Original Article

Shear Bond Strength of the Repair Composite Resin to Zirconia Ceramic by Different Surface Treatments

Sakineh Arami[1], Masoumeh Hasani Tabatabaei[1], Fatemeh Namdar[2]
Nassimeh Safavi[3], Nasim Chiniforush[4]

[1]Department of restorative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[2]Department of restorative Dentistry, School of Dentistry, Birjand University of Medical Sciences, Birjand, Iran
[3]Laser Applications in Medical Sciences Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[4]Laser Research Center of Dentistry, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran

Abstract:

Introduction: The purpose of this study is the evaluation of the amount of surface roughness (Ra) of Zirconia Ceramic following different surface treatments as well as the assessment of its shear bond strength to composite resin.

Methods: 40 sintered zirconia ceramic block samples were randomly divided in 4 groups of 10 and underwent the following surface treatments:

a) Control group without treatment
b) Air abrasion with Al_2O_3 particles (50um)
c) Er:YAG laser with 2W power for 10s
d) Nd:YAG laser with 1.5W power for 2min

Then the mean surface roughness (Ra) was evaluated by profilometer. In the next step, Alloy primer was used on a section of 9mm^2 on the samples following the manufacturer's instructions. After that Clearfil AP-X composite resin in cylinder shape with an internal diameter and height of 3mm were cured on the sections mentioned. At the end, all samples were tested to assess the shear bond strength by the Universal Testing Machine at a speed of 0.5mm/min until fracture occurred. The mean shear bond strengths were calculated and statistically analyzed by One Way ANOVA.

Results: ANOVA analysis showed that roughness (Ra) was significantly different between the groups ($P \leq 0.05$). Ra was higher in the Nd:YAG group compared to the other groups ($P \leq 0.05$). The lower Ra was related to the control group. Air abrasion group showed highest amounts of shear bond strength and Nd:YAG laser group demonstrated lower amounts of shear bond strength ($P \leq 0.05$).

Conclusion: Various surface treatments are differently effective on bond strength. Air abrasion is the most effective method to condition zirconia ceramic surfaces.

Keywords: zirconia ceramic; laser; abrasion.

Please cite this article as follows:
Sakineh Arami, Masoumeh Hasani Tabatabaei, Nasim Chiniforush, Nassimeh Safavi, Fatemeh Namdar .Shear Bond Strength of the Repair Composite Resin to Zirconia Ceramic by Different Surface Treatments. J Lasers Med Sci 2014;5(4):171-5

Corresponding Author: Fatemeh Namdar, DDS, Ms; Department of restorative Dentistry, School of Dentistry, Birjand University of Medical Sciences, Birjand, Iran. Tel: +98-2188015017; Fax: +98-2188994824; E-mail: f.namdar90@gmail.com

Introduction

Today, ceramics are frequently used for dental indirect restorations in visible oral regions[1]. Because of the esthetic limitations of metal cores in metal ceramic crowns, application of whole ceramic systems as alternative greatly increased. One of the whole ceramic systems is zirconia ceramic. This material has good mechanical and optical properties, and is highly biocompatible with the mouth environment[2]. Therefore they are widely used in the manufacture of endodontic posts, implants, dental prosthetic frameworks and crowns. Zirconia framework unlike natural tooth is not translucent, thus requires a veneering ceramic layer in order to give a more natural appearance to the crown[3]. With the increasing tendency for use of whole ceramic restorations such as inlay, onlay, veneers and crowns, the probability to observe chipping and fractures in restorations has been increased. Chipping of ceramic veneer of Y-TZP frameworks (Yttria-Stabilized Tetragonal Zirconia Polycrystals) were reported to be 13% after a 3 years period and 15.2% during a 5 years period[4]. These fractures can occur for various reasons like trauma, laboratory defects, insufficient occlusal adjustment, premature contacts or incorrect design[5]. Depending on the extension of the area involved, costs and available time, treatment plan can range from a simple composite repair to fabrication of a new prosthesis[5]. But fabrication of new prosthesis will result in damage to remaining dental tissues, more money spending and more time for retreatment. Another choice is the use of composite resin and adhesive systems in a direct way, in order to repair the fractured region[6]. Advantages of composite application include esthetics, low price and easy use in clinic. Success of these treatments depends on the bond strength between the ceramic surface and composite resin. Since various systems are available for repair, which operate based on different strategies of surface conditioning, choosing the best method could be difficult[7]. In order to condition ceramic surface, mechanical and chemical methods have been proposed to achieve maximum bond strength between ceramic and composite. Mechanical roughening of surface with coarse diamond bur, sandblasting with aluminum oxide particles (AL_2O_3), etching with hydrofluoric acid and use of silane, lead all to acceptable bond strength in ceramics with silica base. However, because of the absence of silica and glass phases in zirconia ceramics, etching with acid has no significant effect on bond strength[8].

