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Effect of Er,Cr:YSGG surface treatment of fiber post on surface roughness and morphology compared with other surface treatment modalities

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***Abstract*---**Objective: To evaluate and compare the influence of fiber post surface treatments (Er,Cr:YSGG laser sandblasting, and 9% hydrofluoric acid) on surface roughness and morphology. Materials and Methods: A total of sixty fiber posts were used in this study. They were randomly divided into 4 groups according to surface treatment method into: Group I: control (no pretreatment), Group II: sandblasting (Al2O3), Group III: etch 9% hydroflouric acid etching , Group IV: Er,Cr:YSGG laser iradiation (2790 nm) .Group IV was further subdivided according to laser power to; subgroup A: 0.5W, subgroup B: 1W, subgroup C: 1.5W. Surface roughness (Ra) of the posts before and after surface treatment was measured using surface profilometer. The posts were examined under SEM for assessment of surface morphology. One-way ANOVA followed by Tukey post hoc test was used to compare between more than two groups in non-related

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samples. Results: There was statistical significant difference in the Ra value between the control group and all the tested groups ($p<0.001$). Sandblasting showed the highest significant mean Ra value while hydrofluoric acid had the lowest significant values. Conclusion: All the tested surface treatments method increased the surface roughness, and changed the surface morphology of the tested fiber posts. However, sandblasting and Er,Cr:YSGG 1.5W caused distinctive irregularities, fiber rupture and cracks.

***Keywords*---**fiber post, Er,Cr:YSGG, surface treatment, surface roughness, scanning electron microscope, hydrofluoric acid etching, surface profilometer.

Introduction

Prefabricated fiber post had been widely used and showed promising clinical results in term of durability in restoring primary anterior teeth with moderate amount of remaining coronal tooth structure. The mechanical properties and bonding capacity of fiber post to dentine using adhesive cement allow formation of homogenous structure with the tooth resulting in reduced risk of catastrophic fracture [1]. Fiber posts are mostly composed of a polymeric epoxy resin reinforced with carbon, quartz, zirconia, glass or silica fibers with a high degree of conversion and cross-linked structures. The fibers are oriented parallel to the longitudinal axis and might comprise 30–50% of the fiber post structure. Despite several advantages of fiber post, it has always been challenging for the dentist to retain the restoration. Some surface treatment methods including micromechanical, chemical or combination has been introduced in an attempt to increase the surface roughness and thus enhancing the mechanical bonding characteristics of the posts [2]. Posts surface treatments include; sandblasting with aluminium oxide particles [3, 4, 5], hydrofluoric acid [4], and laser irradiation [3,6, 7]. Laser etching technology has become available as an alternative method for improving roughness and bond strength of dental substrates and materials [8,9].

Akin et al [10], reported that Nd:YAG at 1 W produced the highest surface roughness. However there was no significant improvement in roughness values between Al_2O_3 (110mn, for 10sec), silica coated Al_2O_3, hydrofluoric acid (9.5% for 20sec), and Er:YAG (1.5W). On the other hand, Sipahi et al [11], revealed that sandblasting resulted in a significant higher roughness when compared to Nd:YAG and Er:YAG laser with insignificance difference between laser groups. Moreover, Akin et al [12], concluded that surface treatments with sandblasting and Er:YAG laser is effective methods for improving the surface roughness with no correlation with bond strength.

The newly introduced laser, Er,Cr: YSGG, is proposed for treatment of both soft and hard tissues with minimal thermal side-effects using a wavelength of 2.79 mm which represent strong absorption in water (ma = 7000/7cm) [13]. Siquera [14], showed that Er,Cr:YSGG produced the highest surface roughness values compared to Er:YAG and diode 980 nm all at 1.5W. Recently many of the

technological advances have been directed to the use of lasers as an alternative to acid etching of dental materials or teeth to improve the mechanical properties (Arslan et al 2014). Therefore the aim of the current in vitro study was to evaluate and compare the influence of post surface treatments (sandblasting, 9% hydrofluoric acid and Er,Cr-YSGG laser), on the surface roughness and morphology of fiber post under standardizes conditions to distinguish the surface treatments that could be proposed.

Materials and Methods

Sample grouping

A total of sixty fiber posts were randomly used during the present study. Posts were divided according to the surface pretreatment method into the following groups:

Group I (n=10):control, received no pretreatment,
Group II (n=10):Al_2O_3 sandblasted,
Group III (n=10): 9% hydrofluoric acid etched , and
Group IV(n=30): Er,Cr:YSSG laser 2970 nm pretreated post which was further subdivided into:
- subgroup A (n=10): 0.5W ,
- subgroup B (n=10): 1W, and
- subgroup C (n=10): 1.5W.

Posts surface treatment
Al_2O_3 sandblasting

Posts (n=10) were sandblasted with aluminum oxide 110 microns for 10 s (Ney, Blastmate II, Yucaipa, CA). The air pressure for sandblasting was maintained at 2 bars. Posts were perpendicularly mounted in a special holder at a distance of 10 mm between the post surface and the blasting tip. Then the posts were rinsed under running water and then dried with oil-free compressed air to remove the remnants for 20s.

