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Surface Alteration Of Zirconia Ceramics After Erbium Lasers Irradiation

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ABSTRACT

Purpose: This study evaluated the surface roughness of zirconia treated with erbium-doped yttrium aluminum garnet 2,940 nm (Er-YAG) andErbium chromium: yttrium scandium gallium garnet 2,780 nm (Er,Cr:YSGG)

Materials and Methods: fifty disc-shaped zirconia specimens (10 mm in diameter and 8 mm in thickness) were fabricated by a computer-aided design andcomputer-aided manufacturing (CAD/CAM) system according to the manufacturer's instructions. Samples were divided into five groups (n = 10). One group as control, was air-particle abraded with Al_2O_3 particles. For the laser treatment groups, laser irradiation was applied at two different pulse lengths (long pulse and ultra-short pulse) and for scanning times 15 sec, Surface roughness was evaluated with contact profilometer and specimens were evaluated with scanning electron microscopy (SEM). Data were analyzed by ANOVA test.

Results: there is statistically difference between sand blast (control group) and laser groups (test groups) $p<0.5$.
Sand blast more effective than laser etching methods, also no significance difference between long pulse and short pulse in the laser groups $p>0.5$, However, laser type and pulse length not effective in surface roughness according to this study.

Conclusion: Erbium laser etching may be an alternative to air-particle abrasion for zirconia ceramics to improve surface roughness for better adherence to luting agents.

Keywords: Zirconia; Roughness; Er-YAG Laser; Er,Cr:YSGG laser.

INTRODUCTION

The name zirconia refers to zirconium dioxide (ZrO2), which was first found in 1789. Zirconia was first utilized in biomedical research in 1969, as it was used as a surgical implant(Anusavice, 1996). Zirconium oxide ceramics are common in prosthodontics fields especially after evolution of CAD/CAM (computer-aided design and manufacturing) technology, that expand the use of this material. Zirconia has superior properties such as high compressive strength, high esthetic quality, chemical stability and thermal expansion coefficient comparable to hard dental tissues. It is a substitute for metal substrate for crowns and bridges, implant abutments, and post-core systems (Usumez et al., 2013). In compared to other ceramics like feldspathic, lithium disilicate-based, leucite, and silica-based ceramics, Zirconia ceramic has a significant disadvantage in the etching process.By hydrofluoric acid etching and silanization, such ceramics can form adhesive bonds.Because of silica and glass phase in zirconia ceramics, such methods are not applicable. Chemical bonding with silane is ineffective as well (Yun et al., 2010).Surface treatments raise the micro-irregularities on the ceramic, which improves mechanical retention.

Coarse grinding, diamond bursing, air-particle abrasion using silica coating, Al2O3 particles, acid etching, or any combination of such techniques are among the possible treatments(Akin et al., 2014).According to the majority of studies in this sector, airborne particle abrasion using Al2O3 particles is one of the most successful ways for increasing bond strengths for oxide-ceramics like zirconia and alumina (Miyazaki et al., 2013).An in vitro research found a five-year follow-up survival rate of more than 90% after surface alteration using the sandblast method (Sassea & Kernb 2013). Grinding and sandblasting, on the other hand, have been claimed to cause phase change from t–m due to shrinkage potential by certain studies (Chevalier et al., 2009) Delamination or chipping difficulties after zirconia surface treatment have been observed in studies as a prevalent possible issue. The incidence rate of delamination problems in veneer ceramics was observed to be 2.9 percent for metal-ceramic and 2.8 percent for zirconia after five years. Furthermore, another study found that zirconia crowns had greater failure rates between 24 and 60 months of follow-up (Pjetursson et al., 2018).Since Maiman developed the first ruby laser applications in 1960, lasers have really been frequently employed in medical and dentistry. Laser treatment of dental materials is a relatively new field of study, particularly for ceramics. This is done with “Erbium: yttrium-aluminum-garnet (Er:YAG) and Neodmium: yttrium-aluminum-garnet (Nd:YAG) lasers”(Dilber et al., 2012).Researchers are currently concentrating on laser technology as a modern method to improving the surface characteristics of ceramic materials. Er:YAG, Nd:YAG, and CO2 lasers are three of the most popular kinds of lasers used in the area (Arami et al., 2014). Ceramic materials have previously been shown to be able to absorb wavelengths sufficiently to allow laser therapy (Abdullah et al., 2019). Recently, a Ti:Sapphire laser has been created, which produces ultra-short pulses in the femtosecond range and is regarded an ideal alternative since it causes no thermal or mechanical harm to a ceramic surfaces (Vicente et al., 2016a, Vicente et al., 2016b,Varel et al., 1997 and Fiedler et al., 2013).The Er:YAG (2940 nm) laser and the Er,Cr:YSGG (2790 nm) laser are the two most popular erbium laser wavelengths used in dentistry. They have a high water and hydroxyapatite absorption rate, making them suitable for 'optical drilling' in enamel, dentin, and composite (Hibst, 2002). It's difficult to compare these lasers based on previously published research since they vary not only in wavelength but also in other laser characteristics such as energy, pulse duration, and spatial beam profile.The objective of this in vitro investigation is to determine the surface roughness of zirconia ceramic surfaces following Er:YAG laser etching, Er,Cr:YSGG laser etching, and airborne particle abrasion. On the surface roughness of Y-TZP, varied scanning durations and pulse lengths of Er: YAG and ER CR: YSGG laser applications were used. The null hypothesis stated that laser roughness would not improve as contrasted to particle roughness.

