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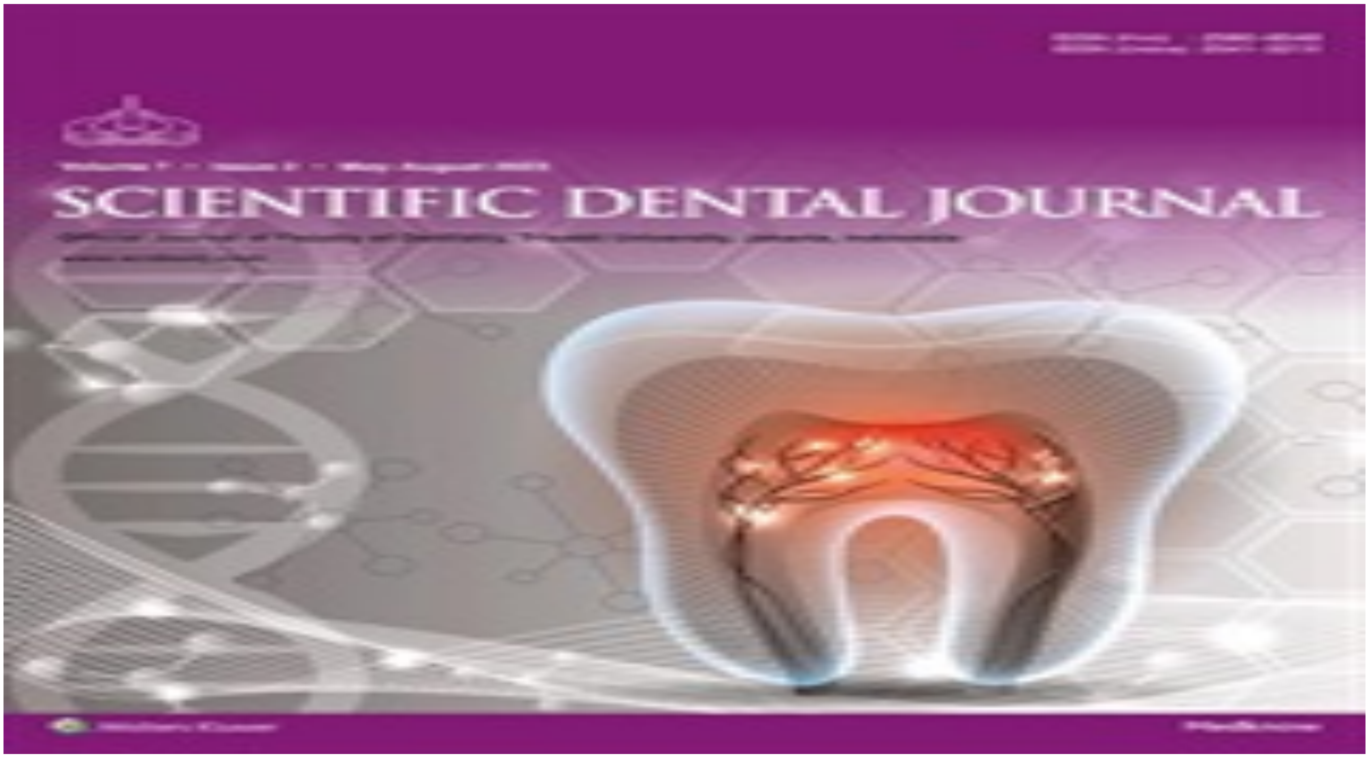

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Original Article

The Effect of Surface Treatment and Post-Length on Fiber Post-Bond Strength

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ABSTRACT

Background: Endodontically treated teeth with extensive loss structure may require a post. Fiber post is made of a resin polymer matrix held by epoxy resin, which has a high conversion rate and high cross-linking, which may not interact with the monomer of resin cement that can reduce the bond strength that may cause post-debonding, which is a common failure of fiber post. Post-surface treatment and post-length are factors that affect post-bond strength. **Objective:** This study aims to determine the effect of surface treatment on fiber post and post-length on the bond strength of fiber post. **Materials and Methods:** Thirty mandibular premolars were selected, decoronated 15 mm from the coronal to the apical region, and then subjected to root canal treatment, obturation, and post-preparation. The samples were initially divided into two groups; each was assigned to a specific post-length; then, each group was randomly divided into a negative control group, air abrasion group, and laser group, for a total of six groups (n = 5). Self-adhesive resin cement is used for post-cementation. Self-adhesive resin cement is used for post-cementation. The evaluation of fiber post-bond strength in this study was evaluated with the pull-out test using a universal testing machine at a speed of 0.5 mm/min. Data were analyzed by two-way ANOVA and Tukey's test. **Results:** The air abrasion group showed a higher bond strength ($P < 0.05$) compared with the control and Er:Cr:YSGG laser groups. No significant difference in bond strength was observed between the control and Er:Cr:YSGG laser groups with both post-lengths. Moreover, post-length had no effect on bond strength, and no significant interaction was found between surface treatment and post-length. **Conclusion:** In this study, the bond strength was higher with surface treatment by air abrasion. Post-length had no impact on bond strength.

KEYWORDS: *Air abrasion, bond strength, Er:Cr:YSGG laser, fiber post, post-length, surface treatment*

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BACKGROUND

Endodontically treated teeth with extensive loss of tooth structure in excess of 50% require intraradicular retention, such as posts with metal cores or prefabricated posts for retention.[1] The use of prefabricated fiber posts demonstrates a high success rate in terms of treatment time, cost, and aesthetics.[2,3] Moreover, these posts allow for cementation with resin cement materials, which improves physical and chemical retention.[4] Although they offer several advantages,

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fiber posts may also fail. Debonding is the main concern with fiber posts apart from post-fracture, core fracture, and root fracture.[5] Debonding is indeed one of the major disadvantages of post-restoration. Fiber posts consist of a resin polymer matrix usually held together by an epoxy resin. Epoxy resins exhibit a high conversion rate and high cross-link density. Preventing fiber posts from interacting with the monomers of cement resin.[6]

Post-retention is influenced by the design, length, and diameter of posts and by surface treatment. A study found that the retention of titanium posts was influenced by post-length more than by post-diameter.[7] In another study, the 2/3 fiber post-length of root canal showed a significantly higher bond strength compared to 1/2 and 1/4 fiber post-length of root canals. The bonding strength of fiber posts with different lengths and the fiber post-group with length 2/3 of the root canal was significantly better than the fiber post-group with length 1/2 and 1/4 root canals.[8]

