Influence of the Surface Treatment on Shear Bond Strength of Coating Ceramics of Zirconia

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Abstract

Several surface treatments have been suggested to improve coating ceramics adherence to zirconia. However, which of these treatments results in larger bond resistance is yet to be determined.

This work measured bond resistance between coating ceramics E.max Ceram (Ivoclair Vivadente®, Germany)(E), ZirLiner (Ivoclair Vivadente®, Germany) and zirconia samples Vipi Block Zirconn (Vipi, Brazil). Specimens were divided into six groups (n=10) and submitted to different surface treatments.

Group1: smooth block + E; group 2: smooth block, ZirLiner + E; group 3: blasting with Aluminum Oxide 110um + E; group 4: blasting with Aluminum Oxide 110um, ZirLiner+ E; group 5: rough block + E; group 6: rough block, ZirLiner+ E.

Results showed that the surface treatment significantly influenced shear bond resistance ($p < 0.001$). ZirLiner application significantly reduced bond resistance between zirconia and coating ceramics where the surface was not roughened nor submitted to blasting. ZirLiner did not reduce bond resistance of roughened surfaces. Smooth, roughened and blasted surfaces without the application of ZirLiner showed no differences in bond resistance.

Hence, we conclude that the application of ZirLiner does not increase shear bond resistance.

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Introduction

The pursuit for aesthetical results and for improved prosthetic solutions have motivated technological, biological and mechanical improvements in restoration materials.[1]

It is known that clinical longevity of restorations is the result of a combination of factors, such as the mechanical properties of materials, damage caused by the processing methods and by the cyclical loads to which materials are subjected when in use.[2] Among these materials are dental ceramics, with its excellent aesthetical and mechanical properties, and biocompatibility.

Regarding aesthetical results, advancements in *metal-free* prosthesis meet the limitations found in metalloceramics related to the lack of transluscency of the metallic substrate. The presence of the metallic band in the infrastructure makes the dark metal halo often visible, thus, preventing a more natural appearance of the restoration.

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Zirconia's high resistance to fracture and tenacity support its wide range of applications in dental aesthetics. All-ceramic crowns in fixed partial restorations in the molar region are enabled by zirconia, particularly yttrium stabilized tetragonal polycrystalline zirconia (y-tzp). *In vitro* studies show a flexural strength of 900-1200 Mpa.[3,4] However, ceramics delamination is still one of the main reasons for failure.[5] Failures and delamination of coating ceramics have been reported in 13.0% to 15.2% of cases after three to five years, respectively. On the other hand, studies focused on metallic prosthesis show that fractures on ceramic coating vary from 2.7% to 5.5% within a period of ten to fifteen years, respectively.[6,7]

Bond resistance between zirconia and coating ceramics is influenced by several factors, including surface treatment of the substructure, defects development on the interface nucleus-porcelain, residual stresses of thermal incompatibility between nucleus and porcelain coating, reactions on the interface between substrates and coating porcelain, and surface wettability properties.[8,9] Several surface modification techniques have been suggested, such as blasting with oxides of different particle sizes,[5] acid application, increase in temperature to change zirconia structure, and mechanical grinding.

The main factors that explain the bonding mechanisms between zirconia and coating ceramics are not well defined yet. Clinical studies on the success and failure of zirconia and coating ceramics are limited. However, several manufacturers recommend surface treatment or coating application. In this context, more studies on the relationship between the surface treatment and bond resistance between coating ceramics and zirconia are needed.

Materials and methods

Sixty zirconia blocks Vipi Block Zirconn (Vipi Produtos Odontológicos, Pirassununga, São Paulo, Brazil) were milled to be shaped as cubes (5x10x10mm), using a CAD/CAM Zenotec/Wieland® (Rielasingen-Worblingen, Germany) machine and were coated by IPS e.max Ceram (Ivoclair Vivadente®, Germany) (E) coating ceramics, following the manufacturer's recommendations.

The zirconia blocks were sintered according to the manufacturer's recommended cycle and sonicated (Odontobras ULTRAsonic 1440 plus - Odontobrás Equipamentos Odontológicos, Ribeirão Preto, São Paulo, Brazil) for 10 minutes before stratification with alcohol and dystilled water solution.

Following cleaning, the blocks were divided into six groups (n=10) and submitted to different surface treatments. Blocks in group 1 were applied coating ceramics only (E). Group 2 specimens were applied a layer of Zirliner + E. Specimens in group 3 were submitted to blasting with aluminum oxides of 110 µm +E. Group 4 was submitted to blasting with aluminum oxides of 110 µm, ZirLiner + E. Specimens in group 5 were roughened + E; and those in group 6 were roughened, ZirLiner+ E.