MATERIALS AND METHODS

Fifty ceramic specimens with dimension of 10 mm diameter and 8mm thickness were prepared from pre-sintered zirconia disk ceramic material, was cutting with CAD–CAM machine (GmbH, Eiterfeld, Germany).All zirconia blocks were ultrasonically cleaned in 96 percent isopropanol for 3 minutes, then dried in oil-free air before surface treatment, according to a well-known procedure utilized in prior investigations (Aboushelib et al., 2007, Cavalcanti et al., 2009 and Blatz et al., 2003).

The samples were then split into 5 groups (N=10) at random: -

G1 (control sandblasting): The zirconia surfaces were sandblasted by a sandblasting machine

“(Micro etcher ERC sand blaster, Danville, CA, USA) with 50-micron Al_2O_3 particles from a distance of 10mm and at a pressure of 20 psi for 5 seconds” (Kumbuloglu et al., 2006).This group did not get any surface conditioning.

Laser groups (G2-G5): The specimens were treated by using two types of erbium lasers:

1) Er,Cr:YSGG laser (Waterlase; Biolase Technology, San Clemente, CA, USA)) at 2780 nm angled biolase gold dental hand piece with fiber-optic tip for tooth preparation was used at an incidence angle of 90° with water irrigation.

2) Er: YAG laser “(Fotona light walker AT, Ljubljana, Slovenia) 2940 nm where a 90°-angled dental hand instrument (R14-C, Fotona)” with a sapphire cylindrical fiber-optic tip was utilized with water irrigation at a 90° incidence angle;

- G2: ER CR ultrashort pulse 15sec scanning time.
- G3: ER CR long pulse 15sec scanning time.
- G4: ER YAG ultrashort pulse 15sec scanning time
- G5: ER YAG long pulse 15sec scanning time.

Exposure parameters as power, frequency, non-contact mode of application, air and water percent (4.5 w 15 HZ 60% water 60% air (were adjusted for the two laser units before irradiation for standardization The distance of laser application was range 2-4 mm in all groups. water irrigation was determined automaticallyat high powers with increasing of the temperature,

Preparation of Samples for Profilometric Analysis: The samples were cleaned by soaking them in 1 percent sodium hypochlorite for 24 hours. To enable the measurement of roughness metrics, organic debris was thoroughly cleaned using an ultrasonic cleaner, Using self-cured resin material, all of the specimens were placed into a brass mold, sufficiently isolated from all sources of vibration (Cerci et al., 2012),Zirconia surface roughnesswas described by Ra parameters found with a profilometer. Surface roughness (Ra) is a measurement of the finer imperfections in the surface texture generated by the action of the manufacturing process or the material condition, and it is measured in micrometers.Three roughness measures were assessed using a profilometer “(Ra, µm) a diamond stylus of tip radius 2 µm and tip angle 60° was used. under a constant load of 5 N with a measuring speed of 0.5 mm/s”. Ra was measured from the graph by taking an arithmetic average of the absolute values of the profile heights over an evaluation length of Ra averaged all peaks and valleys of the roughness profile and then neutralized a few outlying points so the excessive points had no marked influence results (Walia et al., 2019). The specimens used in profilometry were coated in gold-palladium to measure surface morphology “(Quorum Technologies Polaron SC7620, Newhaven, East Sussex, UK) and observed under SEM (JSM-6610 LV Scanning electron microscope, JEOL USA)” with 2000X magnifications and 15 kV voltage for all samples (fig 1-5).

