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The Impact of CO_2 Laser on the Bond Strength of Translucent Zirconia and Traditional Zirconia with the Resin Cement- in Vitro Study

SUMMARY

Background/Aim: *The aim of this study is to compare the impact of CO_2 laser on traditional zirconia and translucent zirconia in terms of the bonding strength to resin cement.* ***Material and Methods***: *In this in-vitro study 20 zirconia disks (10 mm diameter and 2 mm thickness) were assigned to two groups (n = 10). Group 1: 10 discs of traditional zirconia, Group 2: 10 discs of translucent zirconia, CO_2 lasers were used for pretreatment of zirconia surface, respectively. Dentinal disks were cemented on zirconia disk using dual-curing resin cement. Shear bond strength tests were performed at a crosshead speed of 1 mm/min after 24 h distilled water storage. Data was analyzed by T Student's test.* ***Results***: *The means and standard deviations of shear bond strength values in Group 1, and Group 2 were 1.15, 0.38, 1.99 , 0.65 MPa respectively. Data showed that application of CO_2 laser resulted in a significant higher shear bond strength of resin cement to translucent zirconia ceramics ($p < 0.05$).* ***Conclusions***: *Application of CO_2 laser treatment (3W) increases the bond strength to the resin cement of translucent zirconia compared to traditional zirconia.*

Key words: CO_2 laser, Translucent Zirconia, Traditional Zirconia, Bond strength, Surface Treatment

Rima Jawdat Saker, Bashar Moukhles Zleik

[1]Department of Prosthodontic, Faculty of Dentistry, Tishreen University, Latakia, Syria

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Introduction

Zirconia ceramic dental restorations have gained considerable prevalence in dentistry and their use has spread significantly[1]. Zirconia is crystallized in three stages: Monoclinic, Tetragonal, and cubic shape. Pure zirconia remains in the Monoclinic phase at room temperature and is stable up to 1070 C° and turns into the Tetragonal phase under higher temperatures and then to the cubic stage at 2370 C°. When the zirconia surface is exposed to fracture, stress is concentrated at the top, causing the Tetragonal crystals to become Monoclinic crystals; This shift is accompanied by a volume expansion that closes the surface cracking place; This property protects the zirconia surface from applied stress and enhances its resistance. Clinically, there are several types of zirconia used in dentistry: Tetragonal Zirconia Traditional (900 to 1200 MPA), High Translucent Zirconia HT (900 to 1200 MPA), Ultra Translucent cubic zirconia UT (from 500 to 800 MPA) that possesses high Optical properties and secures aesthetic requirements well improving their clinical use, Super translucent Zirconia ST (750 MPA) which appeared in 2015[2].

The most common zirconia used in dentistry is the traditional multi-crystal Tetragonal zirconia fortified with Eitria (Y-TZP) with excellent strength but little transparency which is why new types of transparent zirconia with improved optical properties have emerged to be used either for Anterior or posterior restorations, since it has a different molecular structure and physical properties compared to traditional zirconia that combines the strength of zirconia with lithium dual silicate aesthetic due to its high transparency[3].

In order to enhance the adhesive bonding of traditional Y-TZP zirconia and other ceramic materials to resin cement, many authors have performed various surface treatments on these substances and suggested various techniques such as surface abrasion, Sandblasting with Al2O3, abrasion with diamond rotary instruments, Tribochemical Silica-coating (TBS) and acid etching with hydrofluoric acid[4].unfortunately, Zirconia has a problem in bonding compared to other ceramic types such as glass ceramics reinforced with lithium disilicate crystals. The application of Hydrofluoroacid and silane to glass ceramics contributes to the formation of bonds during adhesion while this does not affect crystal phase ceramics such as zirconia[5].

Recently, due to advances in laser techniques, many studies have suggested the application of laser beams such as CO_2, Er: YAG, and Nd: YAG to make changes in zirconia ceramics to improve the bonding strength, these studies have shown that the use of CO_2 and Er:YAG lasers improves the bonding strength of zirconia to resin cement[6,7].CO_2 laser was proposed to treat ceramic materials because the wavelength of its emissions is almost totally absorbed by the ceramic[8].

