JFCR

Journal of Fundamental and Clinical Research
https://jfcr.journals.ekb.eg/
ISSN 2735-023X
Vol. 2, No. 1, 1-13, June 2022

Effect of Posts Surface Treatments on the Pull-out Bond Strength of Glass Fiber Post to Root Dentin "A Comparative In-Vitro Study"

Amr Mekky[1], Maged El-Hakim[2], Tamer Shokry[3]

ABSTRACT

Background: Glass fiber posts is the gold standard for the treatment of endodontically treated teeth with insufficient coronal tooth structure. Although it offers better retention and stress distribution when used, debonding is still the most common mode of failure for glass fiber posts. To overcome this problem, multiple surface treatments were tried to modify the post surface either chemically or mechanically to improve the post adhesion to resin cements. ***Objectives:*** To evaluate the pull-out bond strength of glass fiber posts to root dentin after different surface treatments using air-borne particle abrasion, diode laser and Er-Cr:YSGG laser. ***Materials and Methods:*** Forty freshly extracted single rooted teeth were root canal treated and divided into four groups according to surface treatment of the post: (Control, air borne-particle abrasion with alumina-oxide particles, irradiation with diode laser and irradiation with Er-Cr:YSGG). Pull-out test was done using a universal testing machine and the mode of failure of each sample was inspected under a stereomicroscope. ***Results:*** The Er-Cr:YSGG laser irradiation group showed the highest statistically significant bond strength value among all groups. Diode laser group showed the least bond strength value among all other groups significantly. No significant difference was found between air-borne particle abrasion and control groups. ***Conclusion:*** Er-Cr:YSGG laser irradiation improved the pull-out bond strength of the glass fiber post to root dentin compared to diode laser and air-borne particle abrasion.

Keywords: Fiber post, air-borne particle abrasion, Er-Cr:YSGG, Diode laser, pull-out bond strength.

INTRODUCTION

Due to the similar modulus of elasticity of glass fiber posts to dentin, stress distribution along the root surface becomes more preferable.[1-3] Many studies directed their efforts trying to provide the best retention of these posts through different

1.Post graduate Researcher, Fixed Prosthodontics Department, Faculty of Oral and Dental Medicine, Misr International University, Cairo, Egypt.

2.Professor of Fixed Prosthodontics, Faculty of Dentistry, Cairo University, Cairo, Egypt.

3.Professor of Fixed Prosthodontics, Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt.

surface treatments and luting cements.[4,5] These studies allowed different surface treatment options either chemical, mechanical or chemico-mechanical. Silane is considered the most popular chemical mediator used in dentistry due to its hybrid organic–inorganic compounds that can mediate adhesion between inorganic and organic matrices through an intrinsic dual reactivity.[6-9]

Mechanical modifications include the air-borne particle abrasion process, which depends on air pressing small sized alumina-oxide particles with certain parameters (particle type, size, distance, time of application and air pressure) modifying the surface topography of the post from a smooth highly condensed form into a rougher surface with multiple narrow defects.[10, 11] Despite the increased surface roughness, some authors didn't agree with the air-borne particle abrasion surface treatment due to surface cracks and dimensional alterations that might be associated with the process.[12, 13] On the other hand, many authors proved an increased bond strength values of glass fiber posts when the process is applied with specific parameters.[14-16]

Diode lasers with wavelengths varying from (460-980 nm) are considered soft tissue laser devices due their high absorption in hemoglobin and melanin.[17] Diode laser surface treatment has been applied previously in attempt to modify the glass fiber post surface topography through heat energy transfer to the post surface. Although previous studies showed an increased post surface roughness, the diode laser surface treatment remains an ineffective way in increasing the bond strength values of glass fiber posts.[15, 18] In addition, visual color changes were always evident when diode laser is applied on glass fiber posts.[19, 20] Unfortunately, no studies compared different diode laser parameters individually and the effect of these parameters on the adhesive properties of glass fiber posts.