ZirLiner layer was applied according to the manufacturer's recommendations. Blasting with aluminum oxides (110 µm, 40 psi) was kept for 15 seconds, at a distance of 10 millimeters and an angle of 90º. To this end, a 10 mm metal shaft was placed at the tip of the blast nozzle to make sure the blast was standardized for all test specimens. Roughening was performed using a diamond tip 2135 KG Sorensen (Kg Sorensen, Cotia, São Paulo, Brazil) in slow rotation for 10 seconds.

A two-part metallic matrix was developed by the author for this study.

One piece of the matrix is internally cut to fit a square block of zirconia with side lengths of 10mm (Figure 1).

Figure 1. Device used in the shear test and matrix to accomodate zirconia. Source: Own authorship.

Over this piece is placed another piece with a central hole of 0.4 mm of diameter and 2 mm thick, where the coating ceramics is poured

(Figure 2). The two pieces were secured together by two screws placed on the opposite ends of the matrix.

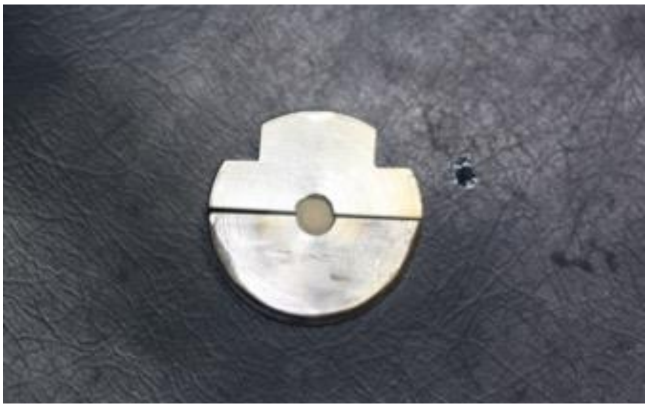


Figure 2. Metal matrix where coating ceramic is applied. Source: Own authorship.

All test specimens (zirconia block + coating ceramics) were liberated from the matrix and taken for MSCT-3 thermal cycling (Biopdi, São Carlos, São Paulo, Brazil) at 1000 cycles and 5º and 55º baths, for 60 seconds of immersion. These test specimens were tied again to a test device (Figure 3) consisting of one side where the test specimens are placed, measuring 40mm of diameter, and a central square recess, measuring 10 mm of side, and a transversal screw that holds a cylinder measuring 20mm long and 24mm of diameter that fits the test machine EMIC DL2000 (EMIC, São Paulo, Brazil) (Figure 1). The test specimens are interchangeable.

Figure 3. Test specimen in the shear test device. Source: Own authorship.

Shear resistance was determined using a test beveled tip at 0.5 mm/min of speed and load cell of 50kgf until fracture.

All interfaces were analyzed using a stereoscopic magnifying glass (Carl Zeiss, Jena, Germany) with magnification of 30x and fracture modes were classified as cohesive zirconia fracture, cohesive porcelain fracture, adhesive or mixed.

Results

Table 1 show the descriptive analysis - mean, median, standard deviation and minimum and maximum values - of shear bond resistance between coating ceramics and zirconia infrastructure submitted to different surface treatments.

Zirconia surface treatment prior to coating ceramics	Mean (standard deviation)	Median	Minimum and maximum values
W/o roughening (smooth block)	33.49 (12.50)	30.04 **AB**	17.85 – 55.96
W/o roughening (smooth block) + ZirLiner	8.12 (11.80)	3.99 **BC**	1.29 – 40.67
Blasting with Al_2O_3	33.26 (9.01)	33.25 **A**	20.98 – 50.73
Blasting with Al_2O_3 + ZirLiner	7.23 (11.79)	1.80 **C**	0.68 – 33.65
Roughening	18.74 (19.28)	7.89 **ABC**	1.86 – 51.67
Rounghening + ZirLiner	8.48 (10.35)	3.57 **BC**	1.21 – 31.41

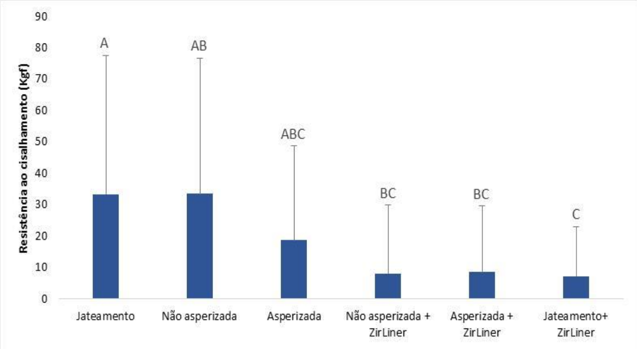
Table 1. Shear bond resistance (Kgf) between coating ceramics and zirconia infrastructure, submitted to different surface treatments.
Caption: Al_2O_3 – aluminum oxide. Means followed by different letters indicate significant difference between surface treatments.
Source: Own authorship.

