Clinical and Experimental
Health Sciences

Investigation of Fracture Resistance of Zirconia Restorations After Different Surface Treatments

Turker Akar[1], Hakan Akin[2]

[1] Erzincan Binali Yıldırım University, Faculty of Dentistry, Department of Prosthodontics, Erzincan, Turkey.
[2] Sakarya University, Faculty of Dentistry, Department of Prosthodontics, Sakarya, Turkey.

Correspondence Author: Turker Akar
E-mail: turkerakar24@gmail.com
Received: 17.09.2020 **Accepted:** 05.01.2021

ABSTRACT

Objective: The purpose of this study was to investigate the effects of the different surface treatments on fracture strength of the zirconia-based ceramic restorations.

Methods: Each of 120 dental implant abutments and analogs were used in the present study. Zirconia core materials were manufactured on dental implants by using CAD/CAM device and they were randomly divided into 6 groups (n=20) according to surface pretreatments; control group (Group C), airborne-particle abrasion (Group AA), silica-coating (Group SC), Nd:YAG laser (Group N), bur-cut from cervical region (Group BC), and bur-cut on the functional tubercule (Group BT). Cementation was succeeded with two different types of cements including a dual-cure resin-cement and a glass ionomer cement. The obtained data were evaluated statistically using one-way ANOVA and Tukey tests ($p=0.05$).

Results: No statistically significant difference was found between the groups ($p>0.05$). Similarly, no statistically significant difference was found between the resin cement and glass ionomer groups with respect to fracture strength values ($p>0.05$).

Conclusion: Within the limitations of the present study, surface treatments and cement have no effect on the flexural strength of zirconia ceramic crowns.

Keywords: Dental implants; dental lasers; fracture strength test; surface treatments, CAD/CAM.

1. INTRODUCTION

Zirconia-based restorations became popular with a high level of flexure strength and fracture toughness, durability, chemical and dimensional stability compared with other all-ceramic restoration systems (1-5). However, a translucent ceramic superstructure should be applied onto the opaque zirconia-substructure to obtain more esthetic restorations (2,4,6,7). Sailer et al. reported that the failure rate of veneered zirconia frameworks was 13.0% and 15.2% after 3 and 5 years and chipping of the veneering ceramic is the one of the main factors responsible for reduced survival rates (8,9). In addition, the bonding between the zirconia core and the tooth is important for the clinical success of zirconia restorations (6,10,11). Thus, there have been considerable efforts by many researchers to modify the surface properties of zirconia, mechanically and chemically by various surface treatments (12,13). Several techniques, especially the airborne particle abrasion with alumina, silica coating, various adhesive monomer and metal primers and CO_2, Nd:YAG, and Er:YAG laser treatments (10,12,14,16) have been reported to facilitate the bond strength between resin cement and Y-TZP ceramic.

On the other hand, recent studies have expressed concern about cracking and surface flaws produced by surface pretreatments including grinding, sandblasting, and laser, which may induce the tetragonal to monoclinic phase transformation of zirconia and, thus reducing the strength and toughness, decreasing reliability and increasing the failures in the clinic (17).

However, limited studies on flexural strength testing after surface treatment of the zirconia have been done. In the light of all these data, the purpose of the present study was to investigate the effects of roughening and abrasion procedures (airborne-particle abrasion, silica coating, Nd:YAG laser irradiation, grinding from the cervical line and grinding from functional tubercule) applied to the zirconia surface on the flexural strength of the zirconia-based restorations. The

DOI: 10.33808/clinexphealthsci.796603

hypothesis tested was that surface treatment procedures applied on zirconia result in lower flexural strength of the restorations.

2. METHODS

120 implant analogs and abutments with a diameter of 4.5 mm and a length of 9 mm (including 3.5 mm gingival length) (AnyOne, MegaGen Co. Ltd., Kyungsan, South Korea) were used in this study. Implant analogs were embedded into the acrylic resin using the copper analogs (Figure 1). Abutments were seated on the implant analogs and tightened with the torque values of 30 N cm according to the manufacturer suggestion.

