The Influence of Short Pulse Er:Cr: YSGG Laser on the Shear Bond Strength of Cad-Cam Zerconia Material to Resin Cement

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Abstract

Background: Surface enhancement of CAD-CAM zerconia for increasing the matching to resin cement, using Er:Cr:YSGG Laser.

Materials and Methods: 40 sintered zerconia disc specimens(VITAYZ HT) were prepared. They are dividedinto six groups, each group of seven samples.Laser groups are depending on laser power, laser irradiation time and pulse duration, group(A): 20 s, 60µs pulse duration. Group (B): 30 s , 60 µs pulse duration. Group (C): 40 s, 60 µs pulse duration. Group (D): 20 s, 700 µs pulse duration. And group (E): 30 s, 700 µs pulse duration, for different powers (1, 1.50, 2, 2.50, 3, 3.50, 4) W.Luting cementwas bonded to treated zerconia surfaces and light cured for 40 s.The Shear bond strength was measured using a universal testing machine. The optained results were stastistically analyzed. Thebond failur modes were also examined.

Results: There was a clear increment in the shear bond strength especielly in group B (4 W, 30 s,60 µs) reaching to 8.63 Mpa.No crackes were observed.

Conclusion: It was detected that the shear bond strength was related to the pulse depth.The pulse duration of Er:Cr:YSGG is a crucial parameter in the enhancement of zirconia ceramic surface.

Keywords: *Er:Cr:YSGGLaser,zirconia surface treatment,pulse duration,Shear Bond Strength.*

Introduction

The most popular technology that was becoming the centre of choice in dental restorations is all-ceramic restoration.[1]One of the most frequently used all-ceramic core material for fixed restorations (crown and bridge)is yttrium-stabilized- tetragonal-zirconia-polycrystal (Y-TZP).[2] The clinical long-term success of Y-TZP depends to a great extent on the strength and durability of resin cement bond to ceramic substrates and teeth that have to integrate all system parts into one coherent structure for enhancing the bonding strength of ceramic dental restorations.[3] A strong cement-ceramic bond requires micromechanical interlocking and chemical bonding to the ceramic restoration surface, which needs surface roughening procedure and cleaning.[4]Polycrystalline structure, which lacks a glass matrix, makes zirconia ceramic more resistant to hydrofluoridric acid etching.[5]Chemical and /or mechanical surface treatments provides a reliable adhesive bonding of resin cements and ceramic.[6]Air-borne particle abrasion,[7]grinding with dimond bur, sandblasting, zirconia primers,[8]tribochemical silica coating (silicatization)have been applied for surface conditioning.[9] Airborne particle abrasion has the potential of removing significant amount of material which could affect their clinical adaptation. Tribochemical silica-coating system has been criticized for possibility of subcritical crack propagation within zirconia in case of thin restorations.[10]Lasers have been employed for different purposes in dentistry including conditioning the tooth structure or restorative surfaces.[11]Studies showed that roughening can be performed on ceramic surfaces with lasers,[12]by using different lasers such as: Nd:YAG,[13]Er:YAG and CO2,[14-15] Er:Cr:YSGG,[16]femtosecond,[17]and Factional

CO2.[18]The current study aims to investigate the effect of pulse duration on the SBS for different powers of Er:Cr:YSGG laser.

Material and Method

In this experimental study, 40discs were milled from presintered zirconium oxide blocks(vita YZ HT zahnfabrik/Germany), thensinteredin a special furnace (Zirkonzahn, type: Oven600-2018) at 1450 °C for 8hours including cooling, following the manufacturer's instructions. The optained final disc diamensionwas:(9 mm in diameter, 2 mm in thickness).The bonding surfaces of zirconia discs were then polished consecutively with 600, 800,1000 and 1200 grit silicon carbide abrasive papers with water coolant to standardize all surfaces. All specimens wereultrasonically cleaned in distilled water and 7o% alcohol for 3 min. And examined under an optical microscope.Samples with cracks or fissures were substituted by other perfect ones.

Specimens grouping:

40 zirconia discs were randomly divided into six groups, each with seven samples.g\Group (O): Serve as control group with no applied surface treatment. The laser groups are:Group (A): 20 s, 60 µspulse duration, group (B):30 s, 60 µs pulse duration, group (C): 40 s, 60 µspulse duration, group (D):20 s, 700 **µ**s pulse duration, and group (E): 30 s, 700 µs pulse duration.For different powers(1, 1.5, 2, 2.5, 3, 3.5, 4) W.