As mentioned above, post-retention is also influenced by surface treatments. A surface treatment removes the epoxy resin layer of posts and exposes the fibers.[10] Although some surface treatments, such as etching and treatment with hydrogen peroxide, had no effect on the bonding strength of fiber posts to a resin surface,[9] other surface treatments, such as air abrasion, are worth investigating. Air abrasion can produce a rough surface, which results from the collision of abrasive particles at high speed. In this treatment, adhesion is achieved through the removal of the resin matrix layer, resulting in microscopic retention on the surface of a post.[11] However, this technique is considered quite aggressive because it can change the shape and density and reduce the strength of a fiber post. Moreover, treatment outcomes may be influenced by treatment time, pressure, distance, and particle size.[12] Alumina oxide particles measuring 30–50 µm are widely used for surface treatment, and the latter produces better results than the former.[11]

Meanwhile, laser technology has found new applications in dentistry, where its use has been growing. A laser can be used for diagnosis, cavity preparation, polymerization, caries prevention, and dentin desensitization; it can also be used as an alternative for etching and can be applied in CAD/CAM technology.[13] Laser has good handling properties as it does not contact surfaces mechanically. Depending on its strength and wavelength, the light energy from a laser can change the chemical and physical structure of a surface.[14] In a study, the treatment of the post-surface using Er:YAG laser with 1.5 W output power (150 mJ and 10 Hz) for 60 s could remove the epoxy resin layer without damaging the fibers in the post.[4]

This study aims to determine the effect of different surface treatments and post-lengths on the bond strength of fiber posts.

Materials and Methods

This laboratory-based experimental study aims to investigate the effect of different surface treatments and post-lengths on the bond strength of fiber posts. Fiber posts measuring one-half and two-thirds the length of the root canal (denoted hereafter as fiber posts with 1/2 post-length and 2/3 post-length, respectively) were subjected to surface treatments using air abrasion and laser Er:Cr:YSGG. A total of 30 mandibular premolars with inclusion criteria of healthy tooth, fully formed root apex, single and straight canal were selected, evaluated, and decoronated 15 mm from the coronal to the apical region, whereas exclusion criteria were root canal treated, crown-root fracture, calcification, resorption and any anomalies of crown-root [Figure 1].

Root canal exploration was performed using a K-file #10 (Dentsply-Maillefer, Ballaigues, Switzerland); the file was inserted into the canal until it reached 1 mm shorter from the apical foramen, obtaining a working length of 14 mm [Figure 2].

Biomechanical preparation was performed with ProTaper Next files from X1 to X5 (Dentsply-Maillefer) at 250 rpm. The root canals were irrigated with 5 mL of 5.25% sodium hypochlorite for the use of each file and with 5 mL of 17% ethylenediaminetetraacetic acid to remove the smear layer; 5 mL of distilled water was used for the final irrigation. The root canals were dried using paper points (Dentsply-Maillefer) and then obturated with gutta-percha points and a resin-based sealer (AH-plus, Dentsply-Maillefer). The samples were stored for 7 days at 100% humidity level and 37°C, and the root canal filling material was removed [Figure 3]; a precision drill (Dentoclic, Itena) was used to obtain filling materials measuring two-thirds and one-half the length of the root canal.

The samples were randomly assigned to the 1/2 post-length or 2/3 post-length group; the posts obtained from each group were randomly assigned into control, air abrasion, and laser Er:Cr:YSGG groups. In the two air abrasion groups (i.e., 1/2 and 2/3 post-lengths), the posts were treated with 50 µm aluminum oxide particles and 2 MPa air pressure, which were delivered from a tip distance of 20 mm and from a 90-degree angle relative to the object [Figure 4]. The treated posts were subsequently soaked in water, subjected to ultrasonic

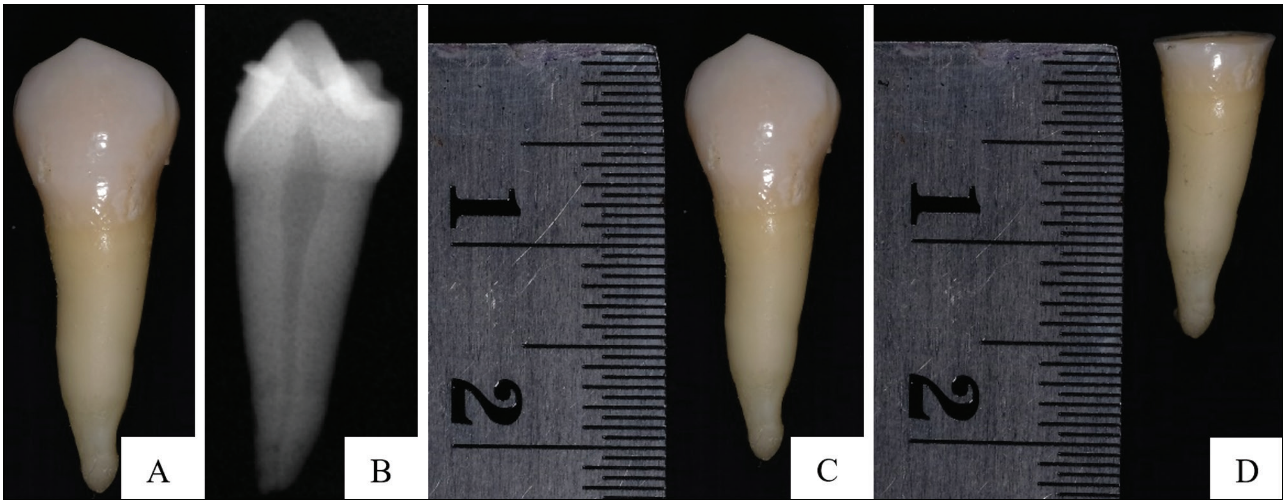

Figure 1: (A) Criteria of sample; (B) radiograph confirmation; (C) tooth length determination; (D) decoronization of sample

