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Efficiency of the new surface treatment modalities of the zirconia ceramic on the bond strength to adhesive resin

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Abstract

Background: Dependable bonding between resin cements and high strength ceramics is difficult to attain because of their chemical inertness and lack of silica content that makes etching impractical. Objectives: 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. Methods: Thirty-two zirconia ceramic specimens were constructed from (IPS e.max Zir CAD), and arbitrarily divided into four groups each containing eight specimens for different surface treatment methods. Group 1(NT), No treatment, and served as a control group, group 2 (SC) tribochemical silica coating using 30 µm alumina particles modified by silica and silanization (CoJet Sand system), group 3 (SB) sandblasted with 110 µm aluminum oxide, and group 4 Nd: YAG laser irradiation. A composite resin discs were made-up 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 ºC. Specimens then subjected to thermocycling for 1000 cycles between 5º C and 55º 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 recorded. Statistical analysis was done using Statistical Package for Social Sciences (SPSS/version 21) software. ANOVA test was used followed by Post Hoc test to detect the significant between each two groups. The level of significant was 0.05. Results: The mean shear bond strength values for the NT SC, SB, and L groups were 10.37± 0.92, 15.99 ± 2.01, 12.88 ± 0.98, and 18.87 ± 1.17 MPa respectively. Conclusions: It can be concluded that the use of Nd: YAG laser irradiation increases the bond strength of bonding resin cement to zirconia ceramics. Silica coating and salinization is an effective and reliable method to increase bond strength on zirconia ceramics. Sandblasting of zirconia ceramics alone is not effective for achieving good bond strength.

Keywords: zirconia ceramics, surface conditioning, bond strength, silica coating, airborne-particle abrasion, laser etching

INTRODUCTION

The great demand of esthetic materials with high strength has increased recently in dentistry. So, the researchers are focusing on the improvement of esthetic requirements and mechanical properties of all-ceramic materials (Ural et al 2012). 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 excellent mechanical properties such as a high flexural strength, appropriate biocompatibility and long term stability .The production of zirconia based restorations for all-ceramic crowns or fixed partial dentures becomes more practical in dentistry with the progress of computer-aided design / computer- aided manufacturing (CAD-CAM) system (Pittayachawan et al 2007 and Atsu et al 2006).

Success of all ceramic restorations is severely reliant on attaining a bond of resin with the underlying tooth structure in addition to with the restoration. Bonding is essential for bond strength of the restorations, improvement of retention, marginal adaptation, and fracture resistance of the restorations (Burke et al 2002). A selection of the suitable ceramic surface conditioning techniques is required for the strength of ceramic restorations that rely on the coherence of luting cement to ceramic (Amaral et al 2006).

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 (Chaiyabutr et al 2008 and Ersu et al 2009). 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 (Thompson et al 2011). Accordingly, other techniques such as using of phosphate acidic monomers on cements or primers (Chen et al 2013 and Mirmohammadi et al 2010), silica coating (Castro et al 2012), laser irradiation (Akyil et al 2010 and Ural et al 2010) and additional methods to change the zirconia ceramic surfaces has been presented for the handling of the zirconia surfaces to be bonded to the resin-based cements (Valverde et al 2013 and. Aboushelib et al 2011).

Different studies comparing different surface treatment techniques has been finished, but the perfect technique for attaining the bond between zirconia and resin cement is still unspecified. The objective of this study was to evaluate the effect of various surface conditioning methods on the shear bond strength between zirconia ceramic and resin cement.

MATERIAL AND METHODS

In this study thirty-two zirconia patterns (IPS e.max ZirCAD; Ivoclar Vivadent, Schaan, Liechtenstein) were prepared from pre-sintered zirconia blocks by aids of water-cooled diamond disc. Following the manufactures instructions, the patterns were sintered in high temperature sintering furnace (Programat S1, Ivoclar Vivadent)). The zirconia patterns were arbitrarily divided into four groups each containing eight specimens for different surface treatment methods. Group 1(NT), No treatment, and served as a control group. Group 2 (SC), tribochemical silica coating using 30 µm alumina particles modified by silica (CoJet Sand, ESPE Dental AG, Germany) at a distance of 10 mm for 10 seconds and 2.8 Psi pressure, later a silane coupling agent (ESPE-Sil, 3M ESPE) was applied and allowed to dry for 60 seconds. Group 3 (SB) sandblasted with 110 µm aluminum oxide (Al_2O_3) particles (Korox, Bego, Germany) for 15 seconds at 35 PSI from 10 mm. Group 4 (L) Laser etching 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} angles on the specimen that 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 were 1800 per minute (30 pulses /second). Prior to surface treatments, all ceramic specimens were ultrasonically cleaned for 5 min in 96 % isopropyl alcohol bath (Vitasonic II, Vita Zahnfabrik H. Rauter GmbH & Co KG), followed by 7 minutes in distilled water.