Studies have suggested that CO_2 laser etching is an effective method for conditioning zirconia surfaces enhancing micromechanical retention and improving the bond strength of resin cement on zirconia ceramic but fewer studies specifically on new generations of zirconia (translucent zirconia)[6,9].

The aim of this in vitro study is to compare the impact of CO_2 laser on traditional zirconia and translucent zirconia in terms of the bonding strength to resin cement.

Material and Methods

The current study was performed on 20 zirconia discs equipped with a standard dimension CAD/CAM (10 mm diameter and 2 mm thickness) evenly distributed to two groups according to the zirconia type used as the following: Group 1:10 discs of traditional zirconia from (LUXEN zr), Group 2:10 discs of translucent zirconia (ST) from (LUXEN smile). The surfaces were treated with CO_2 laser (AirSafe VersaVac 2 Smoke Filtration System, Taiwan/Hong Kong) with a wavelength of 10.6 µm and output energy of 3W and pulse duration of 160 ms. 6 mm in the center of the zirconia disc was irradiated for 10 seconds for 1mm working distance to the ceramic surface (Figure 1).

A total of 20 caries-free human molars (extracted in the periodontal department due to periodontal disease that caused third-degree movement) were selected, cleaned and stored in distilled water. The teeth surfaces were sliced in wet conditions to expose the superficial dentin. The teeth were fixed in custom designed cylindrical acrylic molds (EpoxiCure, Buehler, USA) (Figure 2).

After the surface treatment in the target area (6 mm in the center of the disc), ceramic discs were cemented to dentinal disc surfaces using the resin cement (B&E COREA CO.LTD) according to the manufacturer's instructions. The resin cement was placed between ceramic discs and dentinal discs and each dentinal disc was bonded to a zirconia disk by constant force applied on the disc (20N) for 10 sec. to obtain homogeneous thickness of the cement layer. Excess cement was eliminated and the cement was light-cured by applying light from the four sides of the tooth with a constant distance of the device's head from the disc for 40 sec. each.

Figure 1. CO_2 laser device

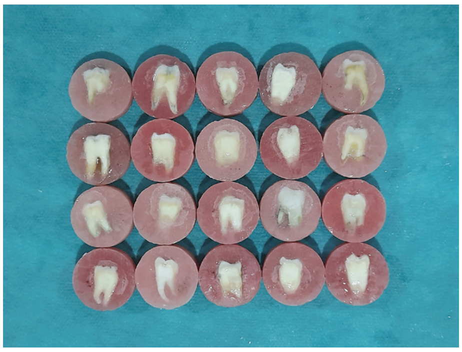

Figure 2. Teeth in acrylic molds

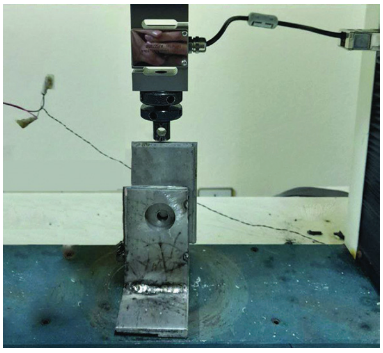

Figure 3. Shear strength test

Shear bond strength was tested in a mechanical testing machine (Tinius olsen H50KS, USA) at a crosshead speed of 1 mm/min (Figure 3). Shear load was applied until failure occurred using a special head designed with a metal mold. Shear bond strength values (MPa) were calculated using the formula: bond strength = F/A, where F is the force at failure (N) and A is the surface area of the ceramic cube (mm^2).

The SPSS (SPSS for Windows, Chicago, SPSS Inc., USA) was used to undertake the analysis and achieve the objectives set out in this research.

Results

T Student's test was conducted to study the differences in bonding strength (MPa) between the translucent zirconia set and the traditional zirconia (Table 1), (Table 2). The mean deviation of bond strength values (MPa) was presented on Figure 4.:

Table 1. Shear bond strength results (MPa)

Group	The mean deviation	The standard deviation	The standard error	Minimum	Maximum
Group I	1.15	0.38	0.12	0.77	2.06
Group 2	1.99	0.65	0.21	1.51	3.37

Table 2. T Student's test results for samples

Average difference	T. value	Significance level
0.84	3.517	0.002

T Student's test showed statistically significant differences in bond strength values between the two groups where translucent zirconia showed a stronger bonding to resin cement than traditional zirconia.