For soft and hard tissue applications, Er:YAG (2940 nm) and ErCr:YSGG (2780 nm) are the most available devices in dental offices. Results obtained from both devices are comparable due to near wavelengths.[21-23] Unlike diode lasers, different parameters of erbium lasers were compared individually. Kurt *et al.*[24] compared 3 different Er:YAG laser power settings (300 mJ,400mJ and 500mJ) to the traditional air-borne particle abrasion and hydrofluoric acid surface treatments on the bond strength of glass fiber posts. The results showed significantly lower bond strength values for all laser groups than other surface treatments groups. On the opposite side, another study conducted by Kurtulmus-Yilmaz *et al.*[25] using different power setting of (ErCr:YSGG) proved that (1W and 1.5W) can improve the bond strength of glass fiber posts to root dentin. Results of this study was supported later by other authors who recommended low power laser parameters for the surface treatment of glass fiber posts.[26,27]

Furthermore, Gomes *et al.*[20] compared the effect of surface treatment on glass fiber posts using 3 different laser devices (Er:YAG, ErCr:YSGG and diode laser). Results showed that ErCr:YSGG has significantly the highest bond strength values compared to all other groups and no significant difference was found between control (no treatment), Er:YAG and diode laser groups.

Therefore, the aim of the present study was to evaluate the pull-out bond strength of glass fiber posts to root dentin after different surface treatments (air-borne particle abrasion, diode laser and Er-Cr:YSGG laser). The null hypothesis was that there was no significant difference in the pull-out bond strength of glass fiber post to root dentin with different surface treatments.

MATERIALS AND METHODS

Forty extracted single rooted maxillary anterior teeth with completely formed roots and closed apices were obtained from the teeth bank of Misr International University (IRB# 00010118). The teeth were examined to make sure they are free from caries, cracks or structural anomalies under (3x) magnifying dental loupes (Univet, Italy). Teeth were cleaned using an ultrasonic cleaner (DB-4820, Coxo, China) and stored in a saline solution. The saline solution was renewed every 5 days till the beginning of the study.

The teeth were randomly divided into four groups according to surface treatment of the post (Fibrekleer, Pentron, Wallingford, USA): Group C (no treatment), Group A (Air-borne particle abrasion), Group D (Diode laser irradiation), and Group E (Er-Cr:YSGG laser irradiation)

Teeth were sectioned horizontally by a diamond disc at the level of the cemento-enamel junction using a sectioning machine (IsoMet precision cutting microsaw, Buehler, USA). Root canal treatment was done using rotary files (ProTaper Universal System, Dentsply Maillefer) reaching a master apical file of the size F3. 3 ml. of 5.25% sodium hypochlorite solution was used to irrigate the canals between each consecutive rotary file, followed by 17% EDTA solution as a final irrigant for smear layer removal. Canals were dried using absorbent paper points followed by lateral condensation obturation technique using gutta percha points size F3 (Meta Biomed Co., Korea) and a resin-based root canal sealer (AH plus, Dentsply Maillefer). After one week storage in 37 C saline solution, teeth were embedded in self-cure acrylic resin, **Figure (1)**, with the help of a dental surveyor using a customized propylene mold.

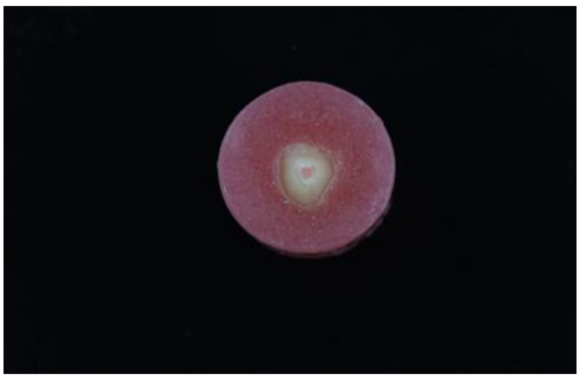

Figure (1): The sectioned tooth inserted in the self-cure acrylic mold.

Post space preparation was done with a post drill #3 (Fibrekleer, Pentron, Wallingford, USA) attached to low-speed straight handpiece. Post space length was determined to 9mm and the preparation was done with the help of a dental surveyor to control the preparation angle.