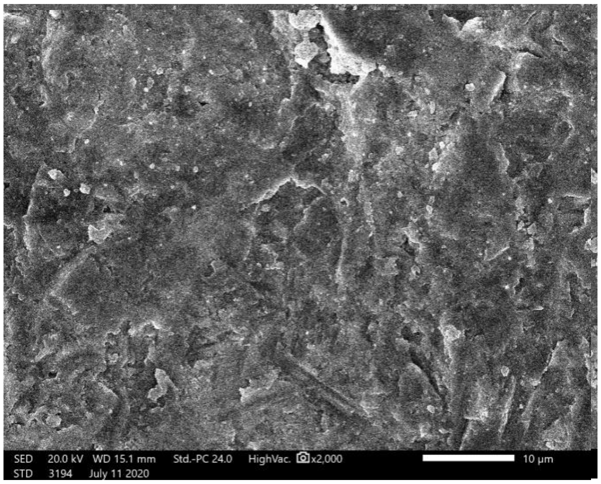

Fig.1: An SEM microgragh (2000x) of a specimen treated with sand blast control groupe G1

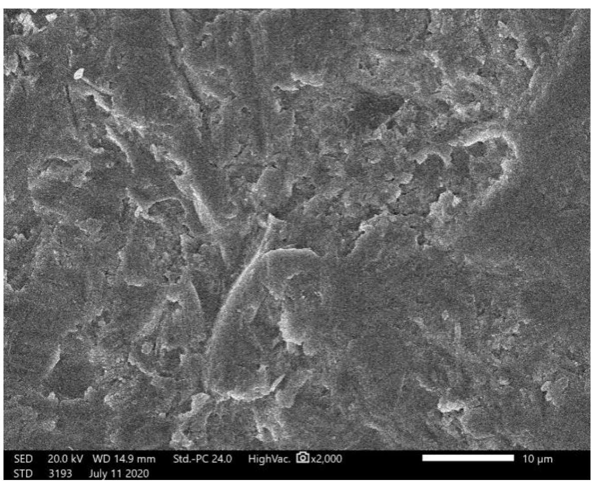

Fig.2: An SEM micrograph (2000x) of a specimen treated theER CR laser ultra-short pulse 15sec G2

Fig.3: An SEM micrograph (2000x) of a specimen treated the ER CR laser long pulse 15sec G3

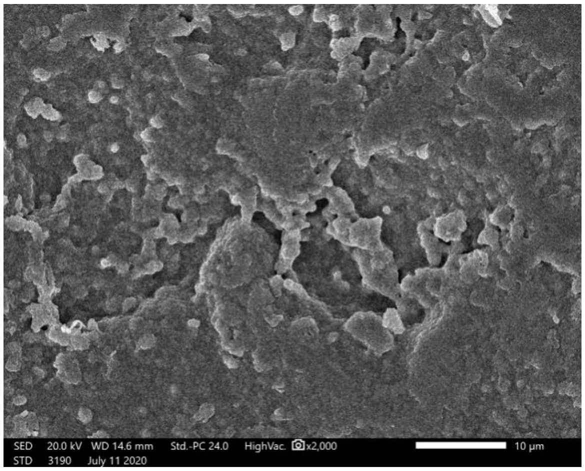

Fig.4: An SEM micrograph (2000x) of a specimen treated the ER yag laser ultra-short pulse 15sec G4