Air abrasion is usually used to clean substrate surface, to achieve rough topography, to increase the surface area for bond, and to change surface energy as well as wettability[2,9]. Though, it creates grooves and defects which act as initiators of fractures in zirconia substrates and compromises mechanical properties and their long-term durability[10]. In addition, unpleasant working conditions with alumina particles are part of the limitations of this system. One of the other zirconia surface conditioning methods attracting attention today is the use of laser which can be performed in the chair side way. Akyil et al by applying Er:YAG (Erbium:Yttrium–Aluminium–Garnet) and Nd:YAG (Neodymium-Doped Yttrium Aluminum Garnet) on zirconia ceramic surfaces reported that this method increased the irregularities on the ceramic surface and as a result improved the adhesion to resin cement[2]. Therefore, application of laser can be considered as a potential method for creation of zirconia surface roughness and for increasing the bond strength of zirconia ceramic to resin cement[11]. Due to the lack of glass phase in zirconia ceramics, adhesive monomers are used instead of silane to reinforce the chemical bond[6]. The zirconia ceramic surface is covered by a layer of metal oxides permitting the adhesive monomers to react with the ceramic surface and chemically improve the bond strength[12]. This study has investigated the application of lasers for surface treatment of zirconia ceramic with the purpose of repair by composite resin. In the present study, based on the results of preliminary study, lower laser power of Er:YAG and Nd:YAG were chosen and then their effect on bond strength of composite resin to zirconia ceramic was evaluated and compared to the air abrasion method. The aim of this study was the evaluation of the effect of various surface treatments on surface roughness (Ra and Rmax) and amount of shear bond strength of repair composite resin to zirconia ceramic. Our null hypothesis was that surface conditioning by Er:YAG and Nd:YAG lasers could cause an increase in shear bond strength.

Methods

40 pre-sintered zirconium oxide ceramic block samples (ICE Zirkon, Zirkonzahn GmbH, Bruneck, Italy) with 10×10×2mm dimensions were obtained using a diamond blade mounted in Mecatome T201 low-speed cutting saw machine (PRESI. Grenoble. France). All samples were sintered according to the manufacturer’s instructions, and immersed in acrylic resin using metal molds. Then their superior surfaces were polished with silicon carbide 800, 1000, and 1200 grit under water flow. The samples were rinsed with distilled water for 6min by ultrasonic device. In the next step, the samples were randomly divided in 4 groups of 10 and received the following surface treatments:

1) Control group without treatment
2) Air abrasion with AL2O3 (50μm), 2.8bar pressure for 10s at 10mm distance 13
3) Er: YAG laser with output power of 2 W(energy density of 5.85 J/cm^2) for 10s

4) Nd: YAG laser with output power of 1.5W(energy density of 111.96 J/cm^2) for 2min

The Er:YAG laser (smart 2940 D, Deka laser, Florence, Italy) was used with a wavelength of 2940 nm, frequency of 10 Hz and pulse duration of 230µsec (very short pulse). The spot size was 1 mm and laser handpiece was used in a distance of 4 mm (focusing distance of the handpiece) above the surface (noncontact mode) for 10 sec accompanied by water and air spray. The Nd:YAG laser (Fidelis, Fotona,Slovenia) was used at wavelength of 1064 nm, frequency of 10Hz and pulse duration of 100 µsec (very short pulse). Total surfaces of the block were scanned by fiber of 320µ about 1mm above the surface for 1 min. All irradiation was done perpendicularly to the surface.