Glass fiber posts were equally and randomly divided into 4 groups (n=10) according to different surface treatments applied, illustrated in **Figure (2).** Sample size calculation was performed using IBM® SPSS® SamplePower® Release 3.0.1

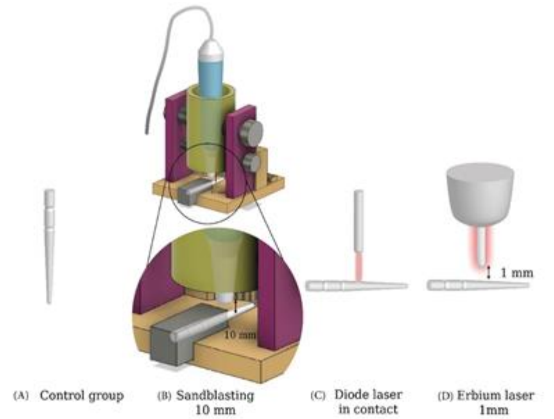

Figure (2): A graphical diagram illustrating the surface treatment applied for each group.

Group C: no treatment

Group A: Air-borne particle abrasion was done using 50 µm aluminum oxide powder (Dentify GmbH, Germany) at 2.8 bar pressure for 5 seconds time interval and a 10mm distance from the post surface.[16] The post was rotated 180 degrees and the procedure was repeated to ensure full post surface abrasion. Post surface treatment was done using a 3D printed custom-made device, **Figure (3)**, to standardize the application

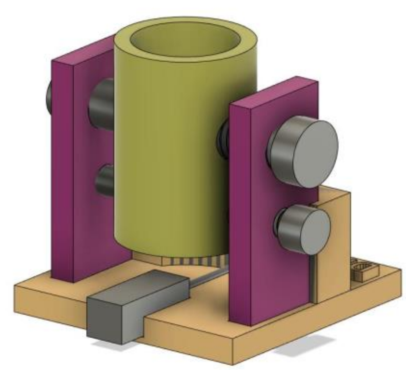

Figure (3): Design of the 3D printed custom-made device used for air-borne particle abrasion.

distance. Following the air-borne particle abrasion, the posts were rinsed under tap water for 10 seconds and air dried with an oil-free compressor.

Group D: Diode laser application was done using 300 µm diameter fiber optic tip attached to the handpiece of the laser device (EpicX, Biolase,Inc.). The tip was applied perpendicularly on the post surface in contact mode, **Figure (4)**, using the following parameters (1.5 W, continuous wave mode and 15 seconds time interval).[20]

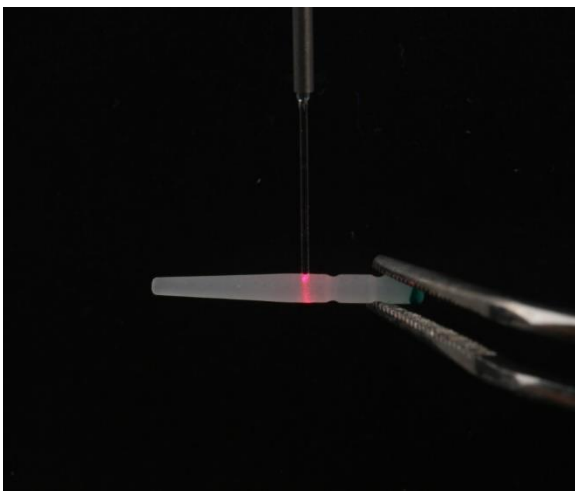

Figure (4): Diode laser irradiation tip applied perpendicularly on post surface in a contact mode.

As the application starts, the fiber optic tip was moved back and forth on the post surface to ensure enough energy for the whole surface. The post was rotated 180 degrees and the procedure was repeated the same way on the untreated post side. The fiberoptic laser tip was cut at 90 degrees every 15 seconds according to manufacturer's instructions. The posts were then cleaned using alcohol and left to dry.

Group E: Er-Cr:YSGG (Waterlase, Biolase,Inc.) laser irradiation for this group was done by the same operator using a 600 µm fiber optic tip (Sapphire MGG6, Biolase,Inc.) held perpendicularly to the post surface in a non-contact mode 1mm away from post surface. Laser irradiation settings were adjusted to a pulsatile mode, 150mJ energy, 1.5w power, 10hz frequency and 140 µs. pulse duration. Laser irradiation was done for 60 seconds using 60% water and 40% air with the tip moving back and forth among the whole post length, **Figure (5)**.[20]

Figure (5): Er-Cr:YSGG laser irradiation tip applied on post surface in non-contact mode.