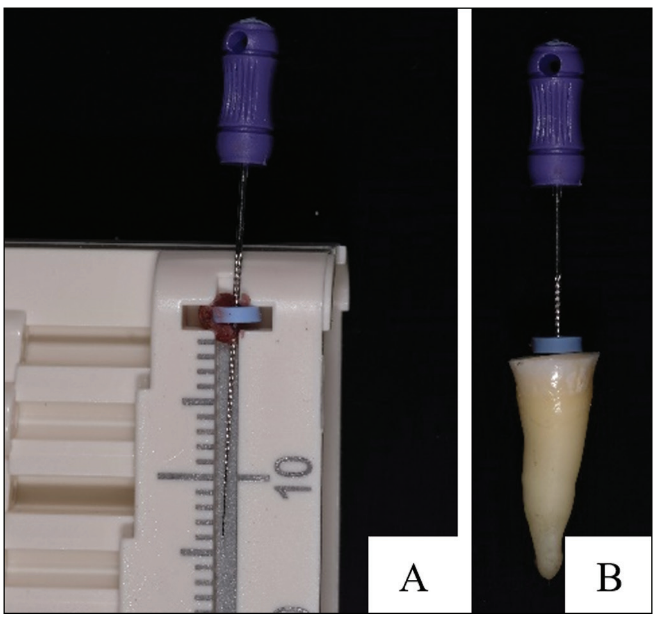

Figure 2: (A) Determination length of k-file; (B) working length determination

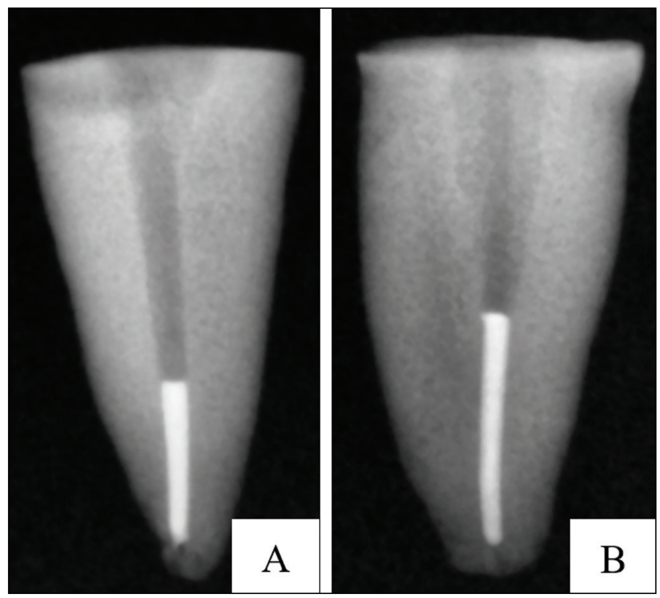

Figure 3: (A) Gutta percha removal of 2/3 root length; (B) Gutta percha removal of 1/2 root length

cleaning to remove any adhered particles, rinsed with alcohol, and then dried.

The posts in the laser Er:Cr:YSGG groups [Figure 5] were treated with 1.0 W laser power, 2780 nm wavelength, and 20 Hz frequency with a pulse duration of 150 s. A Z6 tip with a diameter of 600 µm delivered the laser energy, along with 10% water and 15% air, from a tip distance of 2 mm at 90° relative to the study object for 30 s to cover all surfaces.

The root canal was rinsed with distilled water using a syringe, dried with paper points, and then filled with resin cement using a needle tube. The post from each group was then inserted with light pressure into the root canal, followed by irradiation with curing light for 40 s. The samples were kept in distilled water for 24 h. A pull-out test was subsequently carried out with a universal testing machine using specialized tools for mounting the posts [Figure 6]. A pull-out speed of 0.5 mm/min was applied until the posts were released from the root canal.

Results

The air abrasion group with 2/3 post-length demonstrated the highest bond strength (15.11 ± 0.95 MPa), whereas the laser Er:Cr:YSGG group with 1/2 post-length showed the lowest bond strength (11.19 ± 0.58 MPa) [Table 1].

The Shapiro–Wilk test results showed a normal data distribution for the air abrasion, laser Er:Cr:YSGG, and control groups for both post-lengths ($P \geq 0.05$).

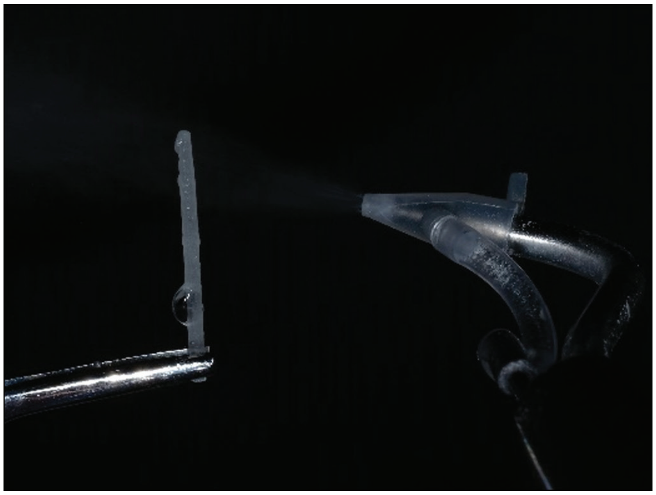

Figure 4: Fiber post surface treatment with air abrasion

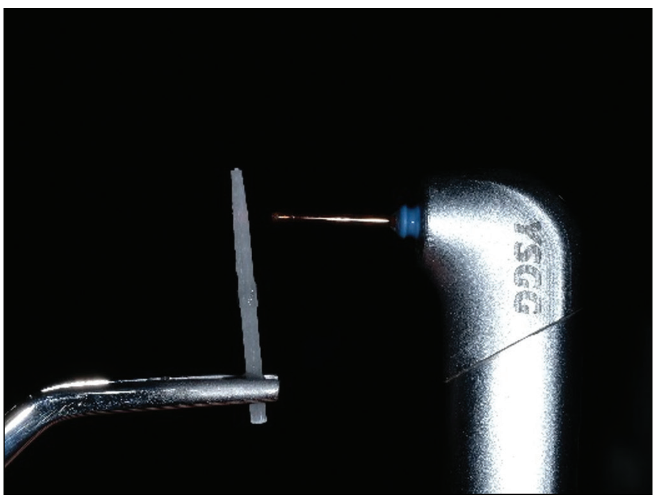

Figure 5: Fiber post surface treatment with laser Er:CR:YSGG

The two-way ANOVA results showed that there was a significant difference between post-length and surface treatment ($P < 0.05$). However, the combination of post-length and surface treatment had no significant effect on bond strength. The Tukey test results [Table 2] showed a significant difference in bond strength between the air abrasion group with 2/3 post-length and the control group with 2/3 post-length ($P < 0.05$). A significant difference in bond strength was also observed between the air abrasion, control, and laser Er:Cr:YSGG groups with 1/2 post-length ($P < 0.05$). Moreover, the bond strength of these groups did not significantly differ from that of their counterparts (with 2/3 post-length).