Kruskal-Wallis' test showed that the surface treatment of zirconia significantly influences its shear bond resistance with coating ceramics ($p < 0.001$).

Dunn's test showed that bond resistance of the specimens treated only with blasting was significantly higher than those treated with ZirLiner, whether blasted or not, roughened or not. There was no significant difference between surfaces treated only with blasting and rough or smooth surfaces.

The application of ZirLiner resulted in a poorer performance than that of zirconia only when the surface was blasted, since when applied on rough or smooth surfaces, ZirLiner was not able to significantly alter bond resistance values (Table 1 and Graph 1).

Regarding failure mode between zirconia infrastructure and coating ceramics, only adhesive ruptures were observed on coating ceramics.



Graph 1. Bar chart with mean shear bond resistance (Kgf) between coating ceramics and zirconia infrastructure submitted to different surface treatments.
Caption: Vertical bars indicate standard deviation. Different letters denote significant difference between surface treatments.
Source: Own authorship.

Discussion

As opposed to the assumption that a rougher surface produces higher bond strength due to the larger surface area and additional mechanics,[8-11] our work shows that the group submitted to blasting with Al_2O_3 present no significant difference compared to the group without roughening. Although literature shows multiple surface treatment techniques available, tests assessing adhesive resistance show conflicting results,[12] implying that there's a need for the standardization of techniques.[13] On the other hand, Su et al.[14] claim that blasting with 110 µm alumina particles of 0.2 MPa for 21 seconds is recommended for a better adhesion between zirconia nucleus and indirect resin (ICR).

The group blasted with particles showed higher shear strength than those applied with ZirLiner. Particle blasting may be more efficient in the increase of bond strength,[15,16] is a simple technique that increases micro-rugosities of the zirconia dioxide surface and, thus, increases shear resistance of the ceramic coating, resulting in less monoclynical content without damaging zirconia substructure.[17] A study showed that 10-Methacryloyloxydecyl dihydrogen phosphate monomer containing primer agents, such as Monobond Plus and Z-PRIME Plus, combined with sand blasting may be an effective method for the adhesion of zirconia restorations.[18] Another authors observed that while adhesive monomers demonstrated significant increases of shear-bond strength, plasma treatment showed inconsistent results.[19]

In our work, Zirliner application resulted in larger standard deviation compared to the other groups, with an expressive variability. Some researchers have showed that the all-ceramic system failed to achieve the bond resistance patterns equivalent to that of metalloceramics systems.[20,21] Some studies praise metalloceramics,[6,22] while others show an improvement in metal-free ceramics performance that matches that of metalloceramics, particularly in single-unit crowns.[23,24]

Some studies observed a lack of significant difference between the group blasted with Al_2O_3 and metalloceramics.[5,25] Even though our sample does not include metalloceramics, we showed that the group blasted with Al_2O_3 performed equivalent to the group usually considered as control.

In our study, Zirliner application impaired shear resistance, corroborating results found by Fischer et al.[26] which observed that *Liners* impaired shear resistance of Ce-TZP/A coating ceramics. The application of ZirLiner on the interface surface of Everest® Y-TZP nucleus also failed to show significant effects in comparison to other surface treatments studied.[27] The application of *Liner* and blasting with Al_2O_3 reduced the interface resistance of zirconia/ceramics and evidenced these treatment methods must be used with caution.[28] According study conducted by Alghazzawi and Janowski[29] a liner should not be used before porcelain application especially when using the layering technique for zirconia restorations. On the other hand, some authors showed that the application of *Liner* provided the best surface treatment for Lava and IPS e.max ZirCAD.[30]

Here we used square-shaped blocks (5x10x10mm). These dimensions do not represent a real clinical situation and is, thus, a limitation of the present study. Also, the heat capacity and the thermal conduction behavior of the substrate in a clinical context are different from the conditions presented here. Notwithstanding, results are comparable to those in a clinical situation.[1-4]

Here we assessed bond resistance between coating ceramics and zirconia samples. Several methods have been used with the aim of improving adhesion, such as surface treatment[10,12,31,32] surface design, and changes in materials composition.[28,33] However, more studies are welcome to broaden the range of possibilities and to improve the clinical performance of the abovementioned materials.

Conclusions

The present study showed that Zirliner application resulted in a significant reduction of shear resistance and, among the groups applied with ZirLiner, blasting with Al_2O_3 did not show higher bond strength in comparison to those with or without roughening.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

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