The post was rotated 180 degrees and the procedure was repeated the same way on the untreated post side. During the whole procedure, the laser fiber optic tip was cleaved at 90 degrees every 15 seconds to ensure a full energy transmission to the post surface. After complete surface treatment, the posts were cleaned using alcohol and air dried using an oil-free compressor.

After posts surface treatments were completed for all groups, a silane coupling agent (Porcelain primer, Bisco, Schaumburg, IL, USA) was applied for all posts for 60 seconds using a micro-brush and posts were allowed to dry for 1 min.

Regarding the cementation process, the dentin was treated using 37% phosphoric acid etchant (Pentron, Wallingford, CT, USA) for 15 seconds, washed and dried using absorbent paper points. A custom-made 3D printed cementation device was constructed to apply a constant pressure over the head of the post during the cementation procedure. A self-adhesive resin cement (Breeze, Pentron, Wallingford, USA) was applied inside the canal with the help of an attached intracanal micro-tip according to the manufacturer's instructions. The fiber posts were seated to full length under an axial load of 2.5N (0.26 kg) simulating finger pressure for 30 seconds, **Figure (6)**.

Excess cement was removed around the post using a micro brush, followed by 1500 mW/cm^2 light curing for 10 seconds using a LED curing unit (Premium Plus, UK LTD). The samples were then left for 4 minutes for full chemical polymerization according to manufacturer's instructions.

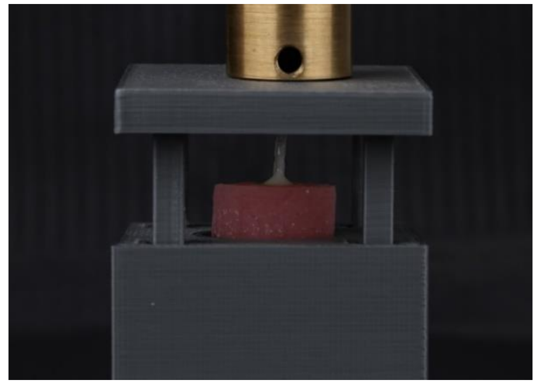

Figure (6): Seating of the post under 2.5N axial load using the cementation device.

The pull-out test was performed using a universal testing machine (Instron 3345, Canton, MA, USA) with a special mandrel at a crosshead speed of 1mm/min. till the post is completely detached from the root dentin, **Figure (7)**. The maximum load value is then recorded for each sample in Newton (N).

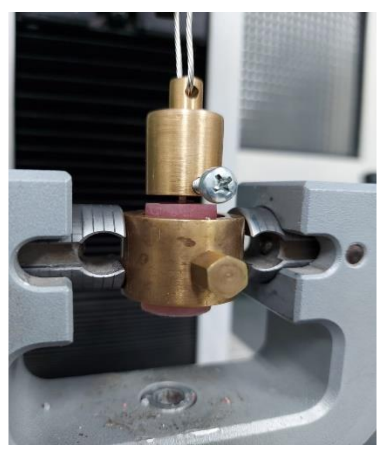

Figure (7): The pull-out test using a universal testing machine with the special mandrel attached to the post head.

Data were examined for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. One-way ANOVA followed by Tukey post hoc test was used to compare between more than two groups in non-related samples. The significance level was set at $P \leq 0.05$.

Each sample was examined using a stereomicroscope (Nikon Eclipse E600, Tokyo, Japan) under (20X) magnification for the inspection of the mode of failure. Failure modes were divided into 3 groups, adhesive (failure occurred at post- resin cement interface or resin cement- root dentin interface), cohesive (failure occurred within post material or root dentin itself) and mixed (failure includes both interface and material).

An additional sample in each test group was prepared for SEM analysis. The SEM images were taken with an acceleration voltage of 20 kV., and a magnification of (1000X) using the Quanta 3D 200i (FEI Co., Netherlands) scanning electron microscope.

RESULTS

The mean and standard deviation values were calculated for all groups, **Table (1)**, and presented by a bar chart, **Figure (8)**. Satisfaction data showed parametric (normal) distribution.