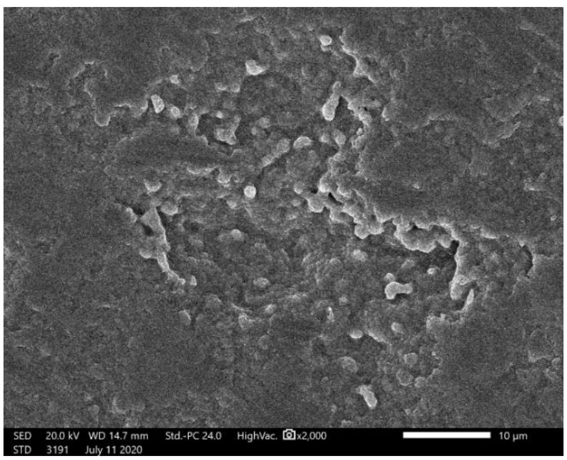

Fig.5: An SEM micrograph (2000x) of a specimen treated the ER yag laser long pulse 15sec G5

RESULTS:

Results of the current work represent the roughness resulting effect by the Erbium Yag laser and Erbium Chromium laser against sandblast roughness effect. The present data in table (1) is showing the descriptive statistics of different treatments. The experiment was designed to compare both laser types long and short pulses at time exposure (15 sec.) against control (sandblast) fig (6). Data is represented by mean and standard deviation as well as the range of data. Number of samples in each group was 10 for all experimental variables

Table (1): Descriptive statistic of ultra-short & long pulse for ER-Cr & ER-YAG in comparison to sand blast.

Desc. Stat.		Mean ± SD	Range
Sand blast		0.89 ± 0.05	0.78 - 0.98
ER Cr	**Ultra-short pulse**	0.67 ± 0.19	0.39 - 1.03
	Long pulse	0.65 ± 0.27	0.28 - 1.04
ER YAG	**Ultra-short pulse**	0.61 ± 0.19	0.32 - 0.88
	Long pulse	0.65 ± 0.25	0.19 - 1.17

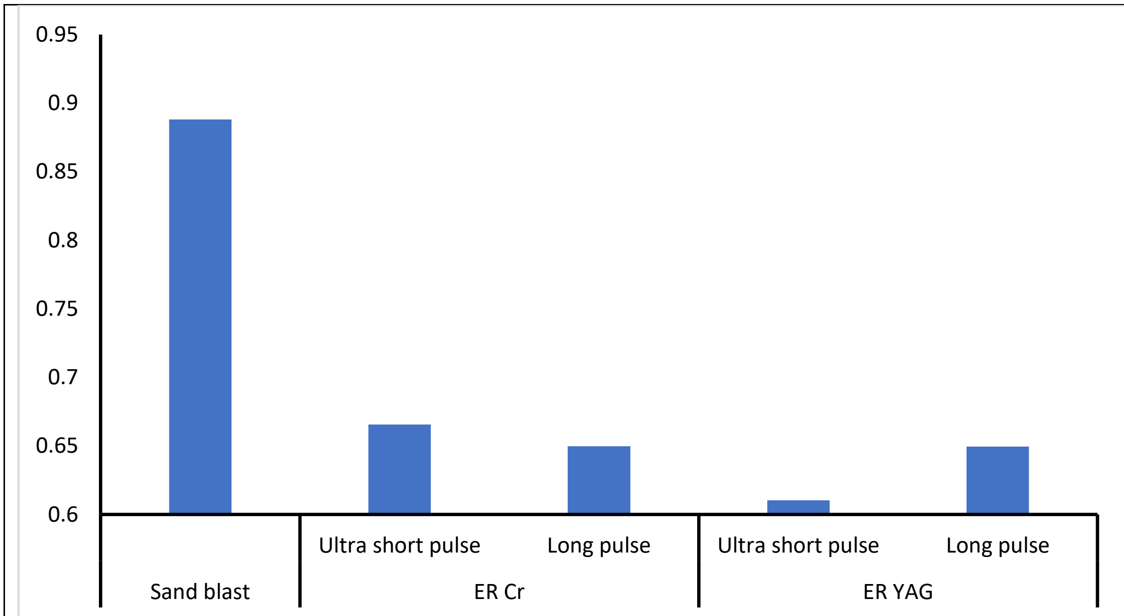

Figure (6): Charts shows the mean value of Er-Cr & Er-YAG in ultra-short & long pulse in comparison to sand blast.

