The Effect of Varying Sandblasting Parameters on the Bond Strength of Zirconia to Ceramic: An *In Vitro* Analysis

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Abstract

Background: Sandblasting is often employed as a surface treatment modality to enhance the bond strength of zirconia to veneering ceramic. Aluminum oxide (Al_2O_3) particles are fired on the zirconia surface to create surface roughness. The objective of the study was to evaluate the effect of varying particle size and pressure settings on the bond strength of zirconia to ceramic. **Materials and Methods**: The study employed 150 zirconia cuboidal specimens with dimensions 5*5*12 mm in dimensions divided into five groups 30 in each. Group 1: Control group with no surface treatment. Group 2: 50 microns and 3.5 bar pressure. Group 3: Sandblasting 110 microns and 1.5 bar pressure. Group 4: 110 microns and 3.5 bar pressure. Group 5: Sandblasting 50 microns and 1.5 bar pressure. The specimens were then layered with ceramic and subjected to shear bond strength (SBS) analysis. **Results:** The mean SBS was highest for Group 5 (36.57) and lowest for Group 4 (27.56). **Conclusion:** Results demonstrated that 50 microns particle size with 1.5 bar pressure had significant improvement in bond strength. The Al_2O_3 particle size and pressure also have a significant importance in sandblasting procedures.

Keywords: Sandblasting, Zirconia, Ceramic, Shear bond strength.

Introduction

Zirconia as a core material is widely used for the fabrication of dental prosthesis. Yttrium stabilized zirconia have the added advantages of superior strength and mechanical properties however lack chemical bonding to the veneering ceramic. The inertness of zirconia causes bonding between zirconia and ceramic, a tedious process leading to debonding or chipping of the veneering ceramic from the zirconia core. This compromises the longevity and aesthetics of the restoration necessitating its replacement.[1] A range of factors determines the bond between zirconia and ceramic such as mechanical interlocking, chemical bonds, defects on the interface, wettability, and compressive strength of the veneering ceramic.[2,3]

The literature suggests various protocols for the surface treatment of zirconia. The methods include sandblasting, liner applications, laser, plasma, and various etching protocols. Either one surface treatment or a combination of treatments is done to enhance the bonding between zirconia and veneering ceramic. The most routinely employed strategy includes sandblasting. Sandblasting otherwise known as air abrasion is the process of projecting aluminum oxide (Al_2O_3) particles at high velocity onto the surface of zirconium oxide.[4-6]

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The studies on sandblasting demonstrate conflicting results with some studies showing no significant increase in bond strength,[5] others showing a negative effect[6,7] and others showing significant increase in bond strength.[8] Sandblasting can induce transformation without developing high temperatures or creating severe surface damage.[9-11] Some surface defects are induced on the surface of the zirconia by sandblasting that can compromise the mechanical strength of the ceramic.[2] Fischer *et al*.[3] stated that sandblasting due to its inherent disadvantages cannot be consider as a necessary surface treatment to zirconia.

There is a significant impact of the Al_2O_3 particle size and pressure at which these particles are fired onto the surface of zirconia that affects its surface characteristics. Studies pertaining to the importance of Al_2O_3 are minimal. There are

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no clinical recommendations on the particle size and pressure that has to be used for sandblasting. Hence, the aim of this study was to compare the shear bond strength (SBS) values for 50 microns and 110 microns Al_2O_3 particles with 1.5 bar or 3.5 bar pressure. The null hypothesis was there will be no significant difference in the SBS between the various particle sizes and different pressure applied.

Materials and Methods

Method of collection of data

A stainless-steel mold with the dimensions of 10 mm diameter and 3 mm height shall be prepared and mounted in a holder. The mold shall be scanned with computer-aided design (CAD)/ Computer-aided machine (CAM) scanner (Amanngirrbach, Germany).

The scanned model shall be used to fabricate 150 discs of the same size from pre-sintered zirconia blocks (Amanngirrbach, Germany). Zirconium oxide blocks shall be milled according to the manufacturers' instructions. Then, they shall be cleaned, dried, and sintered according to the suggested firing schedules.