Pull-out bond strength

There was a statistically significant difference in the bond strength between the tested groups ((p<0.001), **Table (1)**. The highest bond strength value was for (Group E) followed by (Group A) and (Group C) with no significant difference between them(p=0.958). The lowest bond strength value was for (Group D).

Table (1): The mean, standard deviation (SD) values of pull-out bond strength of different groups.

Variables	Pull-out bond strength			
	Mean	SD	95% Confidence Interval for Mean	
			Lower Bound	Upper Bound
Group C	492.11^{b}	68.44	443.15	541.07
Group A	475.19^{b}	69.18	425.70	524.67
Group D	112.99^{c}	28.30	92.75	133.24
Group E	601.72^{a}	111.17	522.19	681.24
p-value	**<0.001***			

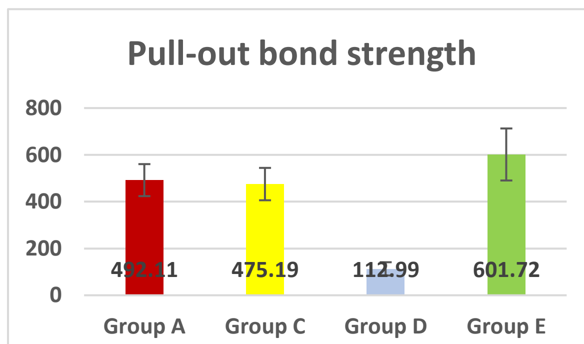

Figure (8): Bar chart representing mean and standard deviation values comparing the pull-out bond strength with different surface treatments.

Failure mode analysis

After surface examination of the 40 glass fiber posts, the samples showed 24 adhesive failure (60%) at the post-cement interface, 10 mixed failures (25%) and 6 cohesive failures

(15%) within the post material, **Table (2)**. The modes of failure were analyzed separately for each surface treatment group and presented with a bar-chart, **Figure (9).**

Table (2): Number of samples and the percentage of the modes of failure for each surface treatment group.

Group	Mode of failure					
	Adhesive		Cohesive		Mixed	
	No. of samples	%	No. of samples	%	No. of samples	%
Group C	6	60%	2	20%	2	20%
Group A	4	40%	3	30%	3	30%
Group D	8	80%	0	0%	2	20%
Group E	6	60%	1	10%	3	30%

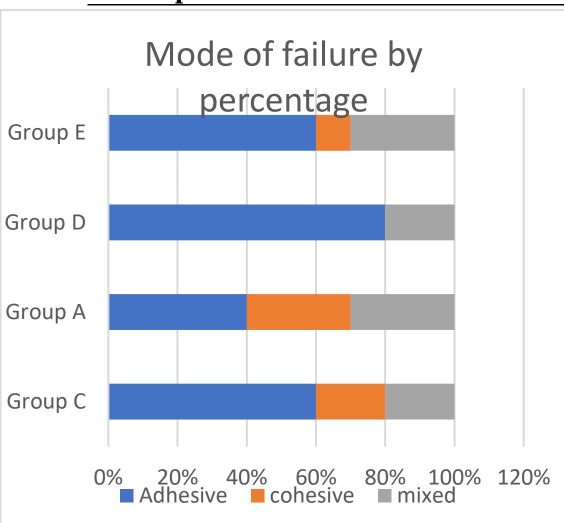

Figure (9): Bar-chart presenting comparing the percentage of different modes of failure for each surface treatment group.

<u>Scanning electron-microscopic analysis</u>

Group C: Untreated glass fiber posts showed parallel arrangement of un-interrupted fibers densely incorporated in an epoxy resin matrix holding the fibers together, **Figure (10).**

Group A: This group showed a slightly rougher post surface, presented as dug-out areas including both the epoxy resin and the fibers. The post also showed a smaller number of surface fibers compared to the control group which appears interrupted by

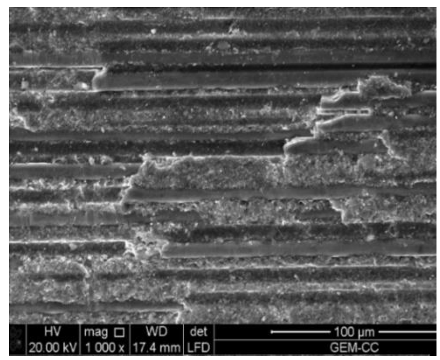

Figure (10): SEM micrograph (x1000) of group (C) showing the surface properties of an untreated glass fiber post.

