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EVALUATION OF DIFFERENT SURFACE CONDITIONING METHODS ON THE BOND STRENGTH OF ZIRCONIA CERAMIC TO A RESIN CEMENT

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ABSTRACT

Surface conditioning methods used for resin bonding to conventional silica base dental ceramics are not dependable for zirconium ceramic. The aim of this study was to evaluate the effect of different surface conditioning methods on the shear bond strength of zirconia ceramic to resin cement. Twenty eight Zirconia ceramic specimens were fabricated from (IPS e.max Zir CAD), and randomly assigned to four groups (n=7).Each group was subjected to the following surface treatments: Control (no treatment), sandblasting with 110 μm aluminum oxide, Silica coating and silanization (CoJet system), and Nd: YAG laser irradiation. A composite resin discs were fabricated and bonded to the treated ceramic surfaces using resin luting agent (Panavia F 2.0) and stored for 24 hours in distilled water at 37 ^{O}C. Specimens then subjected to thermocycling for 1000 cycles between 5^{O}C and 55^{O}C with a 30 s dwell time. All specimens were subjected to shear bond strength test by a universal testing machine at a crosshead speed of 0.5 mm/minute. The shear bond strength values were analyzed with ANOVA to compare between groups using SPSS software .The level of significance was 0.05. Results obtained showed that silica coating and silanization (CoJet system) is an effective method for achieving an acceptable bond between zirconia and resin cement. The use of Nd: YAG laser enhance the bond strength between the zirconia and resin cement.

INTRODUCTION

A high demand for high strength and esthetic materials has increased recently in dentistry. So the researchers are concentrating on the developments of esthetic requirements and mechanical properties of all-ceramic materials [1]. Zirconia is one of the strong materials with high crystalline content which has a superior success rate than those of silica based ceramic systems. It has perfect mechanical properties such as a high flexural strength over 1000 MPa, required biocompatibility and long term stability [2,3]. The development of computer-aided design / computer- aided manufacturing (CAD-CAM) technique allows the fabrication of zirconia based restorations for all-ceramic crowns or fixed partial dentures to be more a practical in dentistry.

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The success of all ceramic restorations is extremely dependent on achieving a bond of resin with the underlying tooth structure as well as with the restoration. Bonding is required for enhancement of retention, fracture resistance, marginal adaptation and bond strength of the restorations [(4)]. A proper use of ceramic surface conditioning methods is necessary for the strength of ceramic restorations that depends on the integrity of luting cement to ceramic [(5,6)].

A strong resin ceramic bond depends on the chemical bond between the ceramic and the luting cement also on the micromechanical retention produced by surface roughening .There are different surface treatment methods as grinding with diamond rotary instruments, air abrasion with alumina, acid etching by hydrofluoric acid, silica coating, coupling with silane and combination of any of these methods [(7, 8)]. However, in case of zirconia ceramics because the limited glass phase and the absence of silica in zirconia structure, it is not susceptible to hydrofluoric acid etching and the formation of a siloxane network with the siloxane groups contained in bifunctional primers [(9,10)].According to this findings, alternative techniques such as silica coating [(11)], use of phosphate acidic monomers on cements or primers[(12-13)], laser irradiation [(14-15)], and other techniques to modify the zirconia ceramic surfaces has been introduced for the treatment of the zirconia surfaces to be bonded to the resin based cements [(16-17)].

There are different studies comparing different surface treatment techniques but the best method for achieving the bond between zirconia and resin cement is still undefined. Therefore the purpose of this in vitro study was to evaluate the effect of different surfaces conditioning methods on the shear bond strength between zirconia ceramic and resin cement.