The bonding surfaces of zirconia core specimens shall be polished with diamond paste using an ascending stepwise approach starting with 120 grit and ending with 800 grit silicon carbide paper, 120-, 240-, 320-, 400-, 600-, and finally 800-, using a rotating metallographic polishing device under a fixed load and water cooling. This will be done to obtain standardized surface roughness.

Surface treatment methods

150 zirconia discs shall be randomly divided into five groups according to the surface treatment methods:

Group 1 Control

CAD/CAM-milled surfaces without surface treatment.

Group 2 Sandblasting

50 microns and 3.5 bar pressure.

Al_2O_3 airborne-particle abrasion will be performed using a sandblast machine with 110 µm particle size for 15 s at a 10 mm distance from the surface and with a pressure of 3.5 bar. Finally, the specimens shall be ultrasonically cleaned in 96% isopropyl alcohol for 3 min and steam-cleaned for 15 s.

Group 3 Sandblasting

Sandblasting 110 microns and 1.5 bar pressure.

Al_2O_3 airborne-particle abrasion will be performed using a sandblast machine with 110 µm particle size for 15 s at a 10 mm distance from the surface and with a pressure of 3.5 bar. Finally, the specimens shall be ultrasonically cleaned in 96% isopropyl alcohol for 3 min and steam-cleaned for 15 s.

Group 4 Sand blasting

110 microns and 3.5 bar pressure.

Al_2O_3 airborne-particle abrasion will be performed using a sandblast machine with 50 µm particle size for 15 s at a 10 mm distance from the surface and with a pressure of 3.5 bar. Finally, the specimens shall be ultrasonically cleaned in 96% isopropyl alcohol for 3 min and steam-cleaned for 15 s.

Group 5 Sand blasting

Sandblasting 50 microns and 1.5 bar pressure.

Al_2O_3 airborne-particle abrasion will be performed using a sandblast machine with 50 µm particle size for 15 s at a 10 mm distance from the surface and with a pressure of 3.5 bar. Finally, the specimens shall be ultrasonically cleaned in 96% isopropyl alcohol for 3 min and steam-cleaned for 15 s.

Surface examination

The surface morphology will be observed by a scanning electron microscope (SEM). Image of each surface will be registered at 2000× magnification.

X-ray photoelectron spectroscopy

The chemical compositions of the outermost surfaces of zirconia specimens shall be analyzed using X-ray photoelectron spectroscopy. Data acquisition and processing shall be performed using Thermo Advantage software.

SBS test

Application of porcelain

Using a specially designed, separable stainless-steel mold, a prepared zirconia disk specimen shall be placed in the mold where clearance of 10 mm diameter and 3-mm height was available above the core material for condensing the veneer ceramic. The veneering procedure shall be performed using the manual layering technique. First, two-liner layers of porcelain shall be applied and fired independently, then the dentin porcelain is condensed using the vibration blotting technique, fired, and finally a glaze firing shall be performed according to the manufacturer's instruction.

Each specimen shall be embedded at the center of a metal holder, with the core-veneer interface positioned at the top level of the holder. All specimens shall be stored in distilled water at 37°C for 1 week. And then thermally cycled for 5000 cycles, 5–55°C with a 30-s dwell time.

Results

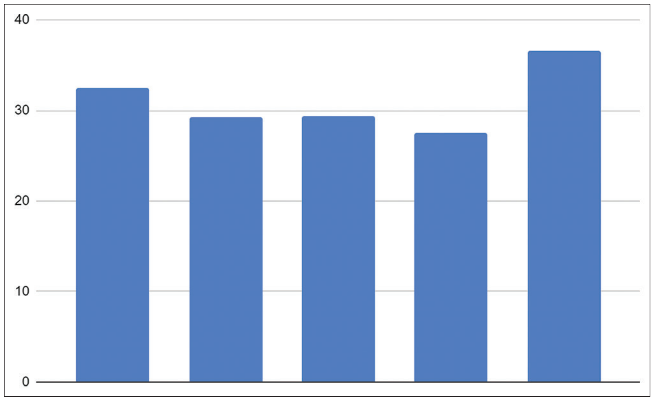
The mean SBS was highest for Group 5 (36.57) and lowest for Group 4 (27.56). The control group performed better than other groups with a mean SBS of 32.53. The least SBS noted was in group 3 with a minimum of 12.9 and highest in group 5 65.9 Mpa (Table 1).

