Shear bond strength analysis of differently treated zirconia

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Abstract

Background: In order to achieve a strong adhesion between zirconia and resin cement, the inner surface of the ceramic tooth restoration must be treated properly.

Aim: To evaluate different surface treatment methods of high translucency CAD/CAM zirconia ceramics, by analysing the shear bond strength (SBS) between zirconia and resin cement.

Material and methods: Surfaces of highly translucent CAD/CAM zirconia specimens were treated differently and allocated into 5 groups: control, 30 µm CoJet, 50 µm Al_2O_3, 125 µm Al_2O_3, coated with glass ceramics glaze and etched with HF acid. Shear bond strength tests were performed to measure the bond strength. 30 specimens were tested - 6 in each group. Statistical analysis was done with the programme „IBM SPSS 22.0".

Results: Greatest values of stress were observed in glazed and etched ceramic group ($p<0,05$). Abrasion with 50 µm Al_2O_3 particles did not provide statistically significant improvement in stress. Abrasion with 30 µm CoJet particles provided the greatest stresses of all airborne-particle abraded groups ($p<0,05$).

Conclusions: Additional surface treatment methods, except for 50 µm Al_2O_3 abrasion, increase shear bond strength between resin cement and zirconia ceramics significantly

Key words:

translucent, zirconia, CAD/CAM, surface treatment, shear bond strength

Introduction

Zirconium oxide (ZrO_2) is used in dentistry since the end of 19th century and can be stated as the prime choice material to restore defects in anterior and posterior segments of dental arches [1]. Zirconia has excellent mechanical properties – polycrystal material is highly resistant to fractures and bending forces [2]. Computer aided design and manufacturing (CAD/CAM) technology leads to frequent and simplified use of highly translucent monolithic zirconia [3]. Restorations made of translucent ZrO_2 have large amounts of stabilising yttrium oxide (Y_2O_3) and cubic phase particles [4].

Up to this day, one universal method of zirconia surface treatment has not been found [5]. Nevertheless, compared with conventional zirconia, the influence of high translucency zirconia surface treatment methods on bond strength have not been described widely in scientific literature [6]. This material, contrary to glass ceramics, cannot be etched with hydrofluoric acid (HF) [7,8], because of the absence of silica particles (SiO_2) ang glassy phase [2]. Zirconia is a chemically inert material, therefore, alternative mechanical and chemical surface treatment methods should be chosen in order to increase the bond strength between restoration and resin cement [9]. Airborne particle abrasion with alumina oxide (Al_2O_3) particles, abrasion with silica coated Al_2O_3 particles [10], glaze coating and HF acid etching, laser irradiation [9] – these are some of the most applicable surface treatment methods in prosthodontics. In order to evaluate strength of adhesion, a shear bond strength test is used, where the highest stress is measured up until load failure occurs [11].

The aim of this study was to evaluate shear bond strength of differently treated zirconia surfaces to resin cement.

Material and methods

To conduct this research, zirconia surfaces were treated differently and allocated into 5 groups. Every group consisted of 2 cubic formed zirconia specimens. To complete shear bond strength analysis, 3 surfaces of each cube were used to make 6 samples in every group. Total sample size was N=30.

Fabrication of zirconia cubes

Zirconia cubes were made of high translucency CAD/CAM milled zirconia "Ceramill ZOLID HT+ Preshade" (Amann Girrbach AG, Austrija). They were designed in computer programme „CHITUBOX 64" (Shenzhen CBD Technology Co., Ltd, China). Using CAD programme software „Ceramill® Mind", data was transferred to CAM milling device „Ceramill® Motion"(Amann Girrbach AG, Austria). Milled specimens were then sintered in sintering device „Nabertherm LHTCT 01/16" (Nabertherm GmbH, Germany) for 2 hours, 1500˚C. Sintered cubes were cleaned in ultrasonic bath „Renfert Easyclean" (Renfert GmbH, Germany) in 30°C distilled water for 3 minutes.

Zirconia allocation into groups

A) Control group – surfaces of sintered ZrO_2 were not treated additionally.

B) 30 µm CoJet group – surfaces of zirconia cubes were treated with silica coated alumina oxide particles with manual sandblasting device „KaVo RONDOflex™ plus 360" (KaVo Dental GmbH, Germany). Settings: time - 15 seconds, pressure – 2,8 bars, distance – 10 mm.