the effect of alumina-oxide particles**, Figure (11).**

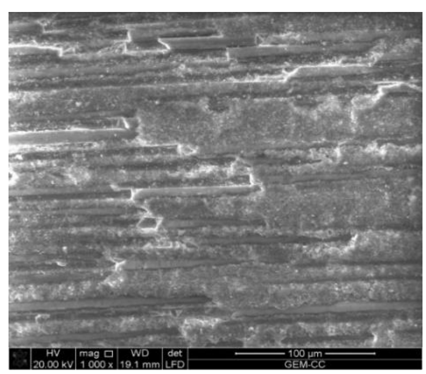

Figure (11): SEM micrograph (x1000) of group (A) showing the effect of alumina-oxide air-borne particle abrasion on the surface of glass fiber post.

Group D: This group showed the greatest surface roughness among all groups. The epoxy resin matrix is completely interrupted with the absence of any arrangement of incorporated fibers. Surface fibers show a high degree of melting and destruction along the post surface, **Figure (12).**

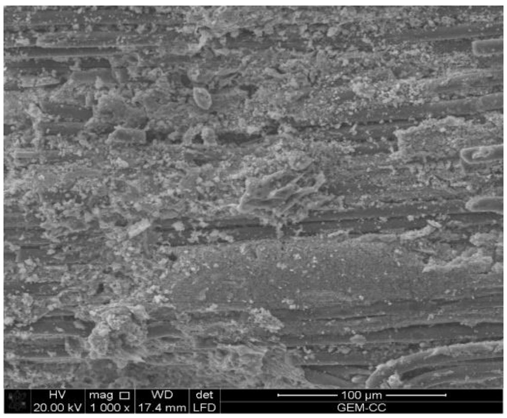

Figure (12): SEM micrograph (x1000) of group (D) showing the complete destruction and loss of surface integrity associated with diode laser surface treatment.

Group E: Er-Cr:YSGG laser showed a great modification of the post surface that targeted only the epoxy resin, leaving the highest amount of surface fibers among all groups. The exposed surface fibers showed a great preservation of their parallel arrangement without any degree of destruction or interruption along the post surface, **Figure (13).**

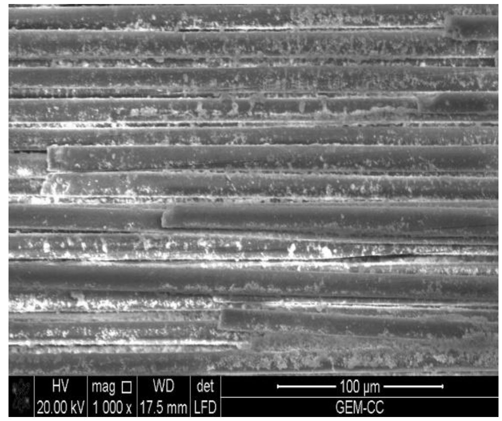

Figure (13): SEM micrograph (x1000) of group (E) showing the effect of erbium laser on enhancing the post surface topography.

DISCUSSION

According to the stated results, the null hypothesis was rejected because there was a statistically significant difference in the pull-out bond strength of glass fiber posts to root dentin with different surface treatments. The Er-Cr:YSGG laser irradiation group (Group E) showed the highest mean bond strength values among all groups. These results came in accordance with other studies done, the superior results were owed to the coolant system of erbium laser devices which uses a pressurized air-water biofilm on the irradiated surface.[16, 18, 20, 26] The transferred energy in turn, initiates micro-ablations of surface water molecules which is responsible of creating surface roughness and color change of the post surface. This suggestion is supported by the SEM outcome, **Figure (13)**, where only a superficial layer of the epoxy-resin matrix is removed by the ablation process, leaving the glass fibers intact and undisturbed, and enhancing the micro-mechanical interlocking of resin cement to the post surface. Despite the main adhesive mode of failure, this group showed the highest percentage of mixed failures which proves a better adhesion of the resin cement to the post surface.

