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Original Article

Evaluation of the Bonding Strength between Yttrium-stabilized Zirconia and Coating Ceramics with Three-point Flexural Test: The Surface Treatment Effect

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Abstract

Aim: This study aimed at evaluating with the three-point flexural test, the bonding strength of tetragonal zirconia polycrystalline stabilized by yttria zirkonzahn (Y-TZP) and two coating ceramics (Ice e Vision Zircon), with two surface treatments (treated and untreated). **Materials and Methods:** Forty Y-TZP bars were divided into four groups (n = 10): vision zircon/without treatment (VZ/woT), vision zircon/with treatment (VZ/wT), ice/without treatment, and ice/with treatment (I/wT). The flexural strength assay was conducted using a 50 N load cell and 1 mm/min speed. Results were analyzed with one-factor ANOVA, two-factor ANOVA, and Tukey's test ($\alpha = 0.05$). **Results:** The treatment surface of Y-TZP affected significantly the bonding strength ($P = 0.019$), with higher values in VZ/woT group in comparison with the groups VZ/wT ($P = 0.027$) e I/wT ($P = 0.034$). The variable "coating ceramic" was not statistically significant ($P = 0.138$), on the other hand, the variable "surface treatment" significantly decreased the strength values when vision zircon ceramics was used ($P = 0.018$). **Conclusion:** This study concluded that the use of the evaluated ceramics did not influence the bond strength and the surface treatment decreased strength depending on the coating ceramics.

Keywords: Bond strength, surface treatment, veneering ceramics, zirconia

Introduction

Numerous possibilities of materials are available for oral rehabilitation. Porcelain esthetic level and the mechanical reliability of metallic frameworks have provided the longer lifespan of these restorations.[1] However, the use of metals and the release of ions frequently cause gingival coloration and allergic and inflammatory reactions.[2] This factors motivating the replacement of metallic alloys by biocompatible materials.

Esthetical solutions are increasingly challenging due to both patient demand and new materials and techniques available. To this end, ceramic materials have been developed with optical properties similar to natural teeth,[3,4] besides excellent mechanical properties.

Among the ceramic materials used in frameworks, zirconia is notable for its tenacity.[5] For use in dental practice, it is usually stabilized on the tetragonal phase with yttrium addition (Y-TPZ).[4,5]

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Clinical evidence about the tetragonal zirconia polycrystalline stabilized by Y-TZP performance challenge the high frequency of coating ceramics chipping in comparison to the metalloceramic system.[6,7] Possible causes are related to adhesion ceramic materials to zirconia surface, thermal and mechanical compatibility, coating ceramics thickness, technical control of manufacture, among others.[6-8] The clinical consequence of a fracture in coating porcelain depends on its length and location.[9]

When associating metalloceramics to zirconia ceramics, both of them need thermal and mechanical compatibility. However,

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the metal is less damaging to the ceramic coating because of its elastcity modulus. Due to its hardness, zirconia produces destructive stress on the coating ceramics, and hence, the mechanical properties of coating ceramics are essential for the restoration long-term success.[10,11]

In view of exposed seems pertinent to assess, with the three-point flexural test, the bond strength between Y-TZP and two coating ceramics, with two surface treatments.

Materials and methods

This study evaluated the bond strength between Y-TZP (yttria zirkonzahn) and coating ceramics (Ice Zirkon Keramik color A3 dentine and Vision zircon color A3 dentine) also altering surface treatment (treated and nontreated).

Forty bar-shaped samples with dimensions of 25 mm × 3 mm × 0.5 mm were submitted to ceramics application on its central portion with dimensions of 8 mm × 3 mm × 1 mm for the flexural test and DIS.[12,13] The DIS test is characterized by the three-point flexural assay where the bonding line of materials is simultaneously under compression, tensile, and shear strength.[14]

The cutting machine was set to 300 rpm (low speed). After cutting, the bars were then sinterized for 8 continuous h at a temperature of up to 1700° in the Zirkonofen 600/v2 oven (Zirkonzahn GMBH - Bolzano - Italy). Subsequently, the surface treatment and the coating ceramic application were carried out.

Surface treatment

The forty sinterized bars were divided into four groups ($n = 10$). Two groups were submitted to mechanical treatment (aluminum oxide blasting 25 μm, the pressure of 4.5 bar, and the other two groups received no mechanical treatment). All samples were cleaned with water before application in an ultrasonic sink for 4 min and 30 s.