To prepare the composite discs, a transparent plastic tubes, 3mm in high and diameter were filled with composite resin (Filtek Z 250, shade A2; 3M ESPE, USA)), light polymerized (Elipar Free Light 2; 3M ESPE) for 40 seconds on each side to ensure adequate polymerization 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 composite discs to the pretreatment zirconia ceramic specimens. A static load of 1Kg was applied to the specimens until polymerization was achieved. Excess cement was removed with a micro- brush. The luting agent was polymerized with a light polymerizing system from two different directions for 30 seconds on each side. The polymerization light tip was placed at 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 water air spray and stored in distilled water at 37^{O} for 24 hours. The cemented specimens were subjected to thermocycling for 1000 cycles between 5^{O} C and 55^{O} C with a 30 s dwell time. All samples were embedded in blocks of self-cure acrylic resin using specially designed steel mold and then seated in the shear-testing jig. 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. Statistical analysis: The Data was collected and entered into the personal computer. Statistical analysis was done using Statistical Package for Social Sciences (SPSS/version 21) software. Arithmetic mean, standard deviation, for numerical data to compare between more than two groups. ANOVA test was used, followed by Post Hoc test to detect the significant between each two groups. 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 various groups are presented in (Table 1).

Table 1: Shear bond strength means (MPa), of different ceramic surface conditioning groups

	No treatment (NT)	Silica coating (SC)	Sandblasting (SB)	Laser (L)
Range	9.11-12.5	12.94-18.16	10.2-15.1	16.0-21.0
Mean	10.37	15.99	12.88	18.87
S.D	0.92	2.01	0.98	1.17
F	15.03			
P	0.0016*			
P1		0.003*	0.09	0.001*
P2			0.017*	0.08
P3				0.009*

F = ANOVA test
P = probability is significant if < 0.05

P1 comparison between (NT) group and other groups
P2 comparison between group (SC) and both (SB) and (L)
P3 comparison between group (SB) and (L)

The mean shear bond strength values for the NT SC, SB, and L groups were 10.37± 0.92, 15.99 ± 2.01, 12.88 ± 0.98, and 18.87 ± 1.17 MPa respectively. The highest shear bond strength values were gained from laser itching (18.87 ± 1.17 MPa), followed by silica coating and silanization (15.99 ± 2.01 Mpa), whereas the lowest shear bond strength values were gained from no treatment group (10.37±0.92 MPa). Significant differences in shear bond strength were observed between the different surface treatment methods (Table 1). No significant differences was observed between no treatment group and sandblasting group. Also there are no significant differences between silica coating and laser itching surface treatment group.

DISCUSSION

The use of silica coating with 30µm SiO_2 and silanization improved the bond strength between the zirconia ceramic and resin cement. The silane works as a coupling agent to add chemical bonding between the silica based ceramic and resin-based material. Because the zirconia ceramic does not have glassy phase, a silica layer is applied on the ceramic surface using silica coating system. This method offers chemical retention through the silica layer implanted on the surface of zirconia and micromechanical retention through the air abrasion technique (Xie et al 2013). Like to our results, (Atsu et al 2006 and Amaral et al 2008) stated that silica coatings in addition to silanization presented reliable microtensile bond strength between the In-Ceram zirconia and Panavia F resin cement. As well Baldissara et al 2013 reported that silica coating with 30µm silica modified alumina offered the best surface treatment for zirconia ceramic. Dislike to this Kern et al 1998 found that tribochemical coating techniques not outcome in reliable and uniform silica layer on the zirconia surface. Added that some problems such as microcrack formation and stress-induced phase transformation may occur during this kind of surface treatment. Russo et al 2019 reported that the combination of a mechanical and chemical treatment is fundamental for satisfactory adhesion. Protocols with greater evidence in the literature involve sandblasting with silica-coated particles (that permits the association of silane primers) and traditional alumina sandblasting (combined with the use of chemical promoters like 10-MDP-based products).

