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

Anderson Fernandes Felipe, Walace Henry Miranda Coimbra<sup>1</sup>, Geraldo Alberto Pinheiro Carvalho<sup>2</sup>, Simone Kreve<sup>2</sup>, Aline Batista Gonçalves Franco<sup>2</sup>, Sergio Cândido Dias<sup>2</sup>

São Leopoldo Mandic Dental Research Center, Departments of <sup>1</sup>Prosthodontics and <sup>2</sup>Restorative Dentistry, São Leopoldo Mandic Dental Research Center, Campinas, São Paulo, Brazil

### 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.<sup>[1]</sup> However, the use of metals and the release of ions frequently cause gingival coloration and allergic and inflammatory reactions.<sup>[2]</sup> 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,<sup>[3,4]</sup> besides excellent mechanical properties.

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

Access this article online				
Quick Response Code:	Website: www.ejgd.org			
	DOI: 10.4103/ejgd.ejgd_100_17			

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.<sup>[6,7]</sup> Possible causes are related to adhesion ceramic materials to zirconia surface, thermal and mechanical compatibility, coating ceramics thickness, technical control of manufacture, among others.<sup>[6-8]</sup> The clinical consequence of a fracture in coating porcelain depends on its length and location.<sup>[9]</sup>

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

> Address for correspondence: Prof. Simone Kreve, Rua Independência 1899, Apto 602, Centro, Toledo, Paraná, Brazil, CEP 85902-015. E-mail: simonekreve@hotmail.com

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

**How to cite this article:** Felipe AF, Miranda Coimbra WH, Pinheiro Carvalho GA, Kreve S, Gonçalves Franco AB, Dias SC. Evaluation of the bonding strength between yttrium-stabilized zirconia and coating ceramics with three-point flexural Test: The surface treatment effect. Eur J Gen Dent 2018;7:14-8. the metal is less damaging to the ceramic coating because of its elasticty 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.<sup>[10,11]</sup>

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  $25 \text{ mm} \times 3 \text{ mm} \times 0.5 \text{ mm}$  were submitted to ceramics application on its central portion with dimensions of  $8 \text{ mm} \times 3 \text{ mm} \times 1 \text{ mm}$  for the flexural test and DIS.<sup>[12,13]</sup> 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.<sup>[14]</sup>

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  $8 \text{ mm} \times 3 \text{ mm} \times 1 \text{ mm}$  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<sup>[15]</sup> [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 ( $\alpha$ =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	$(\alpha = 0.05)$
			Vallalloo		

	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 ( $\alpha$ =0.05)							
Source	Type III sum of squares	Df	Mean square	F	Sig		
Model	24256.472ª	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 ( $31.26 \pm 4.18$  MPa) presented higher DIS values in comparison to the groups VZ/wT ( $25.23 \pm 4.52$  MPa) (P = 0.027) and I/wT ( $25.27 \pm 4.07$  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  $40 \times$  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.<sup>[3]</sup>

Ceramic materials are friable, and their irregular shapes make it difficult to standardize the tests to evaluate their properties. Quinn and Goulet<sup>[15]</sup> 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.<sup>[14]</sup>

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.<sup>[1,11-13,16-25]</sup>

Zirconia surface can be treated with aluminum oxide, diamond drills, or silica coating blasting. Some authors<sup>[13]</sup> 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.<sup>[13]</sup> Other authors<sup>[25]</sup> suggested a chemical bond between zirconia and porcelain and ruled out the need for pretreatment.<sup>[6,25]</sup> 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.<sup>[21]</sup>

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.<sup>[11]</sup> 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.<sup>[10]</sup> 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.*<sup>[26]</sup> 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,<sup>[12]</sup> while others showed worse results with their use.<sup>[20]</sup> 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.<sup>[11]</sup>

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%.<sup>[27]</sup> 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.

# Financial support and sponsorship

Nil.

#### **Conflicts of interest**

There are no conflicts of interest.

# REFERENCES

- Choi BK, Han JS, Yang JH, Lee JB, Kim SH. Shear bond strength of veneering porcelain to zirconia and metal cores. J Adv Prosthodont 2009;1:129-35.
- 2. Schmalz G, Garhammer P. Biological interactions of dental cast alloys with oral tissues. Dent Mater 2002;18:396-406.
- Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). Dent Mater 2015;31:603-23.
- Volpato CA, Fredel MC, Philippi AG, Petter CO. Ceramic materials and color in dentistry. In: Wunderlich W. Ceramic Materials. Croatia: Sciyo; 2010. p. 155-75.
- Volpato CM, Garbelotto LG, Fredel MC, Bondioli F, Sikalidis C, editors. Advances in ceramics – Electric and magnetic ceramics, bioceramics, ceramics and environment. Application of Zirconia in Dentistry: Biological, Mechanical and Optical Considerations. Rijeka: InTech; 2011. p. 397-420.
- Heintze SD, Rousson V. Survival of zirconia- and metal-supported fixed dental prostheses: A systematic review. Int J Prosthodont 2010;23:493-502.
- Raigrodski AJ, Hillstead MB, Meng GK, Chung KH. Survival and complications of zirconia-based fixed dental prostheses: A systematic review. J Prosthet Dent 2012;107:170-7.
- Manicone PF, Rossi Iommetti P, Raffaelli L. An overview of zirconia ceramics: Basic properties and clinical applications. J Dent 2007;35:819-26.