Discussion

The results obtained showed that there was statistically significant difference in the SBS values among the various sandblasted specimens to that of the control group thereby rejecting the null hypothesis. The particle size of Al_2O_3 used for sandblasting varies from 30 to 250 microns and pressure from 0.4 to 3.5 microns. This range of the particle size and

Table 1: Mean shear bond strength among the groups

Groups	n	Minimum	Maximum	Mean	SD
Group 1	30	16.1	46.8	32.53	7.91
Group 2	30	15.4	48.5	29.3	9.761
Group 3	30	12.9	45	29.38	8.81
Group 4	30	16.4	48	27.56	7.53
Group 5	30	21.9	65.9	36.57	9.92



pressure used for sandblasting is the major contributory factor for the anonymity regarding the effect of sandblasting as a surface treatment.

Sandblasting removes the surface contamination layers, increase the surface roughness and surface energy thereby facilitating better wetting of the zirconia.[12,13] Bitencourt *et al*.[14] observed peaks and valleys on sandblasted zirconia specimens in SEM suggestive of increased surface roughness. Matani *et al*.[15] reported the surface characteristics as microcracks, small voids, and nodules. Following sandblasting there is creation of crevices, sharp protrusion, and microcracks that may serve as retentive areas.[16] Sandblasting is often regarded as a successful treatment procedure considering the increased surface roughness and surface energy. However a controversy exists here, some studies show that sandblasting results in the phase transition from tetragonal to monoclinic that causes building up of tensile stress and further in debonding of zirconia. Matani *et al*. reported maximum monoclinic content in sandblasted zirconia specimens. More the monoclinic phase transformation the greater the compressive stresses generated in the zirconia specimens thereby decreasing the bond strength values.

Marefati *et al*. compared the wettability with a different particle size of $Al_2 0_3$ and concluded that higher surface roughness decreased wettability, thereby reducing the bond strength. Group 2, 3, and 4 presented with similar mean bond strength values with Group 4 showing the least mean bond strength. This is due to the particle size of Al_2O_3 that is 110 microns used for the study. This larger particle size of Al_2O_3 could effectively cause the surface defects of zirconia and causing them to have compromised bond strength values. Both groups 3 and 4 that used Al_2O_3 possessed the lowest bond strength values. The use of 110 microns Al_2O_3 particles in airborne-particle abrasion generated lower rates of zirconia survival with debonding of ceramic, due to the impact Al_2O_3 particles that generated a zone of compressive stresses and also micro-cracks on the zirconia surface that can propagate under cyclic loading.[17] However, when smaller particles were used, it was possible to modify the surface without inducing excessive damage and, consequently, less concentration of stress on the treated surface.

One method to decrease the phase transition is to use smaller particles Al_2O_3 of at low pressure. Hence in this study Group 5 with size 50 microns and pressure 0f 1.5 bar demonstrated the highest bond strength. This is in accordance with the study by Bitencourt *et al*. and Yan *et al*. The control group with no surface treatment demonstrated better bond strength than other sandblasted group. This may be due to the possibility that in the no treatment group there were no phase transition from tetragonal to monoclinic.

Conclusion

The use of appropriate particle size and pressure during sandblasting procedure is the key to enhance SBS. Larger particles could create an inherent defect on the zirconia surface and thereby cause debonding. However, the ideal particle size and pressure should be standardized for the sandblasting procedure.

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