Stratification

Two groups, treated and nontreated, were applied ceramics Ice ZirkonKeramik (Zirkonzahn GMBH, Italy) color A3 dentine (same manufacturer as zirconia). The remaining groups were applied vision zircon (Wohlwend AG - Liechtenstein) color A3 dentine.

A hollow matrix of dense addition silicone (Elite HdPutty Soft Normal Set-ZhermackSpA, Italy) measuring 8 mm × 3 mm × 1 mm was prepared to receive the coating ceramics and assure the samples standardization [Figure 1].

A ceramic paste was applied to the matrix and taken to an oven for burning at 490°C for 1 min of precuring. In the following, vacuum was turned on with a heating rate of 55°C/min until reaching the final temperature of 840°C. The sample was once again placed in the matrix and assessed to check the need of material addition due to the ceramics contraction. A second paste was molded and taken to the oven for a second burning, which reached the final temperature of 830°C. Finally, the sample was finished and polished [Figure 2].

Three-point flexural test device

A device was designed (USIMAQ, Brazil) with a distance of 20 mm between supports and support cylinders with 1 mm of radius. From this, a three-point flexural partially articulated device was adapted[15] [Figure 3].

Three-point flexural mechanical assay

The groups were named according to the following: vision zircon/without treatment (VZ/woT), vision zircon/with treatment (VZ/wT), ice/without treatment, ice/with treatment (I/wT).

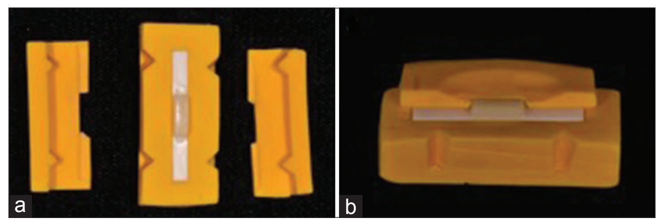

Figure 1: Matrix used in the application of coating ceramics. (a) Silicone matrix that standardize stratification. (b) Visualization of a matrix with a sample after polishing

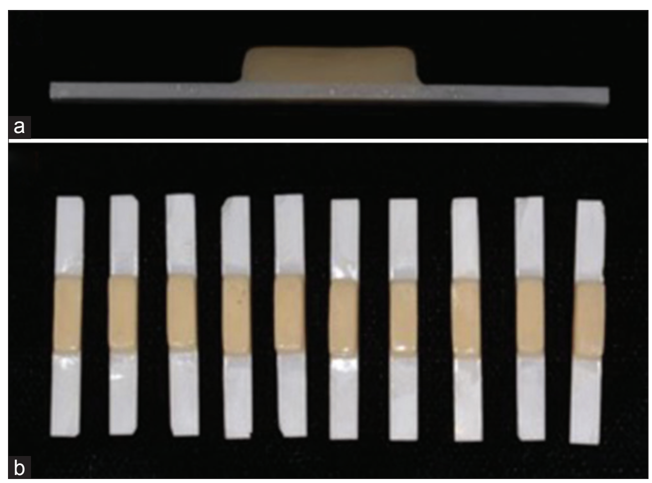

Figure 2: Samples ready for testing. (a) Lateral view of the finished sample. (b) Group of samples prepared for the testing

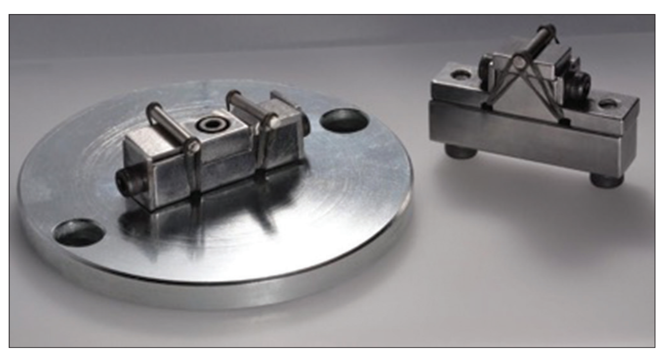

Figure 3: Flexural test device. Superior and inferior support view

The samples were mounted placing the ceramics opposite to the load application. The universal testing machine EMIC DL 2000 (Instron-Equipamentos Científicos Ltda, Brazil) was loaded with 50N load cell and 1 mm/min speed until failure.