2.1. Fabrication of the Zirconia Specimens

A CAD/CAM system (Yenamak, Yenadent Ltd. Şti., Istanbul, Turkey) was used to design and mill the crowns. Mandibular first molar crowns with a buccolingual width of 8 mm, a mesiodistal width of 10 mm, and an occlusal thickness of 1.5 mm was designed over implant abutments. Of the substructures; 20 were fabricated 0.2 mm longer at the cervical line for the group of bur-cut from cervical region whereas 20 were fabricated thicker at 0.2 mm occlusal to the functional tubercules for the group of bur-cut on the functional tubercule. Milled crowns were finished and polished following manufacturers' instructions. Furthermore, crown dimensions were verified with a digital caliper (Altas 905, Gedore-Altas, Istanbul, Turkey).

Specimens were then divided into 6 experimental groups (n=20) according to the surface treatments applied:

Group C—untreated (control): This group served as the control group, so no treatment was applied to the zirconia surfaces in this group.

Group SB—sandblasted: The bonding surfaces of the zirconia specimens were sandblasted (Ney, Blastmate II, Yucaipa, CA, USA) with 120 µm aluminum oxide (Al_2O_3) for 10 s. The air pressure for sandblasting was maintained at 2 bars. Specimens were mounted in a special holder at a distance of 10 mm between the surface of the specimen and the blasting tip. Then, the specimens were rinsed under running water and dried with oil-free compressed air to remove the remnants.

Group SC—silica-coating: 30 µm silica-modified Al2O3 particles (CoJet Sand) were sprayed on the surface of the specimens with an intraoral airborne-particle abrasion device (Co-Jet, 3M ESPE, St Paul, MN, USA) at 2 bars for 10 s. In order to adjust application distance of 10 mm, a special holder was used.

Group N—Nd:YAG laser irradiated with contact mode: Bonding surfaces of zirconia specimens were irradiated with a Nd:YAG laser (Smarty A10, Deka Laser, Florence, Italy). Laser energy was delivered in pulse mode with a 300 mm diameter laser optical fiber, a wavelength of 1,064 µm at 100 mJ (pulse energy), 10 Hz (repetition rate), 1 W (output power), 300 µs (pulse duration), and 141.54 J/cm^2 (energy density) for 20 s. In addition, only air cooling was used during the laser irradiation of the specimens.

Group BC—bur-cut from cervical region: Cervical region of the zirconia was milled 0.2 mm with a black-belt torpedo diamond bur (MDT Dental, Afula, Israel) under water cooling.

Group BT—bur-cut on the functional tubercule: Functional tubercule of the zirconia was milled 0.2 mm with a black-belt torpedo diamond bur (MDT Dental, Afula, Israel) under water cooling.

Silicone index was used to standardize veneer thickness for all groups. Feldspar veneering ceramic were performed on the zirconia frameworks (VITABLOCS Mark II, VITA Zahnfabrik, Bad Säckingen, Germany) according to the manufacturer suggestions.

2.2. Cementation of the Specimens

The obtained crowns were cemented onto the implant abutments (Figure 2). The specimens of each groups were divided into 2 groups and two different cement materials were used in cementation procedure. For each group, half of the specimens were adapted with a dual-cure resin cement material (Panavia SA, Kuraray, Tokyo, Japan) including MDP while other half of the specimen were adapted with a glass ionomer cement material under finger pressure. A 2 kg force was applied on the crown to standardize the force during cementation. In this manner, it was exposed to light for 2 seconds and pre-hardening was performed. Residual cement fragments were cleaned using a sound and radiation was applied for 20 seconds at each surface of the crown in accordance with the instructions of the manufacturer (Elipar, 3M ESPE, St Paul, MN).