Each zirconia disc bonding surface was irradiated withEr:Cr:YSGG laser of λ= 2,780 nm (iPlus, Waterlase, Biolase Technologies Inc., Irvine, CA, USA) at 50 HZ,water/air level: 65/ 55%.600 µm quartz core tip was put at 90º with sample surfaceand 1 mm distant from it. The laser energy was delivered in a circular area of 6 mm diameter at the middle of the specimens. Then, each zirconia disc was embeddedhorizontally in a mixed cold cure acrylicmold, to about 1.5 mm.And the 0.5 mm of theremaining zirconia disc height left exposed for the cementingprocedure.A circular silicon moldprovided with a central circular opening of 5 mm diameter was positioned over the acrylic mold in a way that the circular opening of the silicon mold was centered on thezirconia disce. Adiquate amount of adhesive cement (Relyx U200 self adhesive resin cement, paste/paste mixing system, 3M ESPE, Germany) was mixed and delivered into the opening of the silicon mold.Then photopolymerized using a light cure system (Astralis5, Ivoclar Vivadent, 220-240V, 50-60 Hz, Liechtenstein) for 40 s following manufacturer's instructions. And one hour after cementation, specimens were stored in distilled water at 37 °C for 24 hours before SBS testing.

The SBS was determined by subjecting the samples to a shearing force at zirconia-cement interface in a universal testing machine (Instron, England). The SBS values evaluated in Mpa. The (LPD) were examined by an optical microscope with power mag. of 40X. All debonded samples were evaluated under a stereo microscope (ME, 2665, Euromex, Holland) at 40X mag. The mode of failure was classified as follows: (1) Adhesive: de-bonding only at the cement-ceramic interface. (2) Cohesive: rupture in the cement or zirconia ceramic. (3) Mixed: shows both adhesive and cohesive failure modes.

Surface Analysis:

Samples from all groups Underwent coating with gold-palladium (Q150R RotaryPumpedSputter Coater, Quorum Tec., UK) and observed under scanning electron microscope(SEM) (Inspect S50, FEI, USA) , 500X mag. and 30.00 kV voltage.

Statistical Analysis

This analysis was done with SPSS software version 23/France. SBS and LPD Data were analyzed by one way ANOVA-test (analysis of variance) to calculate the P value between control and tested groups. LSD test was used to calculate the significant differences between tested means.

Results: Surface Analysis

The SEM pictures of zirconia disc surfaces is shown in Fig.1(a-f) .The effect of laser energy pulses on the surfaces is observed as holes with no altering in the surface texture surrounding each laser pule. No obvious cracks were seen. Therefore, no laser optical damage.