Hydrofluoric acid etching

Posts surfaces were etched with 9.5% hydrofluoric acid (Ultradent Products, Inc., South Jordan, UT) for 20sec and rinsed with distilled water for 30sec and air dried for 2 sec.

Er,Cr:YSSG laser irradiation

Er,Cr:YSSG laser irradiation (150 mJ, 10 Hz) was delivered on the specimens. Laser irradiation was performed in free running pulse mode by a 4mm diameter titanium articulated arm transmission system. In addition, a special holder was used in order to fix an application distance of 10mm. Laser irradiation was applied for 20s with a water-cooling device and119.42J/ cm2 of energy density was used.

Surface roughness testing

Following surface treatments, the arithmetic means of the absolute distance of roughness profile (Ra μm) values was recorded with surface profilometer (Taylor Hobson Ltd. Leicester, UK, England). Four readings were taken from each sample and the mean of the four readings was calculated to represent each post. Readings were obtained from a 5mm radius stylus passing across 0.8mm length at 1mm/s to the nearest 0.01mm.

Scanning electron microscopic examination

The posts surface were then evaluated and photographed using a scanning electron microscope (JSM-5200, JEOL, Tokyo, Japan) to analyze surface changes of the fiber posts at 500x magnification. SEM was operated in the secondary electron (SE) mode under 20kV accelerating voltage in vacum (3x10 - 4 Pa) and 80 lA beam current.

Statistical analysis

Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution. 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 $P \leq 0.05$.

Results

Results of surface roughness testing

The mean and standard deviation of Ra values (μm) and the significance between all groups before and after surface treatments are shown in Table (1). Results revealed a statistically significant difference in the mean Ra value between the control group and all the tested groups ($p<0.001$), which revealed the lowest mean Ra value. Group III on the other hand showed the highest significant mean Ra value when compared with all the tested groups ($p<0.001$). No statistical significant difference was found in mean Ra values between group II and the three subgroups treated with Er,Cr-YSGG laser. Results also revealed a statistical insignificant difference in Ra values between the three subgroups treated with Er,Cr-YSGG laser.

Table (1): Summary of results of One-way ANOVA followed by Tukey post hoc test for Ra values obtained by profilometer

Variables	**Ra value (μm)**	
	Mean	**SD**
Group I (Control)	0.824 c	0.092
GroupII (HF)	1.174 b	0.007
GroupIII (SB)	2.661 a	0.486
Group IV (Er,Cr:YSSG)		
Subgroup A(0.5W)	1.154 b	0.052
Subgroup B (1W)	1.265 b	0.109
Subgroup C (1.5W)	1.416 b	0.006
p-value	**<0.001***	

Means with different letters indicate significant difference, while means with the same letters indicate non-significant difference.*; significant ($p<0.05$).

SEM results

Representatives scanning electron (original magnification x500) micrographs of different groups are presented in fig.(1a-f). Scanning electron micrographs (SEM) revealed irregularities of treated posts surfaces had. The control untreated post (figure 1a) and hydrofluoric acid treated post (figure 1b) exhibited more flat uniform surfaces, with small porosities than sandblasted (figure 1c) posts and Er,Cr:YSGG treated posts (figure 1d-f) . Distinctive irregularities, fiber rupture and cracks was revealed regarding sandblasted (figure 1c) posts and Er,Cr:YSGG treated posts (figure 1d-f) . Group IV (Er, Cr:YSGG), revealed shallow pits; however, subgroup c (Er, Cr:YSGG,1.5W) showed more cavities than subgroup a (Er, Cr:YSGG,0.5W).(fig.1)