Various investigations showed that sandblasting with Al_2O_3 particles is an important step in achieving a reliable bond to zirconia ceramics. This mechanical surface condition with air abrasion can enhance the resin-ceramic bonding by increasing the surface roughness and bonding surface area and increasing wetting kinetics of adhesives (Quass et al 2007). Buyukhatipoglua et al in 2016 recommend using the appropriate combination of airborne-particle abrasion and adhesive/silane coupling agent to achieve durable zirconia-resin bonding. Saleh et al in 2019 concluded that sandblasting is a more efficient method to increase shear bond strength on zirconia ceramics than hydrofluoric acid etching. Zandparsa et al in 2014 recommended airborne-particle abrasion followed by the application of a zirconia primer as a promising surface treatment method to achieve high bond to zirconia ceramics. Different sizes of abrasive Al_2O_3 particles, between 50 and 110 µm, are usually used (Blatz et al 2003 and Kern et al 1998). However, differences particle size and the application time may encourage differences in the achieved results. Extremely high pressure during blasting may initiate phase transition, and accelerate the formation of micro-cracks, thus decreasing the mechanical properties of zirconia (Zhang et al 2006). Yagawa et al in 2018 concluded that application of priming agents containing hydrophobic phosphate monomer (MDP) yielded the durable bond strengths of resin-based luting agents to a translucent zirconia material. In addition, Shimizua et al in 2018 added that Al_2O_3 sandblasting resulted in durable bonding of 4-META/MMA-TBB resin to highly translucent zirconia, regardless of chemical pre-treatment. In the present study, the application of airborne particle abrasion to a zirconia ceramic surface resulted in an increase in shear bond strength values. Though, there was no significant difference between sandblasting group and no treatment group. In the present study we used 110-µm Al_2O_3 particles for airborne particle abrasion. No direct comparisons between the effect of different particle sizes and shear bond strength to machined zirconia ceramic have been recognized.

In the existing study Nd: YAG laser pretreatment significantly improved zirconia bond strength to resin cement. This is in agreements with the findings obtained by Paranhos et al in 2011 who found that Nd-YAG laser pretreatment if combined with abrasion method or not, created constant roughness on the zirconia surface and significantly increase zirconia shear bond strength to resin cement. Additional studies have also accepted that Nd-YAG laser irradiation raise the bond strength of zirconia ceramics to resin cement (Usumez et al 2013 and Akin et al 2011). Additional study used CO2 laser irradiation to zirconia ceramics and found that it presented an efficient method for conditioning zirconia surfaces, boosting micromechanical retention and improving the bond strength of resin cement on zirconia ceramic (Ural et al 2010). Disagree with the results obtained by Mahmoodi et al in 2016 who found that the use of Nd: YAG laser did not raise the bond strength between the zirconia and resin cements and he clarified that Nd: YAG laser can cause thermal degradation of the superficial layer of zirconia and the poor connection between this layer and lower layers can cause debonding. In 2011 Foxton et al used Erbium laser (Er-YAG laser) treatment to zirconia surface and found that it did not result in a strong resin ceramic/ceramic bond. However, it should be noted that different outcome could be owing to the type of laser, ceramic, resin cement, test plan and exposing to thermal cycling. Alhassani et al in 2018 concluded that the temperature elevation is a vital factor in the surface roughness of zirconia ceramic with CO2 laser irradiation to enhance its bonding strength to the resin cement and the lowest temperature elevation at best shear bond strength of zirconia ceramic to the resin cement is satisfied with the shorter pulse duration of 0.1 millisecond.

It is suggested that thermocycling should be involved in all studies of bonded restorations. Thermocycling in water bath has been used regularly to resemble the intraoral aging effect on resin cement adhesion. A diversity of thermocycling cycle numbers and dwell times have been reported in the numerous studies (Amaral et al 2008, Yun et al 2010, and Attia et al 2011). Any clue of the number of cycles probably to be attempted in vivo was not yet initiated and this needs additional researches.

Additional in vitro investigations that examine promising procedures and own better symmetry on the test set-up characteristics, as well as extra clinical trials, are needed to have more proof to support an adhesion protocol with certain expected results.

CONCLUSIONS

Within the scope of the present study, the following can be concluded:

a. Silica coating and salinization is an effective and reliable method to increase bond strength on zirconia ceramics

b. Laser irradiation is suggested as an alternative surface treatment technique for bonding resin cement on zirconia ceramic surfaces

c. Sandblasting of zirconia ceramics alone is not effective for achieving good bond strength

REFERENCES

Aboushelib MN; 2011.Evaluaion of zirconia resin bond strength and interface quality using a new technique. J Adhes Dent, 13:255-260. DOI: 10.3290/j.jad.a19241.