ABC

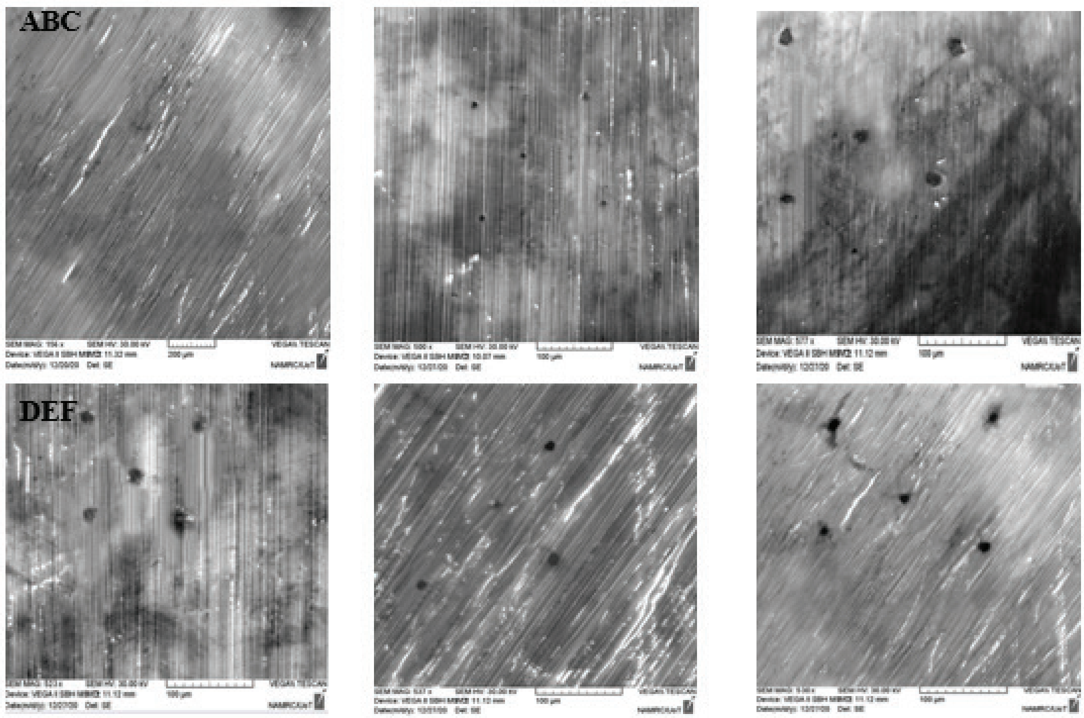

Fig. (I): SEM Pictures of Zirconia specimens (500X). a .Control (untreated) Specimen. b. (20 I.T./60μ).c. (30 I.T./60μ).d.(40 I.T./60μ).E.(20 I.T./700μ).F.(30 I.T./700μ).

DEF

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Table (I) and (II) presenting the descriptive statistics of the SBS. Also the statistical analysis results of SBS and LPD for comparison among the laser groups. The specimen treated with Er:Cr:YSGG laser 30 s, 60 μs, 4W exhibited the highest SBS value. The SBS means increased with increasing the laser power for groups of 60μs. Table (II) clearly show an increase with LD for all groups with power increasing exceptfor group D. The specimen (4W, 30s, 700μs) had The hightest LPD mean and it was NS with specimen (4W, 30s, 60μs) however, the SBS was not increased with depth increasing.

Table (I): Shear Bond Strength and laser irradiation time Measurements of the Groups.

Power/ Shear bond	20 sec/60 μ		30 Sec / 60 μ		40 Sec /60 μ		20 Sec /700 μ		30 Sec /700 μ			
	SBS Mean	Std. Error	SBS Mean	Std. Error	SBS Mean	Std. Error	SBS Mean	Std. Error	SBS Mean	Std. Error	P value C VS G	P value L.G
1W	C 5.24	0.20	C 6.26	0.12	C 5.94	0.41	6.84	0.33	5.79	0.91	0.01	NS
1.5W	C 5.30	0.13	B 6.76	0.30	C 5.44	0.10	6.80	0.68	6.49	0.43	0.01	NS

2 W	C 5.79	0.25	C 6.44	0.30	B 6.14	0.15	6.74	0.00	6.53	0.17	0.001	NS
2.5 W	C 5.86	0.42	C 6.33	0.46	B 6.24	0.03	6.51	0.33	6.59	0.11	0.001	NS
3 W	B 6.16 d	0.03	B 6.86 b	0.37	A 6.56 c	0.00	6.91 b	0.42	7.44 a	0.54	0.0001	0.05
3.5 W	B 6.79 c	0.05	B 6.96 b	0.00	A 6.99 b	0.20	7.05 b	0.20	7.64 a	0.02	0.0001	0.01
4 W	A 7.23 b	0.14	A 8.63 a	0.13	C 5.74 d	0.00	6.94 b	0.02	6.48 c	0.19	0.0001	0.001
CONTROL	4.49	0.16	4.49	0.16	4.49	0.16	4.49	0.16	4.49	0.16	------	-------
*P value C VS L.G.	0.0001		0.0001		0.0001		0.0001		0.0001			
P value L.G	0.01		0.01		0.001		NS		NS			

Tabel (II): LPD and laser irradiation time Measurements of the Groups.

Power/ Depth of laser	20 sec/60 µ		30 Sec / 60 µ		40 Sec /60 µ		20 Sec /700 µ		30 Sec /700 µ		* P value
	Pulse depth Mean	Std. Error	Pulse depth Mean	Std. Error	Pulse depth Mean	Std. Error	Pulse depth Mean	Std. Error	Pulse depth Mean	Std. Error	
1W	D 1.70 c	0.40	E 2.10 b	0.30	F 4.50 a	0.35	2.67 b	0.69	C 2.00 b	0.20	0.05
1.5W	C 2.30 d	0.21	D 4.20 a	0.15	E 3.90 b	0.10	3.40 c	0.00	C 2.30 d	0.10	0.01
2 W	C 2.00 d	0.15	D 4.80 b	0.56	D 4.50 b	0.12	3.70 c	0.40	B 6.20 a	0.21	0.01
2.5 W	C 2.50 d	0.12	D 4.70 b	0.53	C 6.2 a	0.72	3.50 c	0.29	B 6.30 a	0.56	0.001
3 W	B 3.00 d	0.00	C 6.00 c	0.23	B 7.50 a	0.20	3.50 d	0.25	B 6.50 b	0.12	0.001
3.5 W	A 4.10 c	0.51	B 6.90 b	0.06	A 8.00 a	0.58	3.30 d	0.15	A 7.90 a	0.17	0.001
4 W	B 3.30 c	0.65	A 8.00 a	0.21	B 7.70 b	0.35	3.70 c	0.12	A 8.20 a	0.12	0.0001
P value	0.01		0.001		0.001		NS		0.001		