Discussion

The success of a dental treatment depends not only on root canal treatment but also on the restoration of missing tooth structures. An ideal root canal post-exhibits a modulus of elasticity, compressive strength, flexural strength, and thermal expansion that are similar to those of dentin and thus allow for uniform pressure distribution, preventing root fracture.[15,16] Fiber posts have been greatly improved in terms of aesthetics, mechanical properties, and attachment. Some of their advantages include strong resistance, low modulus of

Table 1: The mean value and standard deviation of fiber post-bond strength

Group	*N*	Mean ± SD (MPa)
Control 1/2 post-length	5	12.09 ± 1.87
Control 2/3 post-length	5	13.24 ± 0.87
Air abrasion 1/2 post-length	5	14.66 ± 0.72
Air abrasion 2/3 post-length	5	15.11 ± 0.95
Laser Er:Cr:YSGG 1/2 post-length	5	11.19 ± 0.58
Laser Er:Cr:YSGG 2/3 post-length	5	12.57 ± 1.33

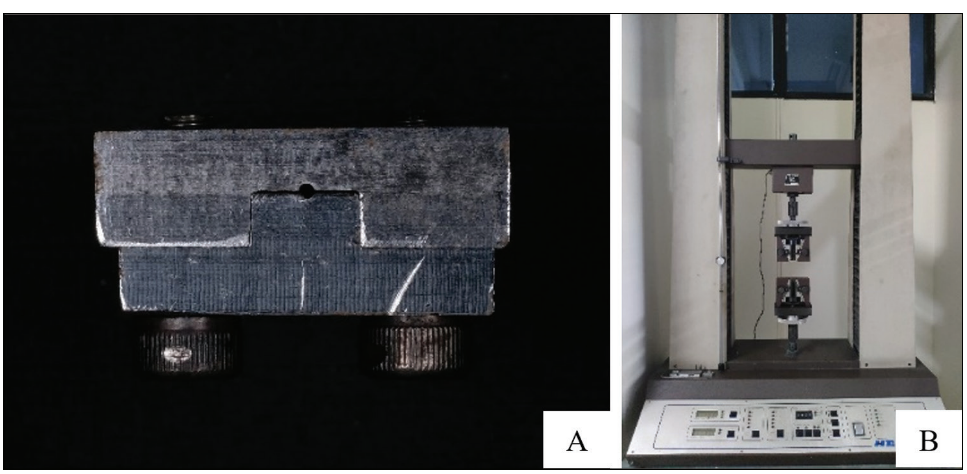

Figure 6: (A) Artificial tools; (B) Universal testing machine

Table 2: Post-hoc with Tukey test of fiber post-bond strength

Group		Control 1/2 post-length	Control 2/3 post-length	Air abrasion 1/2 post-length	Air abrasion 2/3 post-length	Laser Er:Cr:YSGG 1/2 post-length	Laser Er:Cr:YSGG 2/3 post-length
Control 1/2 post-length	*P* value	-	0.617	0.018*	0.040*	0.814	0.984
Control 2/3 post-length	*P* value		-	0.392	0.139	0.088	0.937
Air abrasion 1/2 post-length	*P* value			-	0.988	0.001*	0.078
Air abrasion 2/3 post-length	*P* value				-	0.000*	0.020*
Laser Er:Cr:YSGG 1/2 post-length	*P* value					-	0.425
Laser Er:Cr:YSGG 2/3 post-length	*P* value						-

elasticity, nontoxicity and inertness, easy removal in case of failure, ability to conduct polymerization light, and attachment to the root canal, thereby reducing functional and parafunctional pressure in the root canal.[17]

A fiber post-consists of an epoxy polymer matrix that is cross-linked to bind the post-fibers. The post-bond strength in a root canal can be improved through chemical bonding between a post and composite resin using silane coating and through surface roughening using air abrasion and acid etching or the combination of these two techniques. There is no standard protocol for the treatment of fiber posts.[17]

In this study, post-bond strength was assessed using the pull-out test, which can readily compare the stability of posts. Compared with the push-out test, the pull-out test allows for better pressure distribution and is more suitable for measuring post-retention in root canals. However, it requires a high number of posts and is costly.[19] The pull-out test involves a shear stress that is similar to clinical conditions, and it allows for a more uniform pressure distribution for bond strength measurement between a post and root dentin.[20,21] Moreover, it is more suitable than the push-out test for measuring post-strength in root canals.[22] This study was carried out *in vitro* and made as close as possible to the clinical situation.

The results of the SEM analysis showed that the fiber post in the air abrasion group gave a rougher surface than the control and laser groups. Fiber post-surface treatment using 50 µm alumina oxide showed a rough post-surface and partial loss of the epoxy resin.[23]

Silane coupling agents are organic and inorganic compounds that can form bonds between organic and inorganic matrices by increasing the surface tension, creating chemical bridges with OH-containing substrate. However, the use of silane in posts has been found to result in low bond strength. Previous push-out and retentive test results showed that the use of silane alone does not increase post-bond strength.[17,24]

This study compared the effect of post-length on the bond strength of fiber posts. The standard post-length used for intraradicular posts is 2/3 root length and corresponds to clinical crown length or greater. Braga reported that longer posts, either metal or fiber posts, exhibit greater bond strength than shorter posts.[25] Macedo explained that with increased post-length, the contact surface area between the cementing material and the root surface is also increased, resulting in greater bond strength.[26] However, the above findings contradict the present results, showing no significant difference in bond strength between the posts with 1/2 post-length and those with 2/3 post-length. Similarly, Webber *et al*. found no difference in the strength of fiber posts measuring 14 and 10.5 mm. Thus, shorter fiber posts may be used when the remaining roots are insufficient.[27] The above finding may be attributed to the bond strength being highest in the cervical region. The dentinal tubules in the cervical region have larger diameters than those in the apical region; thus, cleaning in the apical third is more difficult.[28]

Air abrasion or airborne particle abrasion with aluminum oxide is a fine surface treatment applied to achieve mechanical retention. Currently, air abrasion is used to roughen the surfaces of ceramic or composite restorations to increase bond strength.[29]

The fiber posts used in this study contain of 80% parallel fibers and 20% epoxy resin. This composition prevents the formation of mechanical interlocking bonds between a post and cement surfaces.[6,18] Air abrasion can be used to increase the surface area and promote mechanical interlocking between a cementing material and a post.[30] The ability of air abrasion to increase bond strength is influenced by the handpiece tip distance, pressure, and treatment duration. Arslan reported that a distance of 10 mm, a pressure of 2.8 bar, and a treatment time of 20 s could roughen a post-surface, increasing the bond strength. Another influencing factor is the handpiece angle. In this study, 90° was chosen because it did not cause damage to the fiber surface compared with the 45°angle. Note that damages in the surfaces of fiber posts can reduce bond strength.[30] Moreover, the size of aluminum oxide particles affects the surface roughness of fiber posts. Kulunk *et al.* reported that 50 µm aluminum oxide particles produced a significantly rougher surface than the 30 µm-sized particles.[11] Thus, the former was used in this study. As regards treatment time, Maroulakos *et al*. reported that the duration of the air abrasion treatment to not damage the fiber post-surface should not exceed 2 s/mm^2.[31]