Akin H, Ozkurt K, Kirmali O, Kazazoglu E, and AK Ozdemir; 2011.Shear bond strength of resin cement to zirconia ceramic after aluminum oxide sandblasting and various laser treatments. Photomed laser Surg, 29:797-802. DOI: 10.1089/pho.2011.3039.

Akyil MS, Uzun IH, and F Bayindir; 2010. Bond strength of resin cement to yttrium-stabilized tetragonal zirconia ceramic treated with air abrasion, silica coating and laser irradiation. Photomed Laser Surg, 28:801-808. DOI: 10.1089/pho.2009.2697.

Alhassani L and H Jawad ;2018. Influence of fractional CO2 Laser irradiation on temperature elevation and bonding strength of resin cement to the zirconia ceramic. Iraqi J. Laser, 17: 23-31.

Amaral R, Ozcan M, Bottino MA, and LF Valandro; 2006. Microtensile bond strength of resin cement to glass infiltrated zirconia-reinforced ceramics. Dental Mater, 22:283-290. DOI: 10.1016/j.dental.2005.04.021.

Amaral R, Ozcan M, Valandro LF, Balducci I, and MA Bottino; 2008. Effect of conditioning methods on the microtensile bond strength of phosphate monomer-based cement on zirconia ceramic in dry and aged conditions. J Biomed Mater Res, 85:1–9. DOI: 10.1002/jbm.b.30908.

Atsu S, Kilicarslan MA, Kucukesman HC, and PS Aka; 2006.Effect of zirconium oxide surface treatments on the bond strength to adhesive resin. J Prosthet Dent , 95:430-436. DOI: 10.1016/j.prosdent.2006.03.016.

Attia A, Lehmann F, and M Kern; 2011.Influence of surface conditioning and cleaning methods on the resin bonding to zirconia ceramic. J Dent Mat 2, 27:207-213. DOI: 10.1016/j.dental.2010.10.004.

Baldissara P, Querze M, Monaco C, Scotti R, and RG Fonseca; 2013.Efficacy of surface treatments on the bond strength of resin cements to two brands of zirconia ceramic. J Adhes Dent, 15:259-267. DOI: 10.3290/j.jad.a28729.

Blatz MB, Sadan A, and M Kern; 2003. Resin-ceramic bonding: a review of the literature. J Prosthet Dent, 89:268–274. DOI: 10.1067/mpr.2003.50.

Burke FJ, Fleming GJ, Nathanson D, and PM Marquis; 2002. Are adhesives technologies needed to support ceramics? An assessment of current evidence. J Adhes Dent, 4:7-22.

Buyukhatipoglua I, Secilmisb A and G Ergunc; 2016.Effects of surface treatments on the shear bond strength of luting cements to zirconia. J Adhesion Science and Technology, 22:2439–2452. DOI:10.1080/01694243.2016.1184410.

Castro HL, Corazza PH, Paes-junior TA, and A Della Bona; 2012. Influence of Y-TZP ceramic treatment and different resin cements on bond strength to dentin. Dent Mater, 28:1191-1197. DOI: 10.1016/j.dental.2012.09.003.

Chaiyabutr Y, McGowan S, Phillips KM, Kois JC, and RA Giodano; 2008. The effect of hydrofluoric acid surface treatment and bond strength of zirconia veneering ceramic. J Prosthet Dent, 100:194-202. DOI: 10.1016/S0022-3913(08)60178-X.

Chen L Shen H, and BI Suh; 2013.Effect of incorporating Bis-GMA resin on the bonding properties of silane and zirconia primers.J Prosthet Dent, 110:402-407. DOI: 10.1016/j.prosdent.2013.04.005.

Ersu B, Yuzugullu B, Ruya A, and S Canny; 2009. Surface roughness and bond strengths of glass –infiltrated alumina ceramics prepared using various surface treatments. J Dent, 37:847-856. DOI: 10.1016/j.jdent.2009.06.017.

Foxton R, Cavalcanti A, Nakajima M, Sherriff M, Melo L, and T Watson; 2011. Durability of resin cement bond to aluminum oxide and zirconia ceramic after air abrasion and laser treatment. J of Prosthodontics, 20:84-92. DOI: 10.1111/j.1532-849X.2010.00678.x.

Kern M, and SM Wegner; 1998.Bonding to zirconia ceramic: adhesion methods and their durability. Dent Mater, 14:64–71. DOI: 10.1016/s0109-5641(98)00011-6.

Mahmoodi N, Hooshmand T, and S Heidari; 2016.Effect of sandblasting, silica coating, and laser treatment on the microtensile bond strength of dental zirconia ceramics to resin cements. Laser Med Sci, 31:205-211. DOI: 10.1007/s10103-015-1848-9.