<u>One way analysis of variance:</u>

Surface roughness newly was resulting by the Erbium Yag laser and Erbium Chromium laser in contrast to sandblast roughness maker. The present data in table (2) and fig (6) is showing the one way ANOVA for Ultra-short pulse for both ER Cr and ER YAG against sand blast. Ultra-short wave length has been used as roughness producer from 10 replicates of each group. Normality test (Shapiro-Wilk) passed at

(P=0.295). There is a statistical difference (P = 0.002) in the mean values of the treatment groups, which is higher than would be anticipated by chance. Furthermore, (Holm-Sidak test) has been interpreted at overall significance level (P<0.05) between sand blast and the other two types of laser. Both laser types have significant P-value in comparison to control sand blast, table (2A& 2B).

On the other side, the one way ANOVA with long wave length. The type of laser wave length (pulse) has been performed based on the roughness values results from 10 replicates of each group. Normality (Shapiro-Wilk) test passed at (P=0.510). By the way, the source of variance has equal variance (P<0.050). The variations in mean values across treatment groups were more than would be anticipated by chance; the difference is statistically significant (P = 0.036).Over and above that, (Holm-Sidak test) has been interpreted at overall significance level (P=0.05) between sand blast and the other two types of laser. Both laser types have significant P-value in comparison to sand blast, table (2C& 2D).

Table (2): Statistical analysis: A; One-way at 15 sec, B; Holm-Sidak test at 15 sec, C; One-way at 60 sec, D; Holm-Sidak test at 60 sec.

A	**Source of Variation** U. short P.	**DF**	**SS**	**MS**	**F**	**P**
	Between the Groups	2	0.432	0.216	7.780	0.002
	Residual	27	0.750	0.0278		
	Total	29	1.182			

B	**Comparison** U. short P.	**Diff of Means**	**t**	**P**	**P<0.050**
	Sand blast vs. ER YAG	0.278	3.726	0.002	Yes
	Sand blast vs. ER Cr	0.222	2.984	0.006	Yes

C	**Source of Variation** Long P.	**DF**	**SS**	**MS**	**F**	**P**
	Between the Groups	2	0.379	0.189	3.780	0.036
	Residual	27	1.353	0.0501		
	Total	29	1.731			

D	**Comparison** Long P.	**Diff of Means**	**t**	**P**	**P<0.050**
	Sand blast vs. ER YAG	0.238	2.382	0.048	Yes

	Sand blast vs. ER Cr	0.238	2.381	0.025	Yes

Two way analysis of variance (laser wave length effect in type of laser)

Two way ANOVA (table, 3) between the laser type and the laser wave length. Laser wave length varied in parallel to type of laser type based on the roughness values results from 10 replicates of each. Normality (Shapiro-Wilk) test has been passed at (P=0.903). Moreover, the source of variance in this groups means laser types and laser wave length with equal variance (P=0.482). After accounting for the impacts of variations in Period, the difference in mean values across the three laser types is not significant enough to rule out the possibility that the discrepancy is attributable to random sampling variability. The difference is not statically important (P = 0.715). After accounting for the impacts of changes in Technique, the difference in mean values across the different levels of Pulse duration is not significant enough to rule out the possibility that the discrepancy is attributable to random sampling variability. The change is not statistically significant (P = 0.877). The impact of various types of lasers is independent on the amount of Pulse wave length present. The relationship between laser types and laser wave length is not statistically significant (P = 0.716).

Table (3): Statistical analysis: Two-way between different type of laser and laser wave length.

Source of Variation	DF	SS	MS	F	P
Laser types	1	0.00767	0.00767	0.135	0.715
Exposure period	1	0.00137	0.00137	0.0241	0.877
Laser x Period	1	0.00762	0.00762	0.134	0.716
Residual	36	2.045	0.0568		
Total	39	2.061	0.0529		

DISCUSSION

The purpose of this study was to investigate the effect of different pulse lengths of Er: YAG and ER CR: YSGG laser applications on the surface roughness of Y-TZP.