The results were recorded by the software (Tesc version 3.01, EMIC- INSTRON BRASIL, São José dos Pinhais/ Paraná/ Brasil) in the assay machine.

Table 1: One-factor ANOVA (α=0.05)

Variation source	Sum of squares	df	Mean square	*F*	Significant
Between groups	198.746	3	66.249	3.858	0.019
Within groups	497.974	29	17.172		
Total	696.721	32			

Table 2: Tukey's test for variance difference (α=0.05)

	Groups (I)	Groups (J)	Mean difference (i-J)	Std. Error	Sig
Tukey	Vision Zircon wo/Treat	Vision Zircon w/Treat	6.02828*	2.01355	0.027
		Ace wo/Treat	4.69399	2.07193	0.130
		Ace w/Treat	5.98988*	2.07193	0.034
	Vision Zircon wo/Treat	Vision Zircon w/Treat	−6.02828*	2.01355	0.027
		Ace wo/Treat	1.33428	2.01355	0.910
		Ace w/Treat	−0.03840	2.01355	1.000
	Ace wo/Treat	Vision Zircon wo/Treat	−4.69399	2.07193	0.130
		Vision Zircon w/Treat	1.33428	2.01355	0.910
		Ace w/Treat	1.29589	2.07193	0.923
	Ace wo/Treat	Vision Zircon wo/Treat	−5.98988*	2.07193	0.034
		Vision Zircon w/Treat	0.03840	2.01355	1.000
		Ace wo/Treat	−1.29589	2.07193	0.923

Caption: *Mean difference is significant at the level of 0.05. Source: own authorship

Table 3: Two-factor Anova (α=0.05)

Source	Type III sum of squares	Df	Mean square	*F*	Sig
Model	24256.472[a]	3	8085.491	445.854	0.000
Effect type of ceramics	42.070	1	42.070	2.320	0.138
Effect treatment	114.558	1	114.558	6.317	0.018
Interactions	24100.491	1	24100.491	1328.962	0.000
Error	544.045	30	18.135		
Total	24800.517	33			

Results

Statistical analysis

Shapiro-Wilk's test showed normal distribution of the DIS bonding strength test data (*P* = 0.994). Levene's test also showed homogeneity between the experimental groups (*P* = 0.923). Both tests used $\alpha = 0.05$.

One-factor variance analysis showed that the technical effects of coating ceramics application on zirconia in a laboratory setting significantly influenced adhesive strength between these materials (*P* = 0.019) [Table 1]. Tukey's test showed that the group VZ/woT (31.26 ± 4.18 MPa) presented higher DIS values in comparison to the groups VZ/wT (25.23 ± 4.52 MPa) (*P* = 0.027) and I/wT (25.27 ± 4.07 MPa) (*P* = 0.034) [Table 2]. Two-factor variance analysis revealed that the effect "surface treatment" before application significantly affected the bonding strength of coating ceramics and zirconia (*P* = 0.018). On the other hand, the effect "type of ceramics" showed no significance (*P* = 0.138). Interactions show a significant influence of the surface treatment with vision zircon ceramics and no statistical significance with ice ceramics (*P* = 0.000) [Table 3 and Figure 4].

Failure analysis

All failures occurred in two stages: visible delamination of coating ceramics and fracture at the midpoint of the zirconia bar. The analyzes were performed in the 40 × Binocular Stereo Microscope (Tecnival, São Paulo, Brazil).

Discussion

In the last years, new dental ceramic materials have been developed with the aim of increasing the durability of metal-free reconstructions while keeping the esthetic benefits.[3]

Ceramic materials are friable, and their irregular shapes make it difficult to standardize the tests to evaluate their properties. Quinn and Goulet[15] developed an aticulated device for the flexural test. This study used a partially articulated device and during the assay, the strength curve showed a constant oscillation before loading, showing an adjustment of the device to the sample.