Mirmohammadi H, Aboushelib MN, Salameh Z, Feilzer AJ, and CJ Kleverlaan; 2010. Innovation in bonding to zirconia based ceramics: part II. Phosphate monomer resin cements. Dent mate, 26:786-792. DOI: 10.1016/j.dental.2010.04.003.

Paranhos MP, Burnett LH Jr, and P Magne; 2011.Effect of Nd: YAG laser and CO2 laser treatment on the resin bond strength to zirconia ceramic. Quintessence Int, 42:79-89.

Pittayachawan P, McDonald A, Petrie A, and JC Knowles; 2007. The biaxial flexure strength and fatigue property of Lava Y.TZP dental ceramics. Dent Mater, 23:1018-1029. DOI: 10.1016/j.dental.2006.09.003.

Quass AC, Yang B,and M Karen ;2007.Panavia F 2 bonding to contaminated zirconia ceramic after different cleaning procedures. Dent Mater, 23:506-512. DOI: 10.1016/j.dental.2006.03.008.

Russo D,Cinelli F,Sarti C and L Giachetti.2019.Adhesion to Zirconia: A Systematic Review of Current Conditioning Methods and Bonding Materials. Dent J (Basel), 7:74. DOI.org/10.3390/dj7030074.

Saleh NE, Guven MC, Yildirim G and F Erol; 2019. Effect of different surface treatments and ceramic primers on shear bond strength of self-adhesive resin cement to zirconia ceramic.Niger J Clin Pract,22:335-341. DOI: 10.4103/njcp.njcp_394_18.

Shimizua H, Inokoshib M ,Takagakic T, Uod M and S Minakuchie; 2018.Bonding efficacy of 4-META/MMA-TBB resin to surface-treated highly translucent dental zirconia. J Adhes Dent , 20:453-459. DOI: 10.3290/j.jad.a41330.

Thompson JY, Stoner BR, Piascick JR, and R Smith; 2011.Adhesion cementation to zirconia and other non-silicate ceramics: where are we now? Dent Mater, 27:71-82. DOI: 10.1016/j.dental.2010.10.022.

Ural C, Kulunk T, Kulunk S, and M Kurt; 2010. The effect of laser treatment on the bonding between zirconia ceramic surface and resin cement. Acta Odontol Scand , 68:354-359. DOI: 10.3109/00016357.2010.514720.

Ural C,KalyoncuoGlu E, and V Balkaya ; 2012 .The effect of different power outputs of carbon dioxide laser on bonding between zirconia ceramic surface and resin cement. Acta Odontol Scand, 70:541-546. DOI.org/10.3109/00016357.2011.600718.

Usumez A, Hamdemirci N, Koroglu B, Simesk I, Parlar O, and T Sari; 2013.Bond strength of resin cement to zirconia ceramics with different surface treatments. Lasers Med Sci, 28:259-266. DOI: 10.1007/s10103-012-1136-x.

Valverde GB, Coelho PG, Janal MN, FC, and RM Cavalho; 2013. Surface characterization and bonding of Y-TZP following non-thermal plasma treatment. J Dent, 41:51-59. DOI.org/10.1016/j.jdent.2012.10.002.

Yagawa S, Komine F, Fushiki R, Kubochi K, Kimura Fand and H Matsumura;2018. Effect of priming agents on shear bond strengths of resin-based luting.J of Prosthodontic Research ,62: 204–209. DOI: 10.1016/j.jpor.2017.08.011.

Yun Jeong-yeon, Ha Seung-ryong, Lee Jai-bong, and Kim Sung-Hun; 2010.Effect of sandblasting and various metal primers on the shear bond strength of resin cement to Y-TZP ceramic. J Dent Mat, 26:65 0-658. DOI: 10.1016/j.dental.2010.03.008.

Xie H, Chen C, Dai W, Chen G, and F Zhang; 2013.In vitro short-term bonding performance of zirconia treated with hot acid etching and primer conditioning etching and primer conditioning. Dent Mater J, 32:928–938. DOI: 10.4012/dmj.2013-010.

Zandparsa R,Talua N, Finkelman M and S Schaus ; 2014.An In Vitro Comparison of Shear Bond Strength of Zirconia to Enamel Using Different Surface Treatments. J Prosthodont , 23:117-23. DOI: 10.1111/jopr.12075.

Zhang Y, Lawn BR, Malament KA, Van Thompson P, and ED Rekow; 2006.Damage accumulation and fatigue life of particle-abraded ceramics. Int J Prosthodont, 19:442–448.