On the opposite side, the diode laser (Group D) showed the least bond strength values among all other groups. These results came in agreement with previous studies done.[15,20] The diode laser system works differently from the erbium systems. The different wavelength and the absence of water coolant allows more heat energy absorption by the post surface. The SEM changes, **Figure (12)**, as mentioned by Barbosa Siqueira *et al*.[18] were responsible for the low bond strength values of this group. Melting of the resin matrix and glass fibers occurs upon irradiation. This process is further followed by a re-solidification process where both layers become incorporated in each other. This new surface topography inhibits the penetration of resin cement into the post surface; therefore, low bond strength values were achieved. In addition, the dominance of adhesive failures (80%) and the absence of any cohesive failure support the negative influence of diode laser application on glass fiber posts.

The air-borne particle abrasion group (Group A) showed slightly higher bond strength values than the control group but with no significant difference. Despite the ability of alumina-oxide particles to create micro-porosities on the post surface, these particles don't act on the substrate selectively; therefore, glass fibers were attacked and interrupted as well as the epoxy resin matrix.[28] As a result, the resin cement was not offered an appropriate mechanical interlocking into the post surface that could achieve high bond strength values. These results came in agreement with previous studies done.[16, 29, 30]

CONCLUSION

Within the limitations of this study, it can be concluded that:

1.Er-Cr:YSGG laser irradiation surface treatment improved the pull-out bond strength of the glass fiber post to root dentin compared to diode laser and air-borne particle abrasion surface treatments.

2.Diode laser irradiation surface treatment decreased the pull-out bond strength of glass fiber posts to root dentin.

3.Air-borne particle abrasion didn't show a statistically significant difference in pull-out bond strength values compared to the control group.

CONFLICT OF INTEREST: null

REFERENCES

1. Ferrari M, Vichi A, Garcia-Godoy F. Clinical evaluation of fiber-reinforced

epoxy resin posts and cast post and cores. Am J Dent. 2000;13(Spec No):15B-8B.
2. Monticelli F, Grandini S, Goracci C, Ferrari M. Clinical behavior translucent-fiber posts: A 2-Year prospective study. Int J Prosthodont. 2003;16(6).
3. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: A literature review. J Endod. 2004;30(5):289-301.
4. Aksornmuang J, Foxton RM, Nakajima M, Tagami J. Microtensile bond strength of a dual-cure resin core material to glass and quartz fibre posts. J Dent. 2004;32(6):443-50.
5. Goracci C, Raffaelli O, Monticelli F, Balleri B, Bertelli E, Ferrari M. The adhesion between prefabricated FRC posts and composite resin cores: Microtensile bond strength with and without post-silanization. Dent Mater. 2005;21(5):437-44.
6. Sahafi A, Peutzfeldt A, Asmussen E, Gotfredsen K. Bond strength of resin cement to dentin and to surface-treated posts of titanium alloy, glass fiber, and zirconia. J Adhes Dent. 2003;5(2).
7. Matinlinna JP, Lassila LV, Özcan M, Yli-Urpo A, Vallittu PK. An introduction to silanes and their clinical applications in dentistry. Int J Prosthodont. 2004;17(2).
8. Sahafi A, Peutzfeldt A, Asmussen E, Gotfredsen K. Retention and failure morphology of prefabricated posts. Int J Prosthodont. 2004;17(3).
9. Perdigão J, Gomes G, Lee IK. The effect of silane on the bond strengths of fiber posts. Dent Mater. 2006;22(8):752-8.
10. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent. 1999;27(4):275-8.
11. Balbosh A, Kern M. Effect of surface treatment on retention of glass-fiber endodontic posts. The Journal of prosthetic dentistry. 2006;95(3):218-23.
12. Valandro LF, Yoshiga S, De Melo RM, Galhano GAP, Mallmann A, Marinho CP, et al. Microtensile bond strength between a quartz fiber post and a resin cement: Effect of post surface conditioning. J Adhes Dent. 2006;8(2).
13. D'Arcangelo C, D'Amario M, Prosperi GD, Cinelli M, Giannoni M, Caputi S. Effect of surface treatments on tensile bond strength and on morphology of quartz-fiber posts. J Endod. 2007;33(3):264-7.
14. Yavirach P, Chaijareenont P, Boonyawan D, Pattamapun K, Tunma S, Takahashi H, et al. Effects of plasma treatment on the shear bond strength between fiber-

reinforced composite posts and resin composite for core build-up. Dent Mater J. 2009;28(6):686-2.