In this study, the air abrasion group exhibited a significantly stronger bond strength than the control and laser Er:Cr:YSGG groups. These findings are consistent with Tuncdemir's results, showing that air abrasion produced a rougher post-surface and greater bond strength compared with the control and femtosecond laser treatment.[18] Alshahrani *et al.* examined the bond strength between fiber posts and post-cores made from composite materials, and they also found that air abrasion could create a rough surface and fiber openings that could increase the micromechanical and chemical bond between the fiber post and the post-core.[32] Zicari *et al*. explained that air abrasion is an aggressive procedure and that time, distance, and pressure affect treatment outcomes.[33]

Laser is suitable for surface modification. In this technique, laser energy is absorbed by the water on a hydrated surface, leading to microexplosions followed by tissue removal (ablation), resulting in a rougher surface. Laser irradiation increases surface roughness and irregularity and does not produce cracks when used at low settings accompanied by water cooling. Rezaei found that the effects of 1 and 1.5 W laser power were not significantly different, but they significantly differed from the effects of 0.5 W and the control. One watt is thus recommended as it causes less surface damage. Moreover, the direction of treatment application has no effect on the bond strength of fiber posts.[34] In this study, it was found that the bond strength of the fiber post in the laser group was significantly lower than that of air abrasion with 2/3 post-length. Kurt *et al*. found that the fiber posts treated with 300 mJ (0.6 W), 400 mJ (0.8 W), and 500 mJ (1 W) laser power had lower bond strength than the control.[35] Moreover, Kirmali *et al*. reported there was no significant difference in the strength of fiber post-bonding in the laser group to root canal dentin relative to that in the control group. This finding may have been caused by the relatively strong laser power, which damages fibers and modifies the surfaces of a post.[36]

The limitation of this study is that only fiber posts with a cylindrical-cone shape was used and that no comparison with posts of other shapes was made.

Conclusion

Air abrasion improved the bond strength of the fiber posts compared with the control and laser, whereas fiber post-length had no significant effect on bond strength.

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There are no conflicts of interest.

Author contributions

SU: Formal Analysis and Methodology, APD: Conceptualization and Supervision, AS: Validation, RT: Resources.

Ethical policy and Institutional review board statement

All authors declare there is no conflicting or competing interests to this article.

Patient declaration of consent

Did not use patient.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [APD], upon reasonable request.

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The Effect of Surface Treatment and Post-Length on Fiber Post-Bond Strength

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Original Article

The Effect of Surface Treatment and Post-Length on Fiber Post-Bond Strength

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ABSTRACT

Background: Endodontically treated teeth with extensive loss structure may require a post. Fiber post is made of a resin polymer matrix held by epoxy resin, which has a high conversion rate and high cross-linking, which may not interact with the monomer of resin cement that can reduce the bond strength that may cause post-debonding, which is a common failure of fiber post. Post-surface treatment and post-length are factors that affect post-bond strength. **Objective:** This study aims to determine the effect of surface treatment on fiber post and post-length on the bond strength of fiber post. **Materials and Methods:** Thirty mandibular premolars were selected, decoronated 15 mm from the coronal to the apical region, and then subjected to root canal treatment, obturation, and post-preparation. The samples were initially divided into two groups; each was assigned to a specific post-length; then, each group was randomly divided into a negative control group, air abrasion group, and laser group, for a total of six groups (n = 5). Self-adhesive resin cement is used for post-cementation. Self-adhesive resin cement is used for post-cementation. The evaluation of fiber post-bond strength in this study was evaluated with the pull-out test using a universal testing machine at a speed of 0.5 mm/min. Data were analyzed by two-way ANOVA and Tukey's test. **Results:** The air abrasion group showed a higher bond strength ($P < 0.05$) compared with the control and Er:Cr:YSGG laser groups. No significant difference in bond strength was observed between the control and Er:Cr:YSGG laser groups with both post-lengths. Moreover, post-length had no effect on bond strength, and no significant interaction was found between surface treatment and post-length. **Conclusion:** In this study, the bond strength was higher with surface treatment by air abrasion. Post-length had no impact on bond strength.

Keywords: *Air abrasion, bond strength, Er:Cr:YSGG laser, fiber post, post-length, surface treatment*

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Background

Endodontically treated teeth with extensive loss of tooth structure in excess of 50% require intraradicular retention, such as posts with metal cores or prefabricated posts for retention.[1] The use of prefabricated fiber posts demonstrates a high success rate in terms of treatment time, cost, and aesthetics.[2,3] Moreover, these posts allow for cementation with resin cement materials, which improves physical and chemical retention.[4] Although they offer several advantages,

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fiber posts may also fail. Debonding is the main concern with fiber posts apart from post-fracture, core fracture, and root fracture.[5] Debonding is indeed one of the major disadvantages of post-restoration. Fiber posts consist of a resin polymer matrix usually held together by an epoxy resin. Epoxy resins exhibit a high conversion rate and high cross-link density. Preventing fiber posts from interacting with the monomers of cement resin.[6]

Post-retention is influenced by the design, length, and diameter of posts and by surface treatment. A study found that the retention of titanium posts was influenced by post-length more than by post-diameter.[7] In another study, the 2/3 fiber post-length of root canal showed a significantly higher bond strength compared to 1/2 and 1/4 fiber post-length of root canals. The bonding strength of fiber posts with different lengths and the fiber post-group with length 2/3 of the root canal was significantly better than the fiber post-group with length 1/2 and 1/4 root canals.[8]

As mentioned above, post-retention is also influenced by surface treatments. A surface treatment removes the epoxy resin layer of posts and exposes the fibers.[10] Although some surface treatments, such as etching and treatment with hydrogen peroxide, had no effect on the bonding strength of fiber posts to a resin surface,[9] other surface treatments, such as air abrasion, are worth investigating. Air abrasion can produce a rough surface, which results from the collision of abrasive particles at high speed. In this treatment, adhesion is achieved through the removal of the resin matrix layer, resulting in microscopic retention on the surface of a post.[11] However, this technique is considered quite aggressive because it can change the shape and density and reduce the strength of a fiber post. Moreover, treatment outcomes may be influenced by treatment time, pressure, distance, and particle size.[12] Alumina oxide particles measuring 30–50 μm are widely used for surface treatment, and the latter produces better results than the former.[11]

Meanwhile, laser technology has found new applications in dentistry, where its use has been growing. A laser can be used for diagnosis, cavity preparation, polymerization, caries prevention, and dentin desensitization; it can also be used as an alternative for etching and can be applied in CAD/CAM technology.[13] Laser has good handling properties as it does not contact surfaces mechanically. Depending on its strength and wavelength, the light energy from a laser can change the chemical and physical structure of a surface.[14] In a study, the treatment of the post-surface using Er:YAG laser with 1.5 W output power (150 mJ and 10 Hz) for 60 s could remove the epoxy resin layer without damaging the fibers in the post.[4]

This study aims to determine the effect of different surface treatments and post-lengths on the bond strength of fiber posts.

