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Evaluation of the Effect of Sandblasting (120 μm) on Shear Bond Strength Between Ceramic Veneer and Zirconia Core

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ABSTRACT

Background and Aim: Due to the importance of the bond strength between zirconia core (ZC) and porcelain veneer (PV) as well as the paradox about the functionality of sandblasting on the solidity between those layers, this research aimed to evaluate the effect of sandblasting on the shear bond strength (SBS) between ZC and PV.

Materials and Methods: After preparing 20 zirconia discs (7 mm × 3 mm) in this experimental study, they were randomly divided into two groups of case and control. In the case group, sandblasting with 120-μm aluminum oxide particles ($Al2O3$) was performed under 3.5-bar pressure at 10 mm distance from the zirconia surface for 15 seconds. Next, all the samples were cleaned with ultrasonic and 96% isopropyl alcohol for 3 minutes as well as steam cleaning for 10 seconds. Then, the samples were veneered with porcelain (3 mm × 5 mm). SBS was assessed using a universal testing machine. After data collection, the mean and standard deviation (SD) were calculated and analyzed using T-test.

Results: The SBS between ZC and PV was 62.56±8.35 MPa in the case group (after sandblasting) and 94.62±7.69 MPa in the control group. The SBS showed a significant statistical difference between the two groups (P=0.001).

Conclusion: The result of this research indicated that sandblasting reduces the SBS between ZC and PV. Considering the limitations and the methodology of the study, the hypothesis regarding the positive impact of sandblasting on SBS was not proven.

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Introduction:

Of the most important problems in the use of core-veneered ceramic restorations are their durability and fracture resistance.[1] The reason for the popularity of all-ceramic core-veneered restorations is that full bilayered ceramic veneers are more esthetic than metal-ceramic restorations.[2] The tensile bond strength (TBS) between veneer ceramic (VC) and zirconia core (ZC) depends on different factors including the strength of the chemical bonds, mechanical cohesion, the type and the degree of accumulation of defects at the interface, the wetting properties, and the pressure stress in the veneer layer due to the difference in the thermal expansion coefficients between ZC and VC.[3-5] The factors affecting the bond strength between zirconia and veneer include surface roughness, heat treatment, and the use of porcelain liners.[6] The shear tests and microtensile tests are used to measure the bond strength of all-ceramic systems .[4,7-9]

Laboratory studies have shown that veneer failure occurs primarily near the zirconia-veneer interface so that the veneer remains on the zirconia.[9,10] Liu et al conducted a study to compare the effects of three different surface treatments on increasing or improving the bond between zirconium and porcelain.[11] The samples were randomly divided into four groups which were subjected to sandblasting with 50-μm aluminum oxide (Al2O3) particles for 15 seconds and under 3.5-bar pressure at a distance of 10 mm; they stated that sandblasting increased the shear bond strength (SBS) between porcelain and zirconia.[11]

The purpose of the present study was to evaluate the effect of sandblasting of ZC with 120-μm Al2O3 particles on the SBS between ZC and VC compared to the use of thermal therapy alone

Materials and Methods:

This in-vitro experimental study was performed on 20 zirconia discs in two groups with 10 controls. The cylindrical discs of zirconia made of Cercon base ceramic (DeguDent, Hanau, Germany; Table 1) with the dimensions of 7 mm in diameter and 3 mm in height were prepared.[11] The samples were machined using computer-aided design/computer-aided manufacturing system (CAD/CAM; Lava, 3M ESPE, India) with 64 μm milling made of pre-sintered blocks (TZ-3Y-E, Tosoh, Tokyo, Japan), and according to the factory's order (Sintramat, Japan), they were sintered for 6 hours at 1350°C.[11] Bonding surfaces of ZC samples were continuously polished with 600, 800, and 1200 grit silicon carbide sheets (English Abrasives, London, England) under cooling water in a polishing machine (Phoenix Beta Grinder/Polisher, Buehler, Germany) to obtain a standard surface roughness. Sandblasting was carried out in 10 samples of the case group on the bonding surface with 120-μm Al2O3 particles for 15 seconds under 3.5-bar pressure and at a distance of 10 mm from the surface. Finally, all the discs (case and control) were cleaned by ultrasonic and 96% isopropyl alcohol for 3 minutes as well as steam cleaning for 10 seconds.[11] In this study, Cercon Ceram Kiss dentin (Table 1) was used for zirconia veneer.