C) 50 µm Al_2O_3 group – surfaces of zirconia cubes were treated with 50 µm Al_2O_3 particles with sandblasting device „KaVo EWL Typ 5423" (KaVo Dental GmbH, Germany). Settings: time - 15 seconds, pressure – 2,8 bars, distance – 10 mm.

Fig. 1.
Zirconia cubes

D) 125 µm Al_2O_3 group - surfaces of zirconia cubes were treated with 125 µm Al_2O_3 particles with sandblasting device „KaVo EWL Typ 5423“ (KaVo Dental GmbH, Germany). Settings: time - 15 seconds, pressure – 2,8 bars, distance – 10 mm.

E) Glaze coated and HF etched group – surfaces of zirconia were coated with a layer of glazing paste „IPS e.max Ceram“ (Ivoclar Vivadent AG). Glazed surfaces were etched with 9,6% HF acid „Pulpdent Corporation Porcelain etch gel“ (PULPDENT Corporation, USA) for 60 seconds, water washed 90 seconds, air dried.

Fabrication of resin cement specimens

3,5 mm diameter nail was fitted into a rectangular shaped box. The box was filled with translucent A silicone „Zhermack Elite Transparent“ (Zhermack SpA, Italy). After hardening, the nail was removed and the empty space was filled with dual-curing self-etch, self-adhesive resin cement „ITENA TotalCem“ (ITENA Clinical, France). Resin cement was photopolymerised with LED device „Mectron Starlight PRO“ (Mectron s.p.a., Italy) for 20 seconds from all sides. The cylinder was removed from the box and cut into 3 mm height specimens.

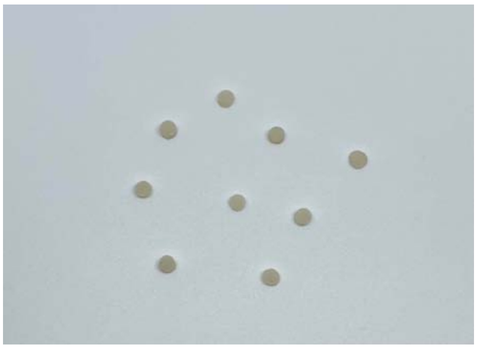

Fig. 2.
Resin cement specimens

Fig. 3.
Final specimens

Fabrication of final specimens

Resin cement specimens were cemented onto zirconia surfaces using the same luting material „ITENA TotalCem“. Photopolymerization was applied for 20 seconds.

Shear bond strength (SBS) testing

SBS testing was performed by using universal testing machine „Tinius Olsen H10KT“ (Tinius Olsen TMC, USA) with speed settings at 1mm/min. During testing the metal blade moved vertically in the site of the connection of resin cement specimen and zirconia. During this procedure, the force of maximum stress was measured up until the load failure occurred. Stress was calculated by formulas below, and the data was put into computer programme „Microsoft Excel 2020“ from which transferred to statistical analysis programme „IBM SPSS 22.0“.

Stress was calculated by formulas:

$$\sigma = \frac{\mathbf{F}}{\mathbf{A}}, \quad A = \pi R^2$$

F – force (N); A – area (mm^2); $\pi = 3{,}14$; R – radius (mm).

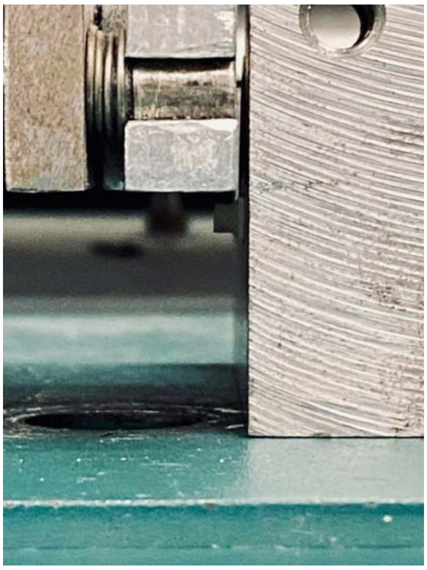

Fig. 4.
SBS testing

Statistical analysis

Statistical analysis was done with programme „IBM SPSS 22.0“. Characteristics presented: average (V), standard deviation (SN), minimal mean, first quartile, median, third quartile, maximal mean. Kruskal-Wallis and Mann Whitney tests were applied.