Materials and Methods

This laboratory-based experimental study aims to investigate the effect of different surface treatments and post-lengths on the bond strength of fiber posts. Fiber posts measuring one-half and two-thirds the length of the root canal (denoted hereafter as fiber posts with 1/2 post-length and 2/3 post-length, respectively) were subjected to surface treatments using air abrasion and laser Er:Cr:YSGG. A total of 30 mandibular premolars with inclusion criteria of healthy tooth, fully formed root apex, single and straight canal were selected, evaluated, and decoronated 15 mm from the coronal to the apical region, whereas exclusion criteria were root canal treated, crown-root fracture, calcification, resorption and any anomalies of crown-root [Figure 1].

Root canal exploration was performed using a K-file #10 (Dentsply-Maillefer, Ballaigues, Switzerland); the file was inserted into the canal until it reached 1 mm shorter from the apical foramen, obtaining a working length of 14 mm [Figure 2].

Biomechanical preparation was performed with ProTaper Next files from X1 to X5 (Dentsply-Maillefer) at 250 rpm. The root canals were irrigated with 5 mL of 5.25% sodium hypochlorite for the use of each file and with 5 mL of 17% ethylenediaminetetraacetic acid to remove the smear layer; 5 mL of distilled water was used for the final irrigation. The root canals were dried using paper points (Dentsply-Maillefer) and then obturated with gutta-percha points and a resin-based sealer (AH-plus, Dentsply-Maillefer). The samples were stored for 7 days at 100% humidity level and 37°C, and the root canal filling material was removed [Figure 3]; a precision drill (Dentoclic, Itena) was used to obtain filling materials measuring two-thirds and one-half the length of the root canal.

The samples were randomly assigned to the 1/2 post-length or 2/3 post-length group; the posts obtained from each group were randomly assigned into control, air abrasion, and laser Er:Cr:YSGG groups. In the two air abrasion groups (i.e., 1/2 and 2/3 post-lengths), the posts were treated with 50 μm aluminum oxide particles and 2 MPa air pressure, which were delivered from a tip distance of 20 mm and from a 90-degree angle relative to the object [Figure 4]. The treated posts were subsequently soaked in water, subjected to ultrasonic

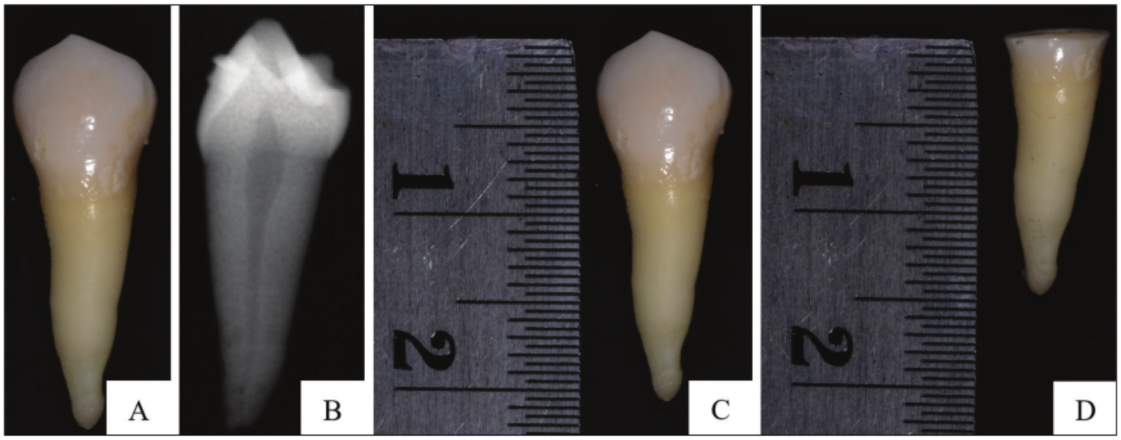

Figure 1: (A) Criteria of sample; (B) radiograph confirmation; (C) tooth length determination; (D) decoronization of sample

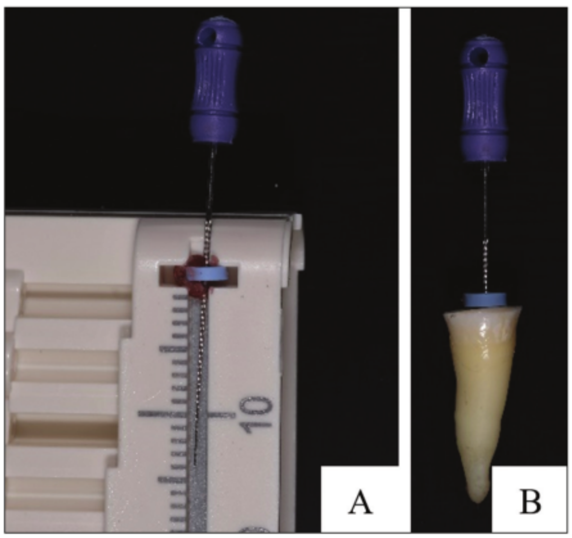

Figure 2: (A) Determination length of k-file; (B) working length determination

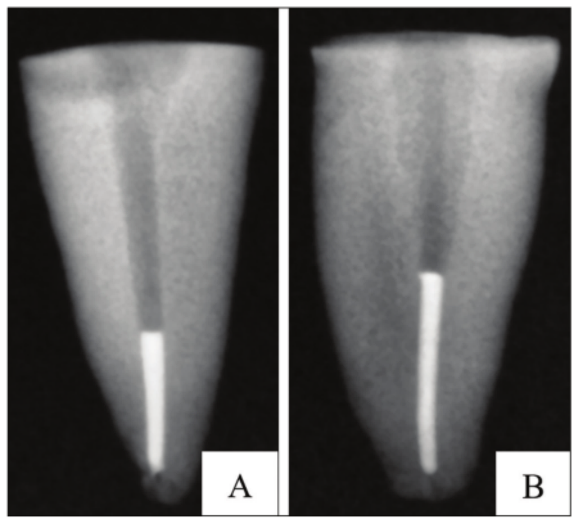

Figure 3: (A) Gutta percha removal of 2/3 root length; (B) Gutta percha removal of 1/2 root length

cleaning to remove any adhered particles, rinsed with alcohol, and then dried.