A stainless steel mobile generator with a 5-mm diameter and a 3-mm internal height was provided. This generator was placed at the center of the zirconia disc. Then, veneering process was performed using the manual layering technique. Dentin porcelain powder was mixed with a dense liquid and compressed with vibration blotting techniques. The extra water was removed using a tissue paper and then compressed into the generator and onto the zirconia disc. Core-veneered discs were prepared according to the manufacturer's instructions and cooked in a customizable porcelain vacuum oven (Programat P700, Ivoclar Vivadent, Germany).

Table 1: Specifications of the materials used in the present research for shear bond strength (SBS) testing

Brand	Composition	Manufacturer	Thermal expansion coefficient
Cercon base	ZrO_2 (92% vol), Y_2O (35% vol), HfO_2 (2% vol)	DeguDent, Hanau, Germany	10.5
Cercon Ceram Kiss dentin/enamel	Feldspathic veneering ceramic (SiO_2 60.0-70.0; Al_2O_3 7.5-12.5; K_2O 7.5-12.5; Na_2O 7.5-12.5)	DeguDent, Hanau, Germany	9.2

The samples were mounted on a custom-made metal jig using a goniometer and cyanoacrylate glue at a 90-degree angle relative to the horizon. According to similar articles, thermocycling was not required.[12] The type of failure at the bonding area is adhesive. Then, the specimens were placed in a universal testing machine (Zwick/Roell Z050, Ulm, Germany) where the core-veneer interface was placed in the same direction as the indenter. During force application, the indenter was in contact with the ceramic at a crosshead speed of 1 mm/min until a fracture occurred. The final force that resulted in fracture was recorded in Newton (N). T-test was used to compare the SBS between the two groups. The significance level was set at 0.05.

Results:

The current study was performed on 20 samples including 10 non-blasted samples (control) and 10 sandblasted samples (case). The distribution of the samples according to SBS and categorized by 120-µm sandblasting is shown in Table 2 and shows that SBS after sandblasting reduced from 94.62 MPa to 61.24 MPa, indicating that the strength reduction is about 33 MPa, which is about 8.33%, and T-test showed that this negative effect of sandblasting (120 µm) is statistically significant ($P<0.05$). Also, the homogeneity (CV) between ZC and VC was increased by sandblasting.

Table 2: Distribution of the samples in terms of shear bond strength (SBS) and sandblasting

Shear bond strength / Sandblasting	Mean±SD	CV
Control (N_1=10)	94.62±7.69 MPa	8
Case (N_2=10)	62.56±8.35 MPa	17
Test result	P<0.05	

SD=Standard Deviation, CV= Coefficient of Variation

Discussion:

In the current study, 20 zirconia discs (Cercon base, DeguDent, Hanau, Germany) with the dimensions of 7 mm × 3 mm were randomly divided into case and control groups. In the case group, 120-µm sandblasting was performed, but samples in the control group were not sandblasted. Then, all specimens were veneered with porcelain (Cercon Ceram Kiss dentin/enamel, DeguDent, Hanau, Germany) with the dimensions of 5 mm × 3 mm. Then, SBS of the samples was measured in the universal testing machine. The SBS between ZC and VC was 62.56±8.35 MPa in the case group (sandblasting) and 94.62±7.69 MPa in the control group (no sandblasting). A statistically significant difference was found in the SBS between ZC and VC in the case and control groups ($P<0.0000$). This study showed that the use of 120-µm sandblasting on ZC reduces the SBS between ZC and VC ($P<0.0000$). Considering the limitations of this study and its methodology, the hypothesis regarding the positive effect of sandblasting on the SBS between ZC and VC was not proven.

The results of the current study are somewhat different from the findings of previous studies. As mentioned, the dimensions of the samples in this study were 7 mm × 3 mm for zirconia disc and 5 mm × 3 mm for ceramic. Preparation of samples in the shape of a tooth is difficult and expensive; therefore, the dimensions and the shape of the samples were chosen according to studies by Ozkurt et al and Mosharraf et al.[13,14]

Various experimental methods have been used to evaluate the core-veneer SBS. Estimation of SBS using these tests is very complicated due to the structural damage associated with the test method and the fracture mechanism. The use of the SBS test for determination of the core-veneer SBS leads to more standard data because the forces applied perpendicular to the interface and the small cross-sectional bonding area eliminate the structural flaws which significantly affect the reliability of the test. As previously stated, this study showed that the use of 50-µm sandblasting reduces the SBS between ZC and VC.