2.3. Fracture Strength Test of the Zirconia-Based Specimens

After cementation procedure was completed, all of the specimens were stored at 37°C distilled water bath device (Nüve BM 302 – Nüve Sanayii Malzemeleri İmalat ve Ticaret A.Ş., Ankara, Turkey) for 24 hours. Then these specimens were subjected to the thermal cycling machine (GM, Gökçeler Makine Tic. ve San. Ltd. Şti., Sivas, Turkey) for 3000 cycles. After aging process, the specimens were attached to a custom jig of a universal testing machine (Lloyd LF Plus, Ametek Inc, Lloyd Instruments, Leicester, UK) and fracture strength test was performed (Figure 3). A 5 mm-diameter metal end was inserted to fit the central fossae of the specimens at a crosshead speed of 1 mm/min to determine their fracture strength in terms of Newton. At the same time, fracture types of the specimens were saved. Fracture types were termed as a crown fracture in presence of fractures in both superstructure porcelain and zirconia or a fracture between superstructure porcelain and zirconia; a cohesive fracture in presence of only fracture of the superstructure porcelain; an adhesive fracture in case of full detachment of crown and cements from the abutment and finally a mixed-mode fracture if the fracture was both cohesive and adhesive at the same time.

2.4. Statistical Analysis

In evaluating the data, the program IBM SPSS Statistics 22 (IBM SPSS, New York, USA) was used for statistical analysis. Since the assumptions for a parametric test (Kolmogorov-Smirnov) were fulfilled, one-way analysis of variance was used to compare the means obtained from more than two independent groups. Tukey tests were used to find the differences between the groups. The data are stated as the mean and standard deviation at the table, and an error level of 0.05 was used.

3. RESULTS

Mean and standard deviation values of the groups for bonding strength were shown (Table 1). No statistically significant difference was found between the groups ($p>0.05$). Similarly, no statistically significant difference was found between the resin cement and glass ionomer groups with respect to fracture strength values ($p>0.05$). In the resin cement groups; the highest fracture strength was encountered in the specimens which were applied 0.5 mm abrasion from the functional tubercule whereas the lowest fracture strength was found in the specimens of silica-coating group. In the glass ionomer groups; the highest fracture strength was encountered in the specimens which were applied laser irradiation whereas the lowest fracture strength was found in the specimens with abrasion at the cervical line.

Table 1. *Statistical analysis of data in groups*

		Fracture Resistance	
Groups	n	Resin cement	Glass ionomer cement
Group C	10	1230 (382)	1153 (407)
Group AA	10	1195 (288)	1256 (472)
Group SC	10	987 (352)	1092 (315)
Group N	10	1001 (244)	1396 (367)
Group B	10	1280 (448)	1064 (282)
Group O	10	1410 (498)	1338 (515)

4. DISCUSSION

In light of the obtained data, the hypothesis that surface treatment procedures applied on zirconia result in lower flexural strength of the restorations was rejected. In the literature, conflicting results could be seen on the effects of grinding with diamond instruments on Y-TZP's mechanical properties. A positive effect could be met in some studies (18,20), due to the phase transformation toughening mechanism, where grinding triggers a t-m phase transformation, which results in a volumetric expansion of nearly %4 around the superficial defects, inducing compressive stress concentration and consequently arresting crack propagation (21). However, grinding introduces important superficial defects that could be deleterious, decreasing the mechanical properties and resulting in higher risk of catastrophic failures were exhibited in other studies (22,27).

In consistent with the results of the present study, Song, advocated that airborne-particle abrasion and heat treatment of the upper surface, corresponding to the outer surface of a crown, did not influence biaxial flexural strength of the zirconia specimens (6). Similarly, Jian found that veneer porcelain applied directly after routine lab grinding of zirconia ceramic, and liner porcelain application on rough zirconia cores may be preferred to slightly enhance strength reliability (28). In addition, Ozcan advocated that silica-coating has positive effect on the flexural strength of the zirconia ceramic (29). However, Bankoglu Gungor exhibited that surface treatments affected the phase transformation and biaxial flexural strength of zirconia ceramics (30). Furthermore, presented that application of surface treatments (laser and airborne-particle abrasion) at pre-sintered stage may be detrimental for zirconia ceramics in terms of flexural strength (31).

On the other hand, clinicians may choose to use resin cements with lithium disilicate crowns due to several studies showing that glass-based crowns luted with resin cement demonstrated a higher strength than those luted with resin-modified glass ionomer (RMGI) cement. Therefore, in the present study, half of the specimens were luted with glass-ionomer cement and half were luted with resin cement. The present study shows that flexural strength is independent to the cement types. However, Lawson advocated that cement type (resin and resin-modified glass ionomer) affected fracture load of crowns but surface treatment did not (32).