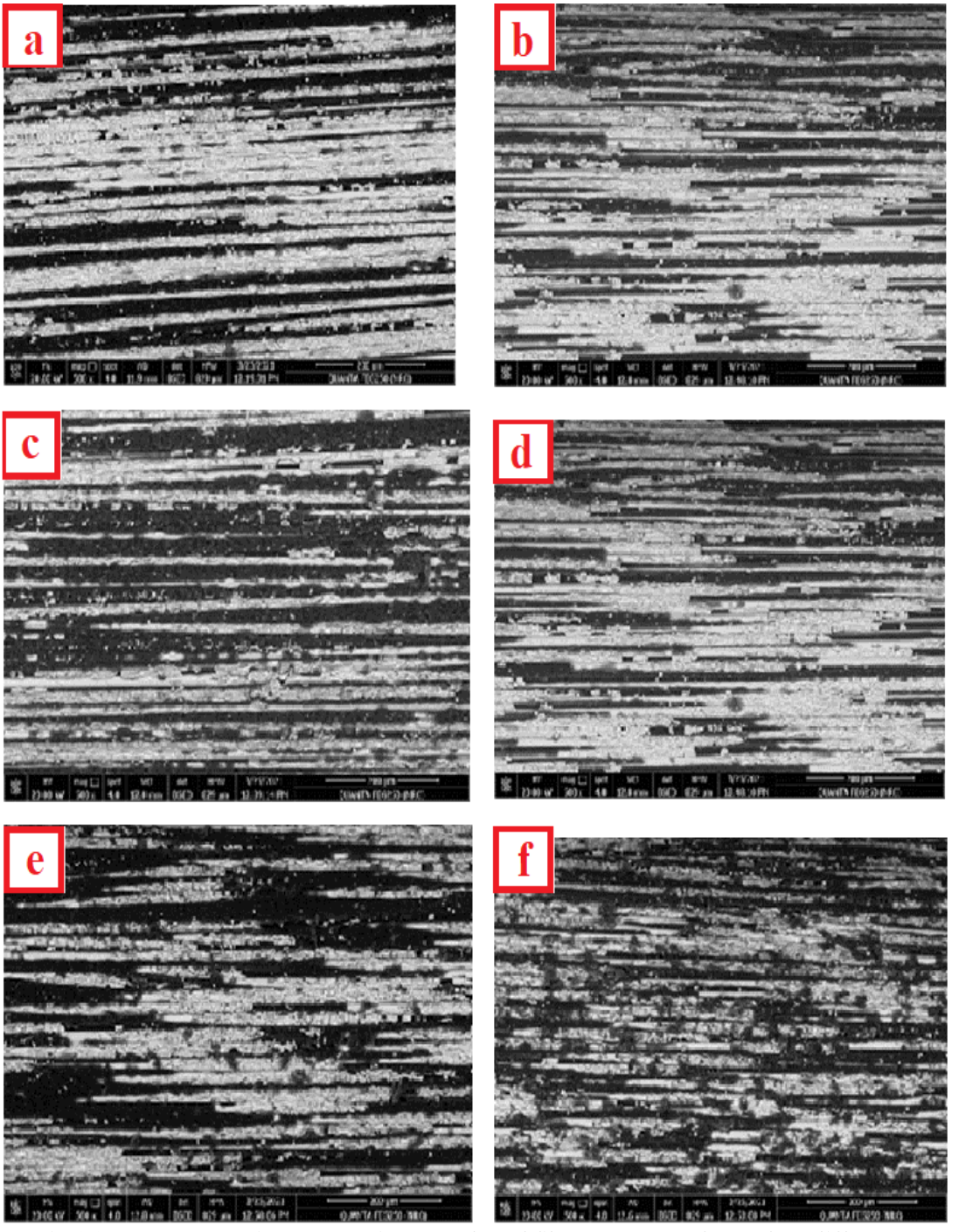

Fig.(1): Representative SEM micrographs of fiber posts surface after different surface treatment: (a) control, (b) hydrofluoric acid etching, (c) sandblasting, (d) Er,Cr:YSGG (0.5W), (e) Er,Cr:YSGG (1W), (f) Er,Cr:YSGG (1.5W). (X500)

Discussion

Studies showed that failure of endodontically treated teeth, restored with fiber posts; were mainly the result of debonding and post fracture [15]. The chemical and mechanical surface treatment has been selected according to previous studies that reported their ability to modify the surface topography thus improving the bond strength as well as the fracture resistance. The composite structure of fiber posts, represent a problem when processing composites with lasers. Composites are, by their inhomogeneous nature formed of pre-stretched fibers embedded in resin matrix characterized by different melting points and different absorption properties. Studies revealed that surface changes after laser irradiation is the result of loss of resin matrix and exposure of filler particles[16]. Previous studies revealed that Er:YAG lasers, cause ablation and thermal effects, where rapid melting occurs upon Er:YAG laser irradiation resulting in large expansion forces due to the volume increase upon melting and thermal vaporization. This also results in explosive ejection of material and thus ablation craters[17].

Different experimental setups have been used in the literature where different lasers parameters was used such as energy, output power and pulse duration and was found to produce different results. Based on results of previous studies[18], Er,Cr:YSGG laser 0.5W, 1W, 1.5W (150 mJ, 10 Hz) were selected. In the present study, surface treatment of fiber posts with different laser parameters exhibited different surface roughness values. Er,Cr:YSGG laser (1.5W) demonstrated higher surface roughness value (Ra) than 0.5W and 1W. SEM micrograph revealed larger cavities due to separation among the fibers by removing the inter fiber area.

Aluminum oxide sandblasting showed the highest mean roughness values, where sandblasting through the use of abrasive particles resulted in discontinuities between the fibers and even their fracture causing more destruction of post structure. However, hydrofluoric acid had the lowest surface roughness values. Surface roughness results regarding hydrofluoric acid etching is in agreement with previous studies, where little success was demonstrated and was attributed to the extreme corrosive effect of hydrofluoric acid on the glass fibers phase[19,20].

Conclusion

Sandblasting and Er,Cr:YSGG 1.5W showed the highest surface roughness values with destruction of fiber post integrity. Future investigations could focus on which parameters are more suitable for improving mechanical properties of fiber post.

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