15. Al-Qahtani AS, AlZain SA, AlHamdan EM, Tulbah HI, Al Alsheikh HM, Naseem M, et al. A comparative evaluation of the effect of phototherapy of fiber post on its bond strength to dental composite. Photodiagnosis Photodyn Ther. 2018;24:228-31.
16. Hashemikamangar SS, Hasanitabatabaee M, Kalantari S, Gholampourdehaky M, Ranjbaromrani L, Ebrahimi H. Bond strength of Fiber posts to composite Core: Effect of surface treatment with Er, Cr: YSGG laser and thermocycling. Journal of lasers in medical sciences. 2018;9(1):36.
17. Acharya SS, Prabhakar R. Lasers in dentistry: A review. Annals and Essences of Dent. 2012;4(4):66-72.
18. Barbosa Siqueira C, Spadini de Faria N, Raucci-Neto W, Colucci V, Alves Gomes E. Evaluation of mechanical properties of glass fiber posts subjected to laser surface treatments. Photomed Laser Surg. 2016;34(10):460-6.
19. Cekic-Nagas I, Ergun G, Egilmez F. Light transmittance of fiber posts following various surface treatments: A preliminary study. Eur J of Dent 2016;10(02):230-3.
20. Gomes KG, Faria NS, Neto WR, Colucci V, Gomes EA. Influence of laser irradiation on the push-out bond strength between a glass fiber post and root dentin. J Prosthet Dent. 2018;119(1):97-102.
21. Cho S, Rajitrangson P, Matis B, Platt J. Effect of Er, Cr: YSGG laser, air abrasion, and silane application on repaired shear bond strength of composites. Oper Dent. 2013;38(3):E58-E66.
22. Garbui BU, de Azevedo CS, Zezell DM, Aranha ACC, Matos AB. Er, Cr: YSGG laser dentine conditioning improves adhesion of a glass ionomer cement. Photomed Laser Surg. 2013;31(9):453-60.
23. Križnar I, Jevnikar P, Fidler A. Effect of Er: YAG laser pretreatment on bond strength of a composite core build-up material to fiber posts. Lasers Med Sci. 2015;30(2):733-40.
24. Kurt M, Güler AU, Duran İ, Uludamar A, İnan Ö. Effects of different surface treatments on the bond strength of glass fiber-reinforced composite root canal posts to composite core material. J Dent Sci. 2012;7(1):20-5.

25. Kurtulmus-Yilmaz S, Cengiz E, Ozan O, Ramoglu S, Yilmaz HG. The effect of Er, Cr: YSGG laser application on the micropush-out bond strength of fiber posts to resin core material. Photomed Laser Surg. 2014;32(10):574-81.
26. Barutcigil Ç, Barutcigil K, Yasa B, Arslan H, Akcay M. Build-Up of a Resin Composite Core in a Fiber-Reinforced Post by a 2.78 µm-Pulsed Laser Treatment. J Laser Micro/Nanoeng. 2015;10(2).
27. Rezaei-Soufi L, Tapak L, Forouzande M, Fekrazad R. Effects of motion direction and power of Er, Cr: YSGG laser on pull-out bond strength of fiber post to root dentin in endodontically-treated single-canal premolar teeth. Biomate Res. 2019;23(1):1-8.
28. Soares CJ, Santana FR, Pereira JC, Araujo TS, Menezes MSJTJopd. Influence of airborne-particle abrasion on mechanical properties and bond strength of carbon/epoxy and glass/bis-GMA fiber-reinforced resin posts. The Journal of prosthetic dentistry. 2008;99(6):444-54.
29. Tuncdemir AR, Yıldırım C, Güller F, Özcan E, Usumez A. The effect of post surface treatments on the bond strength of fiber posts to root surfaces. Lasers Med Sci. 2013;28(1):13-8.
30. Arslan H, Kurklu D, Ayrancı LB, Barutcigil C, Yılmaz CB, Karatas E, et al. Effects of post surface treatments including Er: YAG laser with different parameters on the pull-out bond strength of the fiber posts. Lasers Med Sci. 2014;29(5):1569-74.