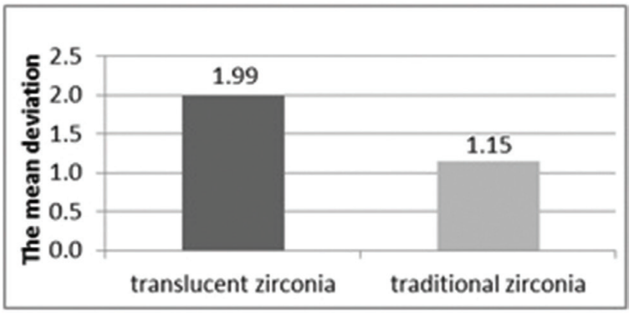

Figure 4. The mean deviation of bond strength values (MPa)

Discussion

The use of zirconia has increased widely in recent years in the field of dentistry but traditional zirconia is rarely used on anterior teeth due to the unattractive color and the risk of breaking ceramic veneers[10]; More recently, highly translucent zirconia has been developed for anterior monolithic zirconia crowns or fixed dental prostheses to achieve the cosmetic aspect required for patients[11], where various microstructural modifications were made to zirconia materials including temperature and time parameters for sintering cycles, alumina quantity, molecule size and ceramic structure[12]; Additionally, the amount of yttria, the stabilizing agent of the tetragonal phase, has been increased. Therefore, these translucent Y4- or Y5-zirconias have lower mechanical properties (flexural strength, fatigue strength, hardness, and fracture toughness) than traditional Y3 zirconia giving zirconia (Y4, Y5) higher transparency than traditional Y3 zirconia and lower mechanical properties[13].

Resin cement is recommended for adhesion due to its reduced solubility in the oral cavity which reduces the microleakage between restorations and teeth that causes discoloration or Caries, as well as good optical properties and secures adequate stabilization[14,15]. But despite the good mechanical strength of zirconia, adhesive restorations with resin cement remains a challenge for dentists as studies have focused on various surface treatments to improve the bonding strength between cement and zirconia, such as Tribochemical Silica-coating, etching with hydrofluoric acid, Sandblasting and laser irradiation[16].

Mechanical etching and Sandblasting can create small cracks within zirconia, causing undesirable changes in mechanical properties and causing micro-cracks, and some studies have indicated fractures in zirconia restorations, which may affect the strength of the bond in the long term[17]; therefore, an alternative treatment method has been developed such as laser irradiation, and it has been used to provide roughness on the surface of zirconia[6] due to the speed and precise control of the laser. Some researchers (Holthaus et all) also indicated that it can replace traditional surface treatment by Airborne-particle abrasion (APA)[18].

Some other studies have shown that using CO_2 and Er:YAG lasers improves the bond strength to zirconia ceramics[6], and CO_2 laser irradiation has been shown to be an effective method for conditioning and roughening zirconia surfaces, creating recesses to enhance precise mechanical bonding, and improving the bond strength of resin cement to zirconia ceramics[6,9]. Some researchers have reported that the use of the mentioned lasers (CO_2 and ER: YAG) alone or after Sandblasting of zirconia surfaces are able to improve the bond strength between Y-TZP and resin cement[19].

In this study, a CO_2 laser was used to treat the surfaces of two types of zirconia. The bond strength of the resin cement applied to a disc of translucent zirconia and dentin was compared with the bond strength of the resin cement applied to a disc of traditional zirconia and dentin. By comparing the two types of zirconia, it was noted a significant difference between the two groups in terms of Bond strength: The bond strength in translucent zirconia was much greater (P=0.002).

The absorption of the CO_2 laser beam can be greater on the surface of the highly translucent zirconia, which gave a higher efficiency of the laser beam in the translucent zirconia ceramic than the traditional one in creating micro-cavities and a higher roughness of its surface, which increased the bond strength of the translucent zirconia with the resin cement compared to the traditional zirconia[20], The difference in the chemical composition, size and quantity of crystals, and the difference in mechanical properties of both types[11,21] may have given the CO_2 laser the ability to cause structural changes and surface scratching to a greater extent and with higher efficiency, which helped increase the bond with the resin cement and create bridges and bonds between the zirconia ceramic and the resin cement.