MATERIAL AND METHODS

Twenty eight zirconia ceramic specimens (IPS e.max ZirCAD; Ivoclar Vivadent , Schaan, Liechtenstein) were fabricated from pre-sintered blocks by means of water cooled diamond disc. The specimens were sintered in Programat S1 high temperature furnace following the manufactures instructions. The sintered specimens were then ultrasonically cleaned with 96% isopropyl alcohol for 3 min and 10 min in distilled water. The zirconia specimens were randomly divided into four groups (n=7) as follows: Group 1, Control (CO)-no treatment. Group 2 (SB) sandblasted with 110 μm aluminum oxide (Al_2O_3) particles (Korox, Bego, Germany) for 15 seconds at 35 psi from a distance of 10 mm, Group 3 (SC), silica coated with 30 μm CoJet Sand (3 M -ESPE, Germany) at a 2.8 Psi pressure for 10 s at a distance of 10 mm , and then a silane coupling agent (ESPE-Sil;3M ESPE) was applied and allowed to dry for 60 s . Group 4(L) Laser irradiation by Nd: YAG laser system (Continuum NY 81-30 USA) at the infrared wave length (p =1064). The laser beam was reflected at 90^{O} angle on the specimen which was fixed on a special holder via a special flat fully reflected dielectric mirror (Melles Groit 02 MPG) held at 45^{O} incident angle. The exposure power densities (210 MW /cm^2) and the number of pulses was 1800 per minute (30 pulses /second).

Transparent plastic tubes , 3mm high were filled with composite resin (Filtek Z 350 XT,3M ESPE), light polymerized (Heliolux DXL ,Ivoclar Vivadent, Schann Liechtenstein) for 40 seconds on each side before bonding to the treated zirconia ceramic specimens. A dual polymerizing adhesive resin luting agent (Panavia F 2.0, Kuraray America, Inc) was used according to the manufactures instructions to bond the filled plastic tubes to the pretreatment zirconia ceramic specimens. A static load of 1Kg was applied to the specimens until polymerization was achieved. Excess resin cement was removed with a brush. The luting agent was polymerized with a light polymerizing system from two different directions for 40 seconds on each side. The polymerization light tip was placed at a distance of 5 mm from the specimen surface. Oxyguard II (Kuraray America, Inc) was applied for 10 minutes before removing the specimens from the press. The specimens were washed with air water spray and stored in distilled water at 37^{O} for 24 hours .Specimens then subjected to thermocycling for 1000 cycles between 5^{O} C and 55^{O} C with a 30 s dwell time. Shear bond strength was tested by the universal testing machine (Instron, Canton, USA) at a crosshead speed of 0.5 mm/minute until failure occurred. The maximum force (MPa) to produce fracture was recorded using corresponding software. The data was collected and entered into personal computer. Statistical analysis was done using Statistical Package for Social Sciences (SPSS/version 20) software. Arithmetic mean and standard deviation, for the numerical data to compare between more than two groups ANOVA test was used. The level of significant was 0.05.

RESULTS

The shear bond strength values were recorded in (MPa), the mean and standard deviation was calculated and results of comparison among different groups are presented in (Table 1). A significant difference between the surface treatments was detected.

The highest shear bond strength value of 18.132 ± 1.051 MPa was obtained with Nd-YAG laser irradiation, followed by silica coating and silanization (CoJet system) 16.52 ± 1.958 Mpa, and lowest value were obtained for control group (no treatment) (10.28±0.859 MPa). The bond strength values did not differ significantly between specimens with no treatment (10.28±0.859 MPa) and specimens treated by sandblasting with 110 μm aluminum oxide (12.91 ± 0.8559). Also the bond strength values did not differ significantly between the specimens treated with silica coating and silanization (16.52 ± 1.958 MPa) and laser group (18.132 ± 1.051 MPa).