- Rinke S, Kramer K, Bürgers R, Roediger M. A practice-based clinical evaluation of the survival and success of metal-ceramic and zirconia molar crowns: 5-year results. J Oral Rehabil 2016;43:136-44.
- Göstemeyer G, Jendras M, Borchers L, Bach FW, Stiesch M, Kohorst P, *et al.* Effect of thermal expansion mismatch on the Y-TZP/veneer interfacial adhesion determined by strain energy release rate. J Prosthodont Res 2012;56:93-101.
- 11. Terui Y, Sato K, Goto D, Hotta Y, Tamaki Y, Miyazaki T, *et al.* Compatibility of ce-TZP/Al2O3 nanocomposite frameworks and veneering porcelains. Dent Mater J 2013;32:839-46.
- Tada K, Sato T, Yoshinari M. Influence of surface treatment on bond strength of veneering ceramics fused to zirconia. Dent Mater J 2012;31:287-96.
- Yamaguchi H, Ino S, Hamano N, Okada S, Teranaka T. Examination of bond strength and mechanical properties of Y-TZP zirconia ceramics with different surface modifications. Dent Mater J 2012;31:472-80.
- Schneider GA, Swain MV. The schwickerath adhesion test: A fracture mechanics analysis. Dent Mater 2015;31:986-91.
- Quinn GD, Goulet RL. Inventores. Articulating Flexural test fixture. United States. Patent. 4,941,359. 1990 Jul, 17.
- Wattanasirmkit K, Srimaneepong V, Kanchanatawewat K, Monmaturapoj N, Thunyakitpisal P, Jinawath S, *et al.* Improving shear bond strength between feldspathic porcelain and zirconia substructure with lithium disilicate glass-ceramic liner. Dent Mater J 2015;34:302-9.
- 17. Matsumoto N, Yoshinari M, Takemoto S, Hattori M, Kawada E, Oda Y, *et al.* Effect of intermediate ceramics and firing temperature on bond strength between tetragonal zirconia polycrystal and veneering ceramics. Dent Mater J 2013;32:734-43.
- Teng J, Wang H, Liao Y, Liang X. Evaluation of a conditioning method to improve core-veneer bond strength of zirconia restorations. J Prosthet Dent 2012;107:380-7.

- Ishibe M, Raigrodski AJ, Flinn BD, Chung KH, Spiekerman C, Winter RR, *et al.* Shear bond strengths of pressed and layered veneering ceramics to high-noble alloy and zirconia cores. J Prosthet Dent 2011;106:29-37.
- Kim HJ, Lim HP, Park YJ, Vang MS. Effect of zirconia surface treatments on the shear bond strength of veneering ceramic. J Prosthet Dent 2011;105:315-22.
- Mosharraf R, Rismanchian M, Savabi O, Ashtiani AH. Influence of surface modification techniques on shear bond strength between different zirconia cores and veneering ceramics. J Adv Prosthodont 2011;3:221-8.
- Doi M, Yoshida K, Atsuta M, Sawase T. Influence of pre-treatments on flexural strength of zirconia and debonding crack-initiation strength of veneered zirconia. J Adhes Dent 2011;13:79-84.
- Komine F, Saito A, Kobayashi K, Koizuka M, Koizumi H, Matsumura H, et al. Effect of cooling rate on shear bond strength of veneering porcelain to a zirconia ceramic material. J Oral Sci 2010;52:647-52.
- López-Mollá MV, Martínez-González MA, Mañes-Ferrer JF, Amigó-Borrás V, Bouazza-Juanes K. Bond strength evaluation of the veneering-core ceramics bonds. Med Oral Patol Oral Cir Bucal 2010;15:e919-23.
- Fischer J, Grohmann P, Stawarczyk B. Effect of zirconia surface treatments on the shear strength of zirconia/veneering ceramic composites. Dent Mater J 2008;27:448-54.
- Cömlekoğlu ME, Dündar M, Ozcan M, Güngör MA, Gökçe B, Artunç C, *et al.* Evaluation of bond strength of various margin ceramics to a zirconia ceramic. J Dent 2008;36:822-7.
- Sulaiman TA, Abdulmajeed AA, Donovan TE, Cooper LF, Walter R. Fracture rate of monolithic zirconia restorations up to 5 years: A dental laboratory survey. J Prosthet Dent 2016;116:436-9.

#### Author Help: Online submission of the manuscripts

Articles can be submitted online from http://www.journalonweb.com. For online submission, the articles should be prepared in two files (first page file and article file). Images should be submitted separately.

1) First Page File:

Prepare the title page, covering letter, acknowledgement etc. using a word processor program. All information related to your identity should be included here. Use text/rtf/doc/pdf files. Do not zip the files.

2) Article File:

The main text of the article, beginning with the Abstract to References (including tables) should be in this file. Do not include any information (such as acknowledgement, your names in page headers etc.) in this file. Use text/rtf/doc/pdf files. Do not zip the files. Limit the file size to 1 MB. Do not incorporate images in the file. If file size is large, graphs can be submitted separately as images, without their being incorporated in the article file. This will reduce the size of the file.

3) Images:

Submit good quality color images. Each image should be less than 4096 kb (4 MB) in size. The size of the image can be reduced by decreasing the actual height and width of the images (keep up to about 6 inches and up to about 1800 x 1200 pixels). JPEG is the most suitable file format. The image quality should be good enough to judge the scientific value of the image. For the purpose of printing, always retain a good quality, high resolution image. This high resolution image should be sent to the editorial office at the time of sending a revised article.

#### 4) Legends:

Legends for the figures/images should be included at the end of the article file.