The posts in the laser Er:Cr:YSGG groups [Figure 5] were treated with 1.0 W laser power, 2780 nm wavelength, and 20 Hz frequency with a pulse duration of 150 s. A Z6 tip with a diameter of 600 µm delivered the laser energy, along with 10% water and 15% air, from a tip distance of 2 mm at 90° relative to the study object for 30 s to cover all surfaces.

The root canal was rinsed with distilled water using a syringe, dried with paper points, and then filled with resin cement using a needle tube. The post from each group was then inserted with light pressure into the root canal, followed by irradiation with curing light for 40 s. The samples were kept in distilled water for 24 h. A pull-out test was subsequently carried out with a universal testing machine using specialized tools for mounting the posts [Figure 6]. A pull-out speed of 0.5 mm/min was applied until the posts were released from the root canal.

Results

The air abrasion group with 2/3 post-length demonstrated the highest bond strength (15.11 ± 0.95 MPa), whereas the laser Er:Cr:YSGG group with 1/2 post-length showed the lowest bond strength (11.19 ± 0.58 MPa) [Table 1].

The Shapiro–Wilk test results showed a normal data distribution for the air abrasion, laser Er:Cr:YSGG, and control groups for both post-lengths ($P \geq 0.05$).

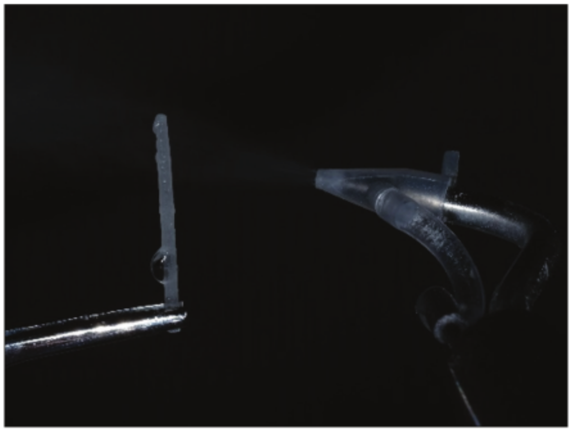

Figure 4: Fiber post surface treatment with air abrasion

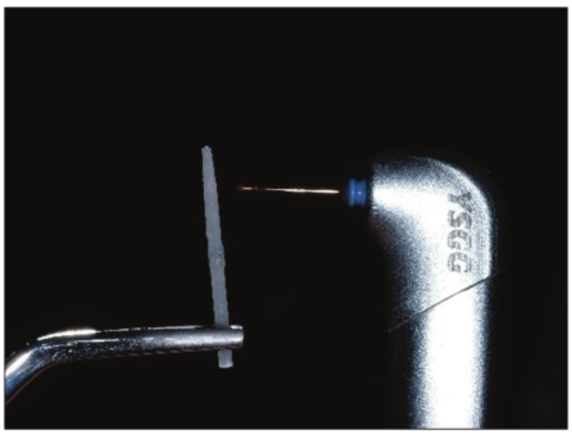

Figure 5: Fiber post surface treatment with laser Er:CR:YSGG

The two-way ANOVA results showed that there was a significant difference between post-length and surface treatment ($P < 0.05$). However, the combination of post-length and surface treatment had no significant effect on bond strength. The Tukey test results [Table 2] showed a significant difference in bond strength between the air abrasion group with 2/3 post-length and the control group with 2/3 post-length ($P < 0.05$). A significant difference in bond strength was also observed between the air abrasion, control, and laser Er:Cr:YSGG groups with 1/2 post-length ($P < 0.05$). Moreover, the bond strength of these groups did not significantly differ from that of their counterparts (with 2/3 post-length).

Discussion

The success of a dental treatment depends not only on root canal treatment but also on the restoration of missing tooth structures. An ideal root canal post-exhibits a modulus of elasticity, compressive strength, flexural strength, and thermal expansion that are similar to those of dentin and thus allow for uniform pressure distribution, preventing root fracture.[15,16] Fiber posts have been greatly improved in terms of aesthetics, mechanical properties, and attachment. Some of their advantages include strong resistance, low modulus of

Table 1: The mean value and standard deviation of fiber post-bond strength

Group	*N*	Mean ± SD (MPa)
Control 1/2 post-length	5	12.09±1.87
Control 2/3 post-length	5	13.24±0.87
Air abrasion 1/2 post-length	5	14.66±0.72
Air abrasion 2/3 post-length	5	15.11±0.95
Laser Er:Cr:YSGG 1/2 post-length	5	11.19±0.58
Laser Er:Cr:YSGG 2/3 post-length	5	12.57±1.33

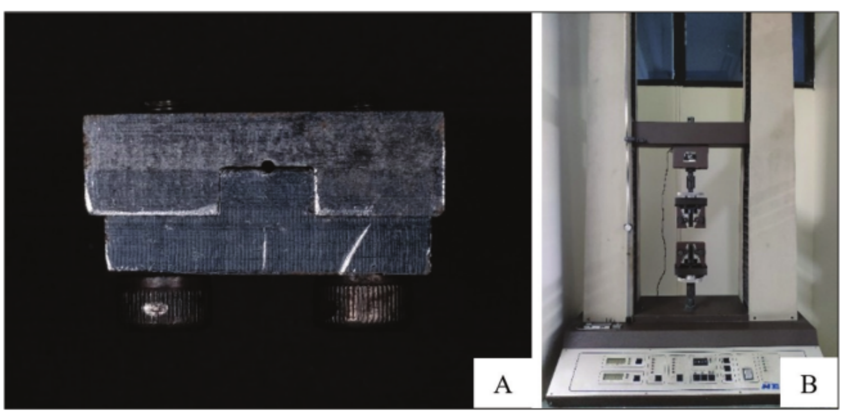

Figure 6: (A) Artificial tools; (B) Universal testing machine

Table 2: Post-hoc with Tukey test of fiber post-bond strength

Group		Control 1/2 post-length	Control 2/3 post-length	Air abrasion 1/2 post-length	Air abrasion 2/3 post-length	Laser Er:Cr:YSGG 1/2 post-length	Laser Er:Cr:YSGG 2/3 post-length
Control 1/2 post-length	*P* value	-	0.617	0.018*	0.040*	0.814	0.984
Control 2/3 post-length	*P* value		-	0.392	0.139	0.088	0.937
Air abrasion 1/2 post-length	*P* value			-	0.988	0.001*	0.078
Air abrasion 2/3 post-length	*P* value				-	0.000*	0.020*
Laser Er:Cr:YSGG 1/2 post-length	*P* value					-	0.425
Laser Er:Cr:YSGG 2/3 post-length	*P* value						-

elasticity, nontoxicity and inertness, easy removal in case of failure, ability to conduct polymerization light, and attachment to the root canal, thereby reducing functional and parafunctional pressure in the root canal.[17]