Then the samples were rinsed for 6min in the ultrasonic device. In the following step, the samples mean surface roughness (Ra) was assessed using an contact profilometer (T-8000 Hommelwerk, JENOPTK, Germany). The device diamond tip was passed on the entire sample surface at 0.15mm/s and 4N force and the mean surface roughness (µm) calculated. The amount of Ra and Rmax were statistically analyzed by One Way ANOVA. Since the profilometer is a non-damaging test and do not alter sample surface, on the sample surface in a 9mm^2 section, Alloy Primer (Kuraray CO, Okayama Japan) was applied following manufacturer's instructions. Then the mixture of Clearfil porcelain bond activator (Kuraray CO, Okayama Japan) and Clearfil SE Bond primer (Kuraray CO, Okayama Japan) was applied on the primed surface and air spray was used to evaporate its solvent. In order to produce standard cylindrical composite resin, plastic tubes with 3mm internal diameter and 3mm height were placed on the site of ceramic bonding. Then Clearfil AP-X composite resin (Kuraray CO, Okayama Japan) was applied incrementally, each layer was light cured for 40s using LED curing device (Guilin woodpecker medical instrument co. china). Then, the plastic tubes were gently cut and removed using a sculpt blade. In the end, all of the samples were tested by the Universal testing machine (Zwick ROELL Z2.5 MA 18-1-3/7 ulm, Germany) with speed of 0.5mm/min and 2.5 KN force, to evaluate the shear bond strength. The mean shear bond strengths were calculated and statistically analyzed by one-Way ANOVA. P ≤0.05 was statistically significant. (Table 1)

Results

Mean surface roughness

The ANOVA analysis showed Ra was higher in the Nd:YAG group compared to the others (P ≤0.05). The lower Ra was related to the control group. Ra did not have a significant difference between Er:YAG laser and air abrasion groups (P ≥0.05). However surface roughness (Ra) was not significantly different between air abrasion, Er:YAG and control groups. (Table 2)

Highest Rmax was observed in Nd:YAG group. Other groups were not shown significant difference (P ≥0.05).

Mean shear bond strength

The samples in air abrasion group showed the highest amount of shear bond strength (P ≤0.05). Followed respectively by the control group, Er:YAG laser and Nd:YAG laser groups which did not have significant difference (P ≥0.05). (Table 3)

Table 2. Mean surface roughness (Ra) according to µm

Treatment	Ra (Mean±SD)	Rmax
Air Abrasion	0.58±0.05 ^{a}	3.99±0.51 ^{a}
Control	0.23±0.07 ^{a}	2.48±1.46 ^{a}
Er: YAG Laser	0.53±0.04 ^{a}	2.43±1.04 ^{a}
Nd: YAG Laser	2.7±0.16 ^{b}	26.12±11.22 ^{b}

Table 1. The brand names and chemical compositions of the materials used in this study

Brand	Chemical composition
Alloy Primer	MDP, VBATDT, Acetone
Clearfil SE Bond primer	MDP, HEMA, dimethacrylate monomers, Water, photoinitiator
Clearfil porcelain bond activator	Bisphenol A polyethoxy dimethacrylate, 3-methacryloxypropyl trimethoxy silane
Resin composite Clearfil AP-X	• Bis-GMA • TEGDMA • Silanated barium glass filler • Silanated silica filler • Silanated colloidal silica • dl-Camphorquinone Inorganic filler is approx. 71 vol%. The particle size of inorganic fillers: 0.02 - 17 µm

Table 3. The Mean±SD of shear bond strength (Mpa) of study groups. The same letters indicate no significant differences according to one-way ANOVA ($P \geq 0.05$)

Treatment	Shear bond strength (Mean±SD)
Air Abrasion	17.24±3.22 ^{b}
Control	11.87±2.97 ^{a}
Er: YAG Laser	11.15±1.36 ^{a}
Nd: YAG Laser	9.32±1.65 ^{a}