One of the limitations of this study is that fatigue loading was not performed on the zirconia crowns. Therefore, future studies could focus on the effects of surface treatment and cement on the fatigue life of zirconia ceramic crowns.

5. CONCLISIONS

Within the limitations of the present study, surface treatments and cement have no effect on the flexural strength of zirconia ceramic crowns.

REFERENCES

[1] Alayad AS. Effect of zirconia core thickness and veneer firing cycle on the biaxial flexural strength of veneering ceramic. J Prosthodont 2020; 29(1):26-33.

[2] Hamza TA, Sherif RM. fracture resistance of monolithic glass-ceramics versus bilayered zirconia-based restorations. J Prosthodont 2019; 28(1):259-264.

[3] Al-Wahadni A, Shahin A, Kurtz KS. Veneered zirconia-based restorations fracture resistance analysis. J Prosthodont 2018; 27(7):651-658.

[4] Turk AG, Ulusoy M, Yuce M, Akin H. Effect of different veneering techniques on the fracture strength of metal and zirconia frameworks. J Adv Prosthodont 2015; 7(6):454-459.

[5] Pereira GKR, Fraga S, Montagner AF, Soares FZM, Kleverlaan CJ, Valandro LF. The effect of grinding on the mechanical behavior of Y-TZP ceramics: A systematic review and meta-analyses. J Mech Behav Biomed Mater 2016; 63:417-442.

[6] Song JY, Park SW, Lee K, Yun KD, Lim HP. Fracture strength and microstructure of Y-TZP zirconia after different surface treatments. J Prosthet Dent 2013; 110(4):274-280.

[7] Kim SY, Choi JW, Ju SW, Ahn JS, Yoon MJ, Huh JB. fracture strength after fatigue loading of lithium disilicate pressed zirconia crowns. int j prosthodont 2016; 29(4):369-371.

[8] Sailer I, Fäher A, Filser F, Gauckler L, Lüthy H, Hämmerle CH. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int J Prosthodont 2007; 20:383-388.

[9] Sailer I, Fehér A, Filser F, Lüthy H, Gauckler LJ, Schärer P, Franz Hämmerle CH. Prospective clinical study of zirconia posterior fixed partial dentures: 3-year follow-up. Quintessence Int 2006; 37:685-593.

[10] Akın H, Ozkurt Z, Kırmalı O, Kazazoglu E, Ozdemir AK. Shear bond strength of resin cement to zirconia ceramic after aluminum oxide sandblasting and various laser treatments. Photomed Laser Surg 2011; 29(12):797-802.

[11] Khan AA, Al Kheraif AA, Jamaluddin S, Elsharawy M, Divakar DD. Recent Trends in Surface Treatment Methods for Bonding Composite Cement to Zirconia: A Review. J Adhes Dent 2017; 19(1):7-19.

[12] Yun JY, Ha SR, Lee JB, Kim SH. Effect of sandblasting and various metal primers on the shear bond strength of resin cement to Y-TZP ceramic. Dent Mater 2010; 26(7):650-658.

[13] Ersu B, Yuzugullu B, Yazici AR, Canay S. Surface roughness and bond strengths of glass-infiltrated alumina-ceramics prepared using various surface treatments. J Dent 2009; 37:848–856.

[14] Akin GE, Kaval ME, Turk T, Akin H. Surface roughness and bond strength of zirconia posts to a resin cement after various surface pretreatments. Photomed Laser Surg 2015; 33(5):246-251.

[15] Kirmali O, Akin H, Kapdan A. Evaluation of the surface roughness of zirconia ceramics after different surface treatments. Acta Odontol Scand 2014; 72(6):432-439

[16] Akin H, Tugut F, Akin GE, Guney U, Mutaf B. Effect of Er:YAG laser application on the shear bond strength and microleakage between resin cements and Y-TZP ceramics. Lasers Med Sci 2012; 27(2):333-338.