The letters (A, B, C, and D for column and a, b, c and d rows) represented the levels of significancy. Highly significant start from the letter (A or a) and decreasing with the last one. Similar letters mean there are no significant differences between tested mean.

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Failure Mode:

Frequency of failure mode after shear bond strength test of each group is shown in Table (III). The results indicated that the failure mode of the groups varied with different laser parameters. In group A and C, type (1) failure mode was frequently observed in those specimens treated with 1-3 W for both groups. On the contrary, failure mode of type 3 was mostly detected in group D and Eexcep for 2, 2.50 W and 1, 1.50 W respectively. And type (2) had the least frequency in group B, 4W and E, 3.5 W.

Table (III): failure mode distribution.

groups	Adhesive Failure (1)		Cohesive Failure (2)		Mixed Failure (3)	
	No.	%	No.	%	No.	%
A	5	50			2	20
B	3	30	1	10	3	30
C	5	50			2	20
D	2	20			5	50
E	2	20	1	10	4	40

Disscusion

The purpose of the current study is the enhancementof the SBS of resin cement to zerconia material with no laser optical damage on zerconia surface such as fractures or crackes. Many laser studies attempted to investigate the effect of laser type, laser power, zerconia-surfacelaser irradiation temperature elevation, zerconia ceramic type and the resin cement type on the SBS, and found conflicting findings. We showed in the previous literature survey that the laser pulse duration is a critical parameter in laser material processing. So we tried to investigate it's influence.Considering The long pulse duration (700 µs), the optained results showed that the highest SBS mean, in the specimens treated with theEr:Cr:YSGG laser, was: 7.64 Mpa. While for the short pulse duration (60 µs), the highest SBS meanwas:8.63 Mpa,which was significantly greater than those of the other groups for the same or for different pulse duration, and greater than that of the Er:Cr:YSGGlaser which showed a maximum SBS of 4.68 Mpa,[19]or other lasers such as Er:YAG, which showed a maximum SBS of 8.65Mpa,[14] used with the same type of zirconia ceramic system.This could be due to the effect of Er:Cr:YSGG laser short pulse duration(60µs) in roughening of the bonding surface inconsentrated laser energy pulses without creating laser zerconia- surface damag. The behaiver of the 60µs short pulses allowed for increased LPD, thereby increasing the SBS and enhancing the matching of zerconia to ceramic. Whereas the 700µs pulse duration allowed for laser heat dissipation that negatively influenced the LPD resulting in decreasd SBS values. The durability of zirconia-cement bondwas also assessed by the bond failure mode analysis as it provide an important definition for the bonding efficacy.[20]The bond failure of group A and C was mostly adhesive due to the inadequate LPD, needed for a durable micro- retentive interlocking that was obtained with low power laser irradiation,except for the specimens treated with 3.50,4 W in both groups, which showed mixed failure mode as a consequence of theinceased LPD with theinceased surface area available for mechanical resin-zerconiainterlocking. In group B,D and E, cohesive andmixedfailure modes were seen with the increased LPD for higher powers. This means that the laser pulse duration had a great influence on the LPD whichhad a compromising effect on the SBS of zirconia ceramic to the resin cement.

Conclusion

From the extracted results,it can be concluded that:The highest SBS of the Er:Cr:YSGGlaser irradiated specimens is obtained with the laser parameter of 30s, 60µs, 4W. The 60µs laser pulse duration is better than the 700µs.The laserpulse duration is a vital parameter in the surface roughness of zirconia ceramic for the enhancement ofthe bonding strength to the resin cement.

Abbreviations

ANOVA: One-way analysis of variance; CAD CAM: Computer aided design computer aided manufacturing; CO2: Carbon dioxide laser; Er YAG: Erbium yttrium aluminum garnet; Ra: Roughness measurements; Y-TZP: Yttrium stabilized tetragonal polycrystalline zirconia

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Ethics approval and Consent to Participate: This study was conducted on dental materials not on ahuman body.

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