We agreed with Shahin Kasraei in 2014, as the results of his study showed that the use of CO_2 and ER: YAG lasers led to a significant increase in the bond strength of zirconia with resin cement, with the CO_2 laser superior to the Er: YAG laser, as the highest bond strength was in the group that used the CO_2 laser[22].

Cagri Ural et al. found that the highest bond strength was when a CO_2 laser with 2W and 3W power was used, and this is consistent with our study[9]. However, translucent zirconia has lower particle size, elastic strength, and fracture toughness values than traditional zirconia causing a different microstructure that negatively affects adhesion which requires further testing[20]. In addition, only a few studies have reported the effect of treatments Surface on translucent zirconia[23,24].

Conclusions

Within the limitations of this study, Application of CO2 laser treatment (3W) increases the bond strength to the resin cement of translucent zirconia compared to traditional zirconia.

References

1. Denry I, Kelly JR (2008). "State of the art of zirconia for dental applications". *Dent Mater.* **24** (3): 299-307. doi: 10.1016/j.dental.2007.05.007. PMID: 17659331
2. Rondoni D (2016). "Zirconia: Some practical aspects from the technologist's point of view". *Int J Esthet Dent*. **11** (2): 270-274. PMID: 27092353
3. Manziuc MM, Gasparik C, Negucioiu M, Constantiniuc M, Burde A, Vlas I, et al. (2019). "Optical properties of translucent zirconia: A review of the literature". *EuroBiotech J*, **3** (1): 45-51. doi: 10.2478/ebtj-2019-0005
4. Miranda PV, Rodrigues JA, Blay A, Shibli JA, Cassoni A (2015). "Surface alterations of zirconia and titanium substrates after Er, Cr: YSGG irradiation". *Lasers Med Sci*, **30** (1): 43-48. doI: 10.1007/s10103-013-1516-x. PMID: 24430726
5. Özcan M, Valandro LF, Pereir, SM, Amaral R, Bottino MA, Pekkan G (2013). "Effect of surface conditioning modalities on the repair bond strength of resin composite to the zirconia core/veneering ceramic complex". *J Adhes Dent*, **15** (3): 207-210. doi: 10.3290/j.jad.a29717. PMID: 23700578
6. Paranhos MPG, Burnett JrLH, Magne P (2011). "Effect of Nd: YAG laser and CO2 laser treatment on the resin bond strength to zirconia ceramic". *Quintessence Int*. **42** (1): 79-89. PMID: 21206937.
7. Akyıl MŞ, Uzun İH, Bayındır F (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** (6): 801-808. doi: 10.1089/pho.2009.2697. PMID: 20969444
8. Ersu B, Yuzugullu B, Yazici AR, Canay S (2009). "Surface roughness and bond strengths of glass-infiltrated alumina-ceramics prepared using various surface treatments". *J Dent*, **37** (11): 848-856. doi: 10.1016/j.jdent.2009.06.017. PMID: 19616883
9. Ural Ç, Kalyoncuoğlu E, Balkaya V (2012). "The effect of different power outputs of carbon dioxide laser on bonding between zirconia ceramic surface and resin cement". *Acta Odontol Scand*, **70** (6): 541-546. doi: 10.3109/00016357.2011.600718. PMID: 21780979
10. Muñoz EM, Longhini D, Antonio SG, Adabo GL (2017). "The effects of mechanical and hydrothermal aging on microstructure and biaxial flexural strength of an anterior and a posterior monolithic zirconia". *J Dent*, **63**: 94-102. doi: 10.1016/j.jdent.2017.05.021. PMID: 28591620
11. Elsaka SE (2019). "Optical and mechanical properties of newly developed monolithic multilayer zirconia". *J Prosthod*, **28** (1): e279-e284. doi: 10.1111/jopr.12730. PMID: 29239067
12. Stawarczyk B, Frevert K, Ender A, Roos M, Sener B, Wimmer T (2016). "Comparison of four monolithic zirconia materials with conventional ones: Contrast ratio, grain size, four-point flexural strength and two-body wear". *J Mech Behav Biomed Mater*. **59**: 128-138. doi: 10.1016/j.jmbbm.2015.11.040. PMID: 26751707
13. Arcila LVC, de Carvalho Ramos N, Campos TMB, Dapieve KS, Valandro LF, de Melo RM, et al. (2021). "Mechanical behavior and microstructural characterization of different zirconia polycrystals in different thicknesses". *J Adv Prosthodont*. **13** (6): 385-395. doi: 10.4047/jap.2021.13.6.385. PMID: 35003554. PMCID: PMC8712112
14. Kitayama S, Nikaido T, Takahashi R, Zhu L, Ikeda M, Foxton RM, et al. (2010). "Effect of primer treatment on bonding of resin cements to zirconia ceramic". *Dent Mater,* **26** (5): 426-432. doi: 10.1016/j.dental.2009.11.159. PMID: 20102781
15. Jevnikar P, Krnel K, Kocjan A, Funduk N, Kosmač T (2010). "The effect of nano-structured alumina coating on resin-bond strength to zirconia ceramics". *Dent Mater*, **26** (7): 688-696. doi: 10.1016/j.dental.2010.03.013. PMID: 20381854