Results

Different surface treatment methods statistically significantly influenced stress ($p = 0,004$). Lowest stresses were recorded in the control group, whereas the highest – in group E. In addition, stress results in groups B, D and E are similar to each other and statistically significantly higher than in group A ($p<0,05$). Stress results in group C did not significantly differed from stresses recorded in group A, however, they were statistically significantly lower in comparison to groups D and E ($p<0,05$). Stress results in group B were statistically significantly higher than in groups A and C ($p<0,05$). Stresses caused in air abraded groups have also differed. Stresses caused by 50 μm Al_2O_3 particles were significantly lower than ones caused by 30 μm CoJet or 125 μm Al_2O_3 particles ($p<0,05$). Numerical values of SBS testing results are shown in Figure 5.

Stress distribution results by different test groups are shown in Table 1.

Stress distribution results, according to test groups are graphically shown in Figure 6.

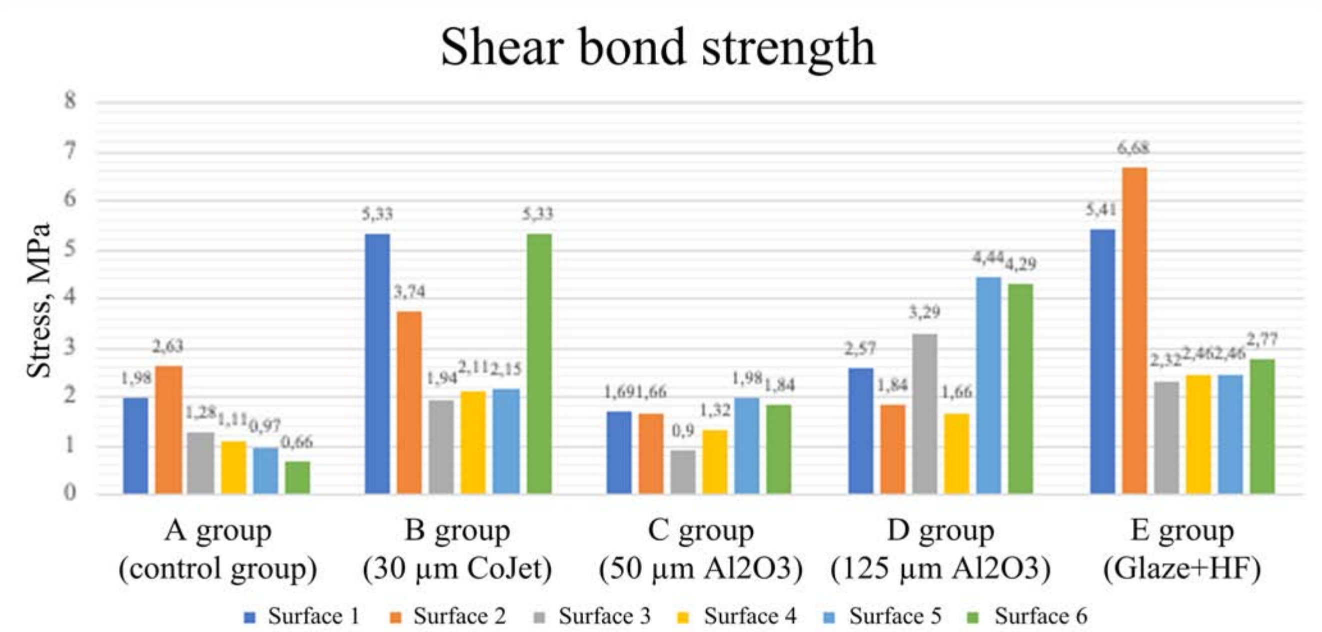

Fig. 5.
SBS testing values

Table 1.
Stress distribution by different test groups

Stress, MPa	Group				
	A	B	C	D	E
Median [25-75 %]	1,2 [0,89-2,14]	2,95 [2,07-5,33]	1,68 [1,22-1,88]	2,93 [1,8-4,33]	2,62 [2,43-5,73]
V (SN)	1,44 (0,73)	3,43 (1,61)	1,57 (0,39)	3,02 (1,2)	3,68 (1,88)
Average rank	7,92	*20,33	+8,08	*,#18,67	*,#22,5
	$\chi^2 = 15,106$, lls = 4, p = 0,004				

V – average, SN – standart deviation, χ^2, lls – number of degrees of freedom, p – significance level, according to nonparametric Kruskal-Wallis test. For multiple comparison Mann-Whitney test was used.
*A group, +B group, #C group, p<0,05.