DISCUSSION

Different studies displayed that sandblasting with Al_2O_3 particles is an essential step in attaining a durable bond to zirconia ceramics. This mechanical surface condition with air abrasion can improve the resin-ceramic bonding by increasing the surface roughness and bonding surface area and improving wetting kinetics of adhesives [18]. Different sizes of abrasive Al_2O_3 particles, between 50 and 110 µm,

TABLE (1): The mean shear bond strength values of different surface conditioning groups

	Group 1 (Control)	Group 2 (Sandblasting with 110 μm Al2O3)	Group 3 (Silica coating and silanization)	Group 4 (Nd:YAG Laser)
Range	9.01-12.3	10.6-14.2	13.2-18.2	16.1-20.1
Mean	10.28	12.91	16.52	18.132
S.D.	0.859	0.8559	1.958	1.051
F	16.85			
P	0.001*			
P1		0.103	0.002*	0.001*
P2			0.016*	0.006*
P3				0.072

F=ANOVA test

P=Probability is significant if <0.05

are generally used [19-20]. However, differences particle size and the application time may induce discrepancies in the attained results .Excessively high pressure during blasting may initiate phase transition, and expedite the formation of micro-cracks, thus reducing the mechanical properties of zirconia [21].In the present study, the application of airborne particle abrasion to a zirconia ceramic surface resulted in an increase in shear bond strength values. However, there was no significant difference between Groups sandblasting and control. In this study we use 110-μm Al_2O_3 particles for airborne particle abrasion. No direct comparisons between the influence of different particle sizes and shear bond strength to machined zirconia ceramic have been identified.

The use of silica coating with 30μm SiO_2 and silanization enhanced the bond strength between the zirconia ceramic and resin cement. The silane works as a coupling agent to provide chemical bonding between the silica based ceramic and resin based material. Since the zirconia ceramic do not have glassy phase, a silica layer is applied on the ceramic surface using silica coating system. This technique provides chemical retention through the silica layer embedded on the surface of zirconia and micromechanical retention through the air abrasion procedure [22]. Close to our results, (Amaral et al and Atsu et al) [23-24] reported that silica coatings plus silanization showed durable microtensile bond strength between the In-Ceram zirconia and Panavia F resin cement. Also Baldissara et al [25] concluded that silica coating with 30μm silica modified alumina provided the best surface treatment for zirconia ceramic. In Contract to this Kern et al [19] reported that tribochemical coating techniques not result in durable and uniform silica layer on the zirconia surface. Some problems such as stress-induced phase transformation and microcrack formation may happen during this type of surface treatment.

In this study Nd: YAG laser pretreatment significantly increased zirconia bond strength to resin cement. This is in agreements with the results obtained by Paranhos et al [26] who found that Nd-YAG laser pretreatment whether associated with abrasion method or not, generated constant roughness on the zirconia surface and significantly increase zirconia shear bond strength to resin cement. Other studies have also approved that Nd-YAG laser irradiation increase the bond strength of zirconia ceramics to resin cement [27-28]. Another study used CO2 laser irradiation to zirconia ceramics and found that it showed an effective method for conditioning zirconia surfaces, enhancing micromechanical retention and improving the bond strength of resin cement on zirconia ceramic [29]. In contrast with the findings obtained by Mahmoodi et al [30] who found that the use of Nd: YAG laser did not improve the bond strength between the zirconia and resin cements and he explained that Nd: YAG laser can lead to thermal degradation of the superficial layer of zirconia and the poor connection between this layer and lower layers can cause debonding. Foxton et al [31] used Erbium laser (Er-YAG laser) treatment to zirconia surface, and found that it did not result in a durable resin ceramic/ceramic bond. However, it should be noted that different results can be due to the type of laser, ceramic, resin cement, test plan and exposing to thermal cycling.

It is recommended that thermocycling should be included in all studies of bonded restorations. Thermocycling in water bath has been used frequently to simulate the intraoral aging effect on resin cement adhesion. A variety of thermocycling cycle numbers and dwell times have been recorded in the many studies [23-33]. Any evidence of the number of cycles likely to be experienced in vivo was not yet found and this requires further investigation.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. For the zirconia surfaces cemented with Panavia F2.0, sandblasting was not as effective as silica coating and silanization
2. Silica coating and silanization (CoJet Sand) is an effective method for achieving an acceptable bond between zirconia and resin cement
3. The use of Nd: YAG laser enhance the bond strength between the zirconia and resin cement.

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