Discussion

The purpose of this study was to assess the shear bond strength of restorative composite resin to zirconia ceramic following ceramic surface treatment by Er:YAG and Nd:YAG lasers compared to air particle abrasion. Today, Y-TZP ceramics are used to make post and core systems as well as copping for whole ceramic systems[12]. With the increasing use of whole ceramic prosthesis, probability to face ceramic veneer fractures has increased. When fracture or chipping occurs, esthetic as well as the contour of the veneer is lost. In this condition, performing a repair is necessary to regain the shape and contour of the fractured region[14]. To obtain adequate bond strength between zirconia ceramic and composite resin, creation of mechanical bond through surface roughening and chemical bond by use of functional monomers is essential[15]. Since the Y-TZP substance comprises metal oxides, surface conditioning with primers containing adhesive functional monomers such as 10-MDP (10-Methacryloyloxydecyl Dihydrogen Phosphate) has been proposed in order to improve bond to cement resin. These adhesives monomers have the capacity to form chemical bonds with the metal oxides present on the surface[16]. Even in case of application of cement containing 10-MDP, surface treatment is recommended in order to obtain acceptable bond strength. It is believed that surface treatment can facilitate movement of primer inside the retentive grooves and undercuts, and improve bond strength of composite to the ceramic substrate[17]. For treating and roughening of zirconia ceramic, different methods have been introduced. Abrasion with AL_2O_3 particles is a common method and it has been said that because of the development of surface roughness and undercuts, it possesses the ability to increase resin cement bond strength to zirconia ceramics. Of course, this method can induce phase transformation and change mechanical properties. In addition it causes the formation of defects which can result in failure of treatment[18]. The results of the present study were in correlation with the results obtained by Kern et al. which stated that air abrasion by AL_2O_3 particles with or without primer resulted in increased tensile bond strength of cement resin to zirconia ceramic. However, the amount of this strength without primer was reduced to zero in the long term[19]. In another study it was concluded that the combination of air abrasion and primers containing phosphate monomers increased bond strength of cement resin to zirconia ceramic[20]. In this study despite the fact that the amount of surface roughness (Ra) in the air abrasion and Er:YAG laser groups did not have significant difference ($P \geq 0.05$), the amount of shear bond strength in the air abrasion group was significantly higher ($P \leq 0.001$). On the other hand, we found that various surface treatments affect differently the bond strength and higher amounts of roughness do not necessarily result in increased bond strength. The samples irradiated by Nd:YAG laser with 1.5W power had a higher amount of surface roughness (Ra) in profilometry evaluation, while this group showed the lowest amount of shear bond strength. Kim et al. determined the lowest acceptable bond strength from a clinical point of view to be 10Mpa[21]. In the present study, samples irradiated with Nd:YAG laser do not guarantee a convenient clinical service, because the shear bond strength is not high enough in them. The results of the present study correlated with Akyil et al. study, which showed that Nd:YAG irradiation decreased shear bond strength in comparison to control group. They stated that Nd:YAG laser irradiation due to heat induction resulted in superficial layer damage which is weakly attached to the underneath layer, and led to a weak bond between cement resin and substrate[2]. The Er:YAG laser showed similar surface roughness (Ra) as the air abrasion group which were not significantly higher than the control group ($P \geq 0.05$). In addition, Er:YAG laser group showed similar bond strength as the control group ($P \geq 0.05$). Subasi et al. reported that zirconia surface treatment with Er:YAG laser irradiation (100µs, 400 mj, 4 w, 10 Hz) in comparison with air abrasion and control groups decreased shear bond strength to resin cement. They stated that micro explosions during laser irradiation create debris which can adhere to melted ceramic surfaces and bond to resin cement. On the other hand this layer may be adhering weakly to under surfaces and compromise bond strength[22].

In contradiction with this study, Akin et al. proposed the application of Er:YAG laser to increase bond strength of resin cement to zirconia ceramic. They also added that Y-TZP surface treatment by different low intensities of laser does not result in internal weakening of ceramic[23]. Cavalcanti et al. expressed that Er:YAG laser possesses the capacity for ablation, which means the elimination of substrate particles through microexplosions and evaporation. This process results in formation of undercuts and surface roughness that allows micromechanical bond of cement resin and increases bond strength[14].

Results of the present study showed that all surface treatments have the ability to increase surface roughness. The application of air abrasion resulted in increase in shear bond strength, while Nd:YAG laser decreased it. Therefore our hypothesis is not acceptable.

Conclusion

Various surface treatments affect bond strength differently. Higher amounts of Ra do not necessarily implicate more bond strength.

Air abrasion is the most effective method for zirconia ceramic surface treatment.

Zirconia surface treatment with Nd:YAG laser resulted in decreased shear bond strength of composite resin to Y-TZP.

Acknowledgement

This research project (code 91-02-97-17964) was approved by Laser Research Center of Dentistry, School of Dentistry, Tehran University of Medical Sciences, which hereby is appreciated from supporting this center.