The three-point flexural strength test evaluates the adhesion of porcelain to metals. It has also been used to assess porcelain adhesion to zirconia.[14]

The average result of 27 MPa of bonding strength between porcelain and zirconia in this study corroborated the results found in other works, regardless of the test applied.[1,11-13,16-25]

Zirconia surface can be treated with aluminum oxide, diamond drills, or silica coating blasting. Some authors[13] reported that surface treatment with aluminum oxide blasting results in roughness and increases zirconia's surface energy. Better

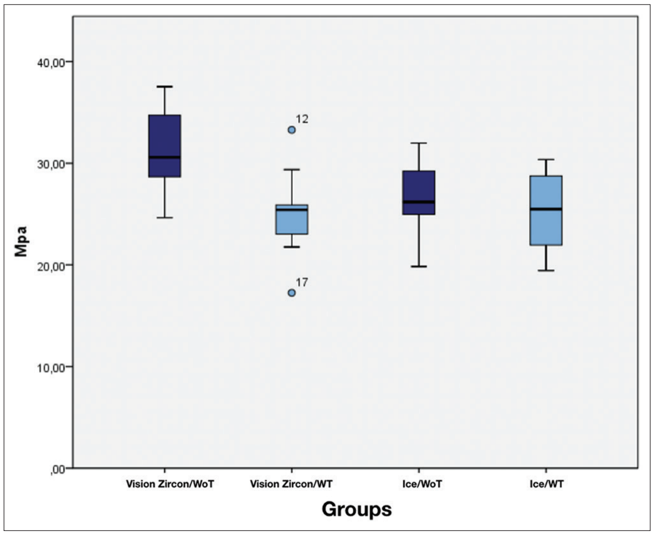

Figure 4: Group comparison

bond strength was observed when a single ceramic coating was used on zirconia.[13] Other authors[25] suggested a chemical bond between zirconia and porcelain and ruled out the need for pretreatment.[6,25] Contrasting the aforementioned studies, in the present study, the surface treatment of Y-TZP with aluminum oxide sandblasting when associated with vision zircon ceramics significantly reduced bonding strength. In agreement, other authors also mention a significant reduction in this adhesion; however, the roughening was performed with diamond drills.[21]

It is of great relevance to study the types of coating ceramic and its mechanical properties. Thermal compatibility and mechanics of materials are essential and can influence results. Some authors have reported that the bigger the difference in the thermal expansion coefficient of a ceramic, the bigger its bond strength.[11] When correlating stress caused by different coefficients of thermal expansion (CTE) of coating ceramics, authors show that there is a limit on the difference in CTE, which if exceeded, the stress caused in the cooling can damage the porcelain. Moreover, this difference can be better defined by correlating the bond strength of the ceramics.[10] In the present study, the ceramic was burned following the technical instruction provided by the manufacturers.

In this study, the type of ceramics did not alter the results; however, the surface treatment of Y-TZP Zirkonzahn with vision zircon ceramic (different manufacturers) allowed a significant reduction in bond strength. Notwithstand, ice showed similar strength. The same result was found by Cömlekoglu *et al*.[26] using ceramics from different manufacturers. Differences in bond strength can occur since the type of grain, CTE, and capacity to resist stress are properties that can change depending on the manufacturer. These variations can show different behaviors according to the application techniques.

The liner or intermediate ceramics have been presented by manufacturers as an enhancer of adhesion of coating ceramics to zirconia. However, some authors do not reported differences in bond strength when using liner,[12] while others showed worse results with their use.[20] Here, no intermediate ceramics were used since the ceramics paste have a larger volume than the liners and therefore have a greater influence on adhesive strength than the liner.[11]

In the present study, the failures found were delamination and fracture at the midpoint of the zirconia bar. Prosthetics restorations involving zirconia are more sensitive to technical errors, contrarily to those based on metals. However, a 5-year clinical study did not show high failure rates with monolithic zirconia restorations. The global rate of fracture for this restorations, regardless of position and type, was 1.09%.[27] Hence, it is important that the clinical stages are compiled to allow the material's adequate thickness, as well as the correct technical process, to result in a proper function of the prosthesis in the oral cavity, absence of trauma, and long lifespan.

It can be seen, therefore, that this study is in addition evidence for a better understanding of the possibilities of the materials studied.

Conclusion

According to the results, it was concluded that the type of coating ceramics evaluated have no influence on the bonding strength, and the surface treatment decreased the bond strength depending on the type of ceramic used.

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Conflicts of interest

There are no conflicts of interest.

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