions can be drawn:

1- Among the core materials, Clearfil Photo Core showed the highest bond strength, however, no significant difference was observed between Clearfil Photo Core and Core Flo material. Clearfil Photo Core or Core Flo may be preferred for clinical use.

2- Sandblasting with Al_2O_3 showed the highest bond strength among the surface treatments. The lowest bond strength was observed in posts treated with YbPL laser, in which the post surface was damaged severely.

Conflict of interest

The author declares no conflicts of interest.

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