References

1. Kim KB, Bae HE, Shim JS, Lee KW. The influence of ceramic surface treatments on the tensile bond strength of composite resin to all-ceramic coping materials . J Prosthet Dent 2005;94:357-62.
2. Akyil MS, Uzun IH, Bayindir F. Bond Strength of Resin Cement to Yttrium-Stabilized Tetragonal Zirconia Ceramic Treated with Air Abrasion, Silica Coating, and Laser Irradiation. Photomed Laser Surg 2010;28(6): 801–8.
3. Alaa Hussein Aref Sabrah . The Effect Of Full-Contour Y-Tzp Ceramic Surface Roughness On The Wear Of Bovine Enamel And Synthetic Hydroxyapatite: An In-Vitro Study . Thesis 2011.
4. Fischer J, Grohmann P, Stawarczyk B. Effect of Zirconia Surface Treatments on the Shear Strength of Zirconia/ Veneering Ceramic Composites . Dent Mater J 2008; 27(3): 448-54.
5. Güler AU, Yilmaz F, Yenisey M, Güler E, Ural C . Effect of acid etching time and a self-etching adhesive on the shear bond strength of composite resin to porcelain. J Adhes Dent 2006;8(1):21-5.
6. Goia TS, Pereira Leite FP, Valandro LF, Özcan M, Bottino MA . Repair Bond Strength of a Resin Composite to Alumina-Reinforced Feldspathic Ceramic. Int J Prosthodont 2006;19:400–2.
7. Özcan M, Valandro LF, Amaral R, Leite F, Bottino MA. Bond strength durability of a resin composite on a reinforced ceramic using various repair systems. Dent Mater 2009;25: 1477–83.
8. Della Bona A, Borba M, Benetti P, Cecchetti D. Effect of surface treatments on the bond strength of a zirconia-reinforced ceramic to composite resin. Braz Oral Res 2007;21(1):10-5.
9. Bottino MA, Valandro LF, Scotti R, Buso L. Effect of surface treatments on the resin bond to zirconium-based ceramic. Int J Prosthodont. 2005;18(1):60-5.
10. Piascik JR, Swift EJ, Thompson JY, Grego S, Stoner BR. Surface modification for enhanced silanation of zirconia ceramics. Dent Mater. 2009;25(9):1116-21. doi: 10.1016/j.dental.2009.03.008. Epub 2009 Apr 18.
11. Kussano CM, Bonfante G, Batista JG, Pinto JH. Evaluation of Shear Bond Strength of Composite to Porcelain According to Surface Treatment . Braz Dent J 2003;14(2): 132-5.
12. Foxton RM, Cavalcanti AN, Nakajima M, Pilecki P, Sherriff M, Melo L, et al . Durability of resin cement bond to aluminium oxide and zirconia ceramics after air abrasion and laser treatment . J Prosthodont 2011;20:84-92.
13. Aydogan Ayaz, Fatih Mehmet Korkmaz, Kıvanç Utku Ulusoy, Yildirim Hakan Bagis. How will surface treatments affect the translucency of porcelain laminate veneers? J Adv Prosthodont. 2014 February; 6(1): 8–13. Published online 2014 February 14. doi: 10.4047/jap.2014.6.1.8
14. Cavalcanti A, Pilecki P, Foxton RM, Watson TF, Oliveira MT, Gianinni M, et al. Evaluation of the Surface Roughness and Morphologic Features of Y-TZP Ceramics after Different Surface Treatments. Photomed Laser Surg 2009;27:473-9.
15. Tsuo Y, Yoshida K, Atsuta M. Effects of Alumina-blasting and Adhesive Primers on Bonding between Resin Luting Agent and Zirconia Ceramics. Dent Mater J 2006; 25(4): 669-74.
16. Prabu PS, Prabu N. Composite as a Ceramic Repair Material – An Invitro Study. J Ind Aca Dent Spec 2010; 1(4): 27-32.
17. Kim BK, Bae HE, Shim JS, Lee KW. The influence of ceramic surface treatments on the tensile bond strength of composite resin to all-ceramic coping materials. J Prosthet Dent 2005;94:357-62.
18. Yang B, Barloi A, Kern M. Influence of air-abrasion on zirconia ceramic bonding using an adhesive composite resin. Dent Mater 2010; 26: 44–50.
19. Kern M, Barloi A, Yang B. Surface Conditioning Influences Zirconia Ceramic Bonding. J Dent Res 2009;88(9):817-22.
20. Matinlinna JP, Lassila LV. Enhanced resin-composite bonding to zirconia framework after pretreatment with selected silane monomers . Dent Mater 2011;27(3): 273–80.
21. Kim MJ, Kim YK, Kim KH, Kwon TY. Shear bond strengths of various luting cements to zirconia ceramic: Surface chemical aspects. J Dent 2011; 39(11):795–803.
22. Subaşı MG, İnan Ö. Evaluation of the topographical surface changes and roughness of zirconia after different surface treatments . Lasers Med Sci 2012;27(4):735-42. DOI 10.1007/s10103-011-0965-3.
23. Akin H, Tugut F, Akin GE, Guney U, Mu-taf B. Effect of Er:YAG laser application on the shear bond strength and microleakage be-tween resin cements and Y-TZP ceramics. Laser med sci. 2012; 27: 333-8.