A fiber post-consists of an epoxy polymer matrix that is cross-linked to bind the post-fibers. The post-bond strength in a root canal can be improved through chemical bonding between a post and composite resin using silane coating and through surface roughening using air abrasion and acid etching or the combination of these two techniques. There is no standard protocol for the treatment of fiber posts.[17]

In this study, post-bond strength was assessed using the pull-out test, which can readily compare the stability of posts. Compared with the push-out test, the pull-out test allows for better pressure distribution and is more suitable for measuring post-retention in root canals. However, it requires a high number of posts and is costly.[19] The pull-out test involves a shear stress that is similar to clinical conditions, and it allows for a more uniform pressure distribution for bond strength measurement between a post and root dentin.[20,21] Moreover, it is more suitable than the push-out test for measuring post-strength in root canals.[22] This study was carried out *in vitro* and made as close as possible to the clinical situation.

The results of the SEM analysis showed that the fiber post in the air abrasion group gave a rougher surface than the control and laser groups. Fiber post-surface treatment using 50 µm alumina oxide showed a rough post-surface and partial loss of the epoxy resin.[23]

Silane coupling agents are organic and inorganic compounds that can form bonds between organic and inorganic matrices by increasing the surface tension, creating chemical bridges with OH-containing substrate. However, the use of silane in posts has been found to result in low bond strength. Previous push-out and retentive test results showed that the use of silane alone does not increase post-bond strength.[17,24]

This study compared the effect of post-length on the bond strength of fiber posts. The standard post-length used for intraradicular posts is 2/3 root length and corresponds to clinical crown length or greater. Braga reported that longer posts, either metal or fiber posts, exhibit greater bond strength than shorter posts.[25] Macedo explained that with increased post-length, the contact surface area between the cementing material and the root surface is also increased, resulting in greater bond strength.[26] However, the above findings contradict the present results, showing no significant difference in bond strength between the posts with 1/2 post-length and those with 2/3 post-length. Similarly, Webber *et al.* found no difference in the strength of fiber posts measuring 14 and 10.5 mm. Thus, shorter fiber posts may be used when the remaining roots are insufficient.[27] The above finding may be attributed to the bond strength being highest in the cervical region. The dentinal tubules in the cervical region have larger diameters than those in the apical region; thus, cleaning in the apical third is more difficult.[28]

Air abrasion or airborne particle abrasion with aluminum oxide is a fine surface treatment applied to achieve mechanical retention. Currently, air abrasion is used to roughen the surfaces of ceramic or composite restorations to increase bond strength.[29]

The fiber posts used in this study contain of 80% parallel fibers and 20% epoxy resin. This composition prevents the formation of mechanical interlocking bonds between a post and cement surfaces.[6,18] Air abrasion can be used to increase the surface area and promote mechanical interlocking between a cementing material and a post.[30] The ability of air abrasion to increase bond strength is influenced by the handpiece tip distance, pressure, and treatment duration. Arslan reported that a distance of 10 mm, a pressure of 2.8 bar, and a treatment time of 20 s could roughen a post-surface, increasing the bond strength. Another influencing factor is the handpiece angle. In this study, 90° was chosen because it did not cause damage to the fiber surface compared with the 45°angle. Note that damages in the surfaces of fiber posts can reduce bond strength.[30] Moreover, the size of aluminum oxide particles affects the surface roughness of fiber posts. Kulunk *et al.* reported that 50 μm aluminum oxide particles produced a significantly rougher surface than the 30 μm-sized particles.[11] Thus, the former was used in this study. As regards treatment time, Maroulakos *et al.* reported that the duration of the air abrasion treatment to not damage the fiber post-surface should not exceed 2 s/mm^2.[31]

In this study, the air abrasion group exhibited a significantly stronger bond strength than the control and laser Er:Cr:YSGG groups. These findings are consistent with Tuncdemir's results, showing that air abrasion produced a rougher post-surface and greater bond strength compared with the control and femtosecond laser treatment.[18] Alshahrani *et al.* examined the bond strength between fiber posts and post-cores made from composite materials, and they also found that air abrasion could create a rough surface and fiber openings that could increase the micromechanical and chemical bond between the fiber post and the post-core.[32] Zicari *et al.* explained that air abrasion is an aggressive procedure and that time, distance, and pressure affect treatment outcomes.[33]

Laser is suitable for surface modification. In this technique, laser energy is absorbed by the water on a hydrated surface, leading to microexplosions followed by tissue removal (ablation), resulting in a rougher surface. Laser irradiation increases surface roughness and irregularity and does not produce cracks when used at low settings accompanied by water cooling. Rezaei found that the effects of 1 and 1.5 W laser power were not significantly different, but they significantly differed from the effects of 0.5 W and the control. One watt is thus recommended as it causes less surface damage. Moreover, the direction of treatment application has no effect on the bond strength of fiber posts.[34] In this study, it was found that the bond strength of the fiber post in the laser group was significantly lower than that of air abrasion with 2/3 post-length. Kurt *et al.* found that the fiber posts treated with 300 mJ (0.6 W), 400 mJ (0.8 W), and 500 mJ (1 W) laser power had lower bond strength than the control.[35] Moreover, Kirmali *et al.* reported there was no significant difference in the strength of fiber post-bonding in the laser group to root canal dentin relative to that in the control group. This finding may have been caused by the relatively strong laser power, which damages fibers and modifies the surfaces of a post.[36]

The limitation of this study is that only fiber posts with a cylindrical-cone shape was used and that no comparison with posts of other shapes was made.

Conclusion

Air abrasion improved the bond strength of the fiber posts compared with the control and laser, whereas fiber post-length had no significant effect on bond strength.

Acknowledgement

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Conflicts of interest

There are no conflicts of interest.

Author contributions

SU: Formal Analysis and Methodology, APD: Conceptualization and Supervision, AS: Validation, RT: Resources.

Ethical policy and Institutional review board statement

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