The conversion of light energy into heat is the primary effect of laser energy, and the absorption of laser energy by the substrate is the most critical interaction in between laser and the substrate(Coluzzi, 2004).The quantity of energy absorbed by the irradiation surface is determined by pigmentation and water content, beside other surface properties.Incident energy is absorbed by water molecules located in dental crystalline structures and biological components on dentinal surfaces. During hard tissue ablation, the laser causes micro explosions, resulting in macroscopic and microscopic imperfections that may form the adhesion surface. However, zirconia ceramic is a water-free substance with an opaque colour that may affect laser energy absorption. Additionally, temperature fluctuations may have a detrimental impact on the mechanical characteristics of zirconia ceramics, resulting in phase transition.

There are a lot of studies to get a strong bond between zirconia restoration and tooth structure as sandblasting, chemical etching and mechanical roughness to enhance retention of zirconia but also, they weaken the mechanical properties. there for recently laser etching can improve surface treatment of zirconia without weakening of mechanical properties.

Sandblasting was determined to be the most effective treatment for roughening the surface of Y-TZP ceramics, according to our findings. Different Er: Yag and Er cr: ysgg laser irradiations cause the Y-TZP ceramics to have less roughness. Following laser irradiation, surface roughness values were nearly identical to those in the control group.

Miranda et al., (2015), evaluated “the surface roughness on Y-TZP surface after Er: YAG laser treatment at 1.5 W/20 HZ found that laser irradiation caused a decrease on surface roughness,in the same study he used maximum 300 mJ output power of the Er: YAG laser with various pulse widths and it was found that it did not roughen the Y-TZP surfaces, he also evaluated the surface roughness on Y-TZP surface after Er, Cr: YSGG laser irradiation at 1.5 W/20 Hz and found that laser irradiation decreased the surface roughness.”

According to (Demir et al. 2012), air abrasion or a 400 mJ Er: YAG laser can be used to enhance micromechanical retention of zirconia; yet, air abrasion is found to be a substantially higher surfaces treatment technique than the control group and other modes of Er: YAG (200, 300, and 400 mJ).

Research evaluated the effect of Er: YAG laser irradiation upon roughness of the surface of zirconia disks, and concluded that reinforcing irradiation intensities.Increasing the irradiation duration will not increase the binding strength of zirconia ceramics, and may result in material defects (Lin et al., 2013).They made use of One control group (without treatment), one air abrasion group, and nine Er: YAG laser groups were created from zirconia ceramic pieces that were randomly split into 11 groups based on surface treatments. Various energy intensities (100, 200, or 300 mJ) and irradiation durations were used to separate the laser groups (5, 10, or 15 sec). Following surface treatments, surface roughness was measured. Alumina particles with air abrasion can obviously improve bonding property of zirconia ceramics to resin cement Er: YAG laser irradiation is not recommended as a surface pretreatment before the bonding of clinic zirconia restorations. The binding strength in between control group and the laser groups handled with varied energy intensities or irradiation durations was not significantly different.

In compared to the earlier research, numerous studies found that irradiating zirconia ceramic surfaces with Er: YAG and Er:YAG lasers increased surface roughness.

Kirmali et al. (2013) investigated air abrasion, no treatment, laser etching (Er: YAG and Nd: YAG lasers), and combinations of these laser applications and sandblasting on pre-sintered zirconia, they found that sandblasting and Er: YAG laser treatments on pre-sintered ZrO2 substructures considerably enhanced surface roughness values.

CONCLUSION

Within the limits of this study the following conclusions could be withdrawn:

1.Recycling, re-cementation of dislodged zircon crowns and bridges, repair fracture parts intraorally and adhesion of displaced veneer layer on zirconia core intraorally; Laser can do that intraoral and at the same visit instead of lab procedures for sand blasting.

2.The formation of micro retentive grooves, distortion of zirconia crystals morphology, and fracture propagation were all observed in the sand blasted group, all of these features result in weak restoration liable to fracture on function

3.Recycling ceramic orthodontic ceramic brackets and re-bonding zircon laminate veneers could be done with laser roughness immediately in the dental office

Conflict of interest

No competing financial interests exist

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