Various studies have reported different results on the effect of sandblasting of ZC on SBS. The results of studies by Kansu et al, Liu et al, and Yavuz et al contradict our findings.[11,15,16] Studies done by Zhang et al and Doi et al confirm our findings.[17,18]

Doi et al conducted a study to assess the effect of zirconia surface treatment on the flexural strength and fracture strength between ceramic veneer and zirconia.[18] Sixty-four zirconia discs were prepared and divided into four groups of 8 samples. In one of the groups, surface treatment was done by sandblasting. The results of the mentioned study showed that sandblasting reduces the fracture strength. However, in this study, the debonding strength has been studied.[18] Liu et al conducted a study to compare the effects of three different surface treatments on increasing or improving the bond between zirconium porcelain.[11]

The samples were randomly divided into four groups which were subjected to surface treatment by sandblasting with 50-µm Al2O3 particles for 15 seconds and under 3.5-bar pressure and at a distance of 10 mm; they stated that sandblasting increased the SBS between porcelain and zirconia.[11] The difference between the mentioned study and our study can be attributed to the type of zirconia and porcelain as well as the dimensions of the samples; also, we can refer to the difference in the number of persons performing the process.

Kansu et al, conducted a study to assess the effects of various surface treatments (air abrasion, acid etching, and laser irradiation) on the surface properties and bond strength in low-fusing ceramics.[15] Surface treatment was done by 50-µm Al2O3 particles in the first group. The authors stated that SBS in the first group under sandblasting was more than that of the other two groups; also, the cited study differs from our experiment in terms of the sample size in each group and preparation of ceramic discs using Al2O3 particles.[15]

Yavuz et al performed a study to evaluate the effect of surface treatment on the SBS of IPS Empress2 and VITA VM9 ceramics.[16] In both groups, ceramic discs with a diameter of 10 mm and a thickness of 1 mm were prepared and were treated with 120-µm Al2O3 particles with a pressure of 8.2 bar and for 20 seconds at a distance of 10 mm. They stated that SBS increased in both groups. The difference between the mentioned study and our experiment was that surface treatment of ceramic was carried out by sandblasting.[16]

Yenisey et al evaluated the effect of surface treatments on the bond strength between resin cement and zirconium oxide ceramic with different adhesions.[19] The cooking time may have affected the bond strength, and 30 µm of silicon veneer (Cojet) along with the silane coupling technique increase the bond strength between the resin cement and various ceramics cooked together with zirconium oxide.[19]

Aurélio et al examined that whether air abrasion affects the flexural strength and phase transformation of yttria-tetragonal zirconia polycrystal (Y-TZP).[20] In a laboratory study, the effect of airborne abrasive particles on the mechanical strength and phase transformation of Y-TZP specimens was evaluated immediately after aging. The subgroups were examined with regard to particle size, pressure, duration of sandblasting, and aging. The airborne abrasive particles improved the flexural strength of Y-TZP, irrespective of the abrasive parameters and aging ($P \leq 0.05$). (20)

Alao et al performed a study aimed at assessing the surface quality of Y-TZP in terms of damage, morphology, and developmental phase in CAD/CAM processes, polishing, burnishing, and sandblasting.(21) The surface under the pre-burnishing process, which was simply polished or burnished, did not show any significantly increased surface roughness (P>0.05). Sandblasting with smaller abrasives is recommended. The cited study provides a technical perspective on the process selection for Y-TZP to increase the quality of restorations.(21)

In the routine powdering procedure in laboratories, the number of layers of porcelain powder and the duration of placement of the crown in the oven are higher compared to in-vivo conditions. For the ease of pouring the powder, a negative template fitted to the required dimensions was prepared, which increased the speed of work and reduced the dimensional error by the technicians.

Few studies have been conducted on the effect of different surface treatments on the bonding quality, and bonding mechanisms are not fully understood. In order to increase the bond strength, sandblasting is a popular tool that increases surface roughness. Sandblasting also initiates phase transformation, resulting in a mechanical strength that likely affects the bonding capacity of the material. The reason for this is that the expansion coefficient of the thermal radiation of zirconia in the clinic is significantly lower than that of tetragonal zirconia.(22-25)

Conclusion:

This study showed that sandblasting of ZC using 120-µm Al2O3 particles reduces the SBS between ZC and VC. Considering the limitations of the present study and according to the methodology, the hypothesis regarding the positive effect of 120-µm sandblasting on the SBS between ZC and VC was not proven.

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