[17] Khan, Guazzato M, Albakry M, Quach L, Swain MV. Influence of grinding, sandblasting, polishing and heat treatment on the flexural strength of a glass-infiltrated alumina-reinforced dental ceramic. Biomater 2004; 25:2153-2160.

[18] Amaral M, Valandro LF, Bottino MA, Souza RO. Low-temperature degradation of a Y-TZP ceramic after surface treatments. J Biomed Mater Res, 2013; 101(8):1387-1392.

[19] Pereira GKR, Amaral M, Cesar PF, Bottino MC, Kleverlaan CJ, Valandro LF. Effect of low temperature aging on the mechanical behavior of ground Y-TZP. J Mech Behav Biomed Mater 2015;45: 183-192.

[20] Ramos GF, Pereira GKR, Amaral M, Valandro LF, Bottino MA. Effect of grinding and heat treatment on the mechanical behavior of zirconia ceramic. Braz Oral Res 2016; 30(12):1-8.

[21] Garvie RC, Nicholson PS. Phase analysis in zirconia systems. J Am Ceram Soc, 1972;5 5(6):303-305.

[22] Kosmac T, Oblak C, Jevnikar P, Funduk N, Marion L. Strength and reliability of surface treated YTZP dental ceramics. J Biomed Mater Res 2000; 53(4):304-313.

[23] Kosmac T, Oblak C, Jevnikar P, Funduk N, Marion L. The effect of surface grinding and sandblasting on flexural strength and reliability of Y-TZP zirconia ceramic. Dent Mater 1999; 15(6):426-433.

[24] Kosmac T, Oblak C, Marion L. The effects of dental grinding and sandblasting on ageing and fatigue behavior of dental zirconia (Y-TZP) ceramics. J Eur Ceram Soc 2008; 28(5):1085-1090.

[25] Kosmac T, Dakskobler A. The strength and hydrothermal stability of Y-TZP ceramics for dental applications. Int J Appl Ceram Technol 2007; 4(2):164-174.

[26] Curtis AR, Wright AJ, Fleming GJP. The influence of surface modification techniques on the performance of a Y-TZP dental ceramic. J Dent 2006; 34(3):195-206.

[27] Iseri U, Ozkurt Z, Yalniz A, Kazazoglu E. Comparison of different grinding procedures on the flexural strength of zirconia. J Prosthet Dent 2012; 107(5):309-315.

[28] Jian YT, Tang TY, Swain MV, Wang XD, Zhao K. Effect of core ceramic grinding on fracture behaviour of bilayered zirconia veneering ceramic systems under two loading schemes. Dent Mater 2016; 32(12):1453-1463.

[29] Ozcan M, Melo RM, Souza RO, Machado JP, Felipe Valandro L, Botttino MA. Effect of air-particle abrasion protocols on the biaxial flexural strength, surface characteristics and phase transformation of zirconia after cyclic loading. J Mech Behav Biomed Mater 2013; 20:19-28.

[30] Bankoglu Güngör M, Yılmaz H, Karakoca Nemli S, Turhan Bal B, Aydın C. Effect of surface treatments on the biaxial flexural strength, phase transformation, and surface roughness of bilayered porcelain/zirconia dental ceramics. J Prosthet Dent 2015; 113(6):585-595.

[31] Kurtulmus-Yilmaz S, Aktore H. Effect of the application of surface treatments before and after sintering on the flexural strength, phase transformation and surface topography of zirconia. J Dent 2018; 72:29-38.

[32] Lawson NC, Jurado CA, Huang CT, Morris GP, Burgess JO, Liu PR, Kinderknecht KE, Lin CP, Givan DA. effect of surface treatment and cement on fracture load of traditional zirconia (3y), translucent zirconia (5y), and lithium disilicate crowns. J Prosthodont 2019; 28(6):659-665.

How to cite this article: Akar T, Akin H. Investigation of Fracture Resistance of Zirconia Restorations After Different Surface Treatments. Clin Exp Health Sci 2021; 11: *318-321*. DOI :10.33808/ clinexphealthsci.796603