16. Ural Ç, Külünk T, Külünk Ş, Kurt M (2010). "The effect of laser treatment on bonding between zirconia ceramic surface and resin cement". *Acta Odontol Sca*nd, **68** (6): 354-359 doi: 10.3109/00016357.2010.514720. PMID: 20818916
17. Yun JY, Ha SR, Lee JB, Kim SH (2010). "Effect of sandblasting and various metal primers on the shear bond strength of resin cement to Y-TZP ceramic". *Dent Mate*r, **26** (7): 650-658. doi: 10.1016/j.dental.2010.03.008. PMID: 20427080 PMID: 21206937
18. Hallmann L, Ulmer P, Wille S, Polonskyi O, Köbel S, Trottenberg T, et al (2016). "Effect of surface treatments on the properties and morphological change of dental zirconia". *J Prosthet Dent*. **115** (3): 341-349. doi: 10.1016/j.prosdent.2015.09.007. PMID: 26581661
19. Akın H, Ozkurt Z, Kırmalı O, Kazazoglu E, Ozdemir AK (2011). "Shear bond strength of resin cement to zirconia ceramic after aluminum oxide sandblasting and various laser treatments". *Photomed Laser Surg*, **29** (12): 797-802. doi: 10.1089/pho.2011.3039. PMID: 22150095
20. Nadal LPO, de Carvalho Ramos N, Tribst JPM, Anami LC, de Melo RM, Bottino MA (2022). "Interfacial Fracture Energy Between New Translucent Zirconias and a Resin Cement". *J Adhes Dent*, **24**: 147-154. doi: 10.3290/j.jad.b2916403. PMID: 35416442
21. Carrabba M, Keeling AJ, Aziz A, Vichi A, Fonzar RF, Wood D, et al. (2017). "Translucent zirconia in the ceramic scenario for monolithic restorations: A flexural strength and translucency comparison test". *J Dent*, **60**: 70-76. doi: 10.1016/j.jdent.2017.03.002. PMID: 28274651
22. Kasraei S, Rezaei-Soufi L, Heidari B, Vafaee F (2014). "Bond strength of resin cement to CO2 and Er: YAG laser-treated zirconia ceramic". *Restor Dent Endod*. **39** (4): 296-302. doi: 10.5395/rde.2014.39.4.296. PMID: 25383349. PMCID: PMC4223100
23. McLaren EA, Lawson N, Choi J, Kang J, Trujillo C (2017). "New high-translucent cubic-phase–containing zirconia: Clinical and laboratory considerations and the effect of air abrasion on strength". *Compend Contin Educ Dent*. **38** (6): e13-e16. PMID: 28586235
24. Wille S, Zumstrull P, Kaidas V, Jessen LK, Kern M (2018). "Low temperature degradation of single layers of multilayered zirconia in comparison to conventional unshaded zirconia: Phase transformation and flexural strength". *J Mech Behav Biomed Mater*. **77**: 171-175. doi: 10.1016/j.jmbbm.2017.09.010. PMID: 28918009.

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Correspondence

Rima Jawdat Saker
Department of Prosthodontic
Faculty of Dentistry, Tishreen University, Latakia, Syria
e-mail: rima.saker@tishreen.edu.sy