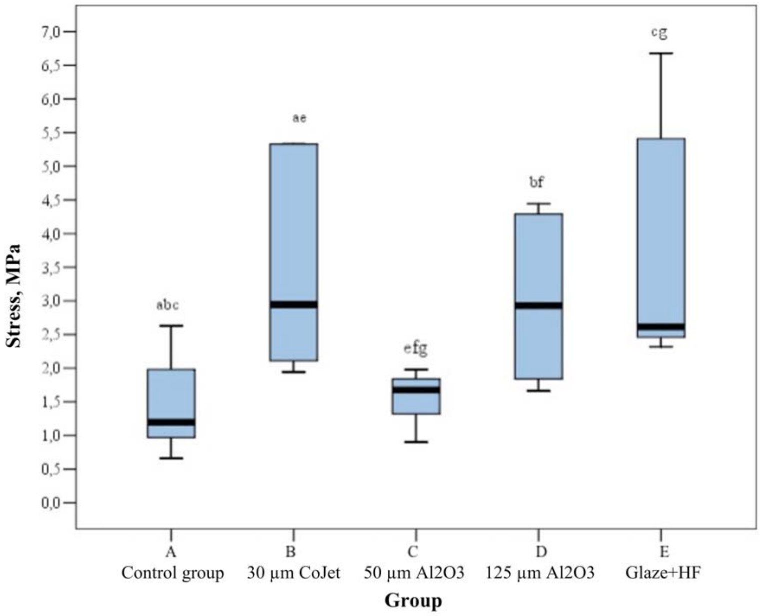

Fig. 6.
Graphic representation of stress distribution results, according to different test groups

Discussion

A strong adhesion between zirconia and resin cement is one of the main factors, impacting long-term success of these restorations [12]. Therefore, it is important to properly choose zirconia surface treatment methods.

After conducting this research, it can be stated, that bond strength between resin cement and non-treated ZrO_2 surfaces is statistically significantly lower than with treated zirconia ($p<0,05$). These results were similar to the findings of the work by Nasr *et al*, published in year 2020, where authors stated that SBS is lower when the air abrasion was not applied to the surfaces of zirconia [13]. These findings can be based on the fact that roughened surface of ZrO_2 was larger, therefore, resin cement could penetrate it in a more extended way.

Results of this *in vitro* research are quite controversial. Even though surface treatment of high translucency zirconia with 30 µm CoJet, 50 µm and 125 µm Al_2O_3 particles increased SBS, statistically significant differences were seen only in 30 µm CoJet and 125 µm Al_2O_3 treated groups ($p<0,05$). In addition, stresses were significantly lower when abraded with 50 µm Al_2O_3 particles in comparison to tribochemically abraded one ($p<0,05$). Contrary to these results, Ruales-Carrera *et al* published an article in 2019, stating that surface treatment of high translucency zirconia with 50 µm Al_2O_3 particles cause greater stresses in comparison to tribochemical abrasion [14]. These findings can be based on surfaces becoming rougher, when using 50 µm Al_2O_3 than 30 µm CoJet particles [14].

The limitation of this study was that it was an *in vitro* research. Therefore, bond strength testing between resin cement and zirconia has not been performed *in vivo*. Additional researches, imitating hydrothermal ageing could be in favour when investigating this topic more thoroughly.

Conclusions

Different surface treatment methods of high translucency zirconia influence SBS between resin cement and zirconia. Greatest SBS is achieved by glazing and HF etching surfaces. 30 µm CoJet abrasion is the best air abrasion method to increase SBS, however, 50 µm Al_2O_3 particles are ineffective to create sufficient SBS between ZrO_2 and resin cement.

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