Rev. FOB
v.10, n.1, p.57-62, jan./mar. 2002

BONDING CERAMIC TO METAL: A COMPARISON USING SHEAR TESTS

UNIÃO DA CERÂMICA AO METAL: UMA COMPARAÇÃO UTILIZANDO TESTES DE CISALHAMENTO

Juliano Milczewsky SCOLARO
Postgraduate student, Department of Prosthodontics, Dental School of Bauru, University of São Paulo, Brazil.

Accácio Lins do VALLE
Associated Professor, Department of Prosthodontics, Dental School of Bauru, University of São Paulo, Brazil.

Many dentists and technicians have used different dental ceramics with different alloys without concerning with the characteristics of compatibility of those materials. It is very important to the dentist to know the properties of the alloy and the ceramic used in metal/ceramic restorations. The purpose of this study was to evaluate the bond strength of a palladium-silver alloy (Pors-on 4) to three ceramics (Ceramco, Noritake and Vita VMK-68) using shear forces at the metal-ceramic interface. A stainless steel cylindrical matrix was used for preparation of the metal dies, application of ceramic and to perform the shear tests. Thirty palladium-silver alloy cylinders received two layers of opaque and two layers of body porcelain, and shear tests were performed in a universal testing machine at a cross-head speed of 0.5mm/min. The mean shear bond strength values were: 28.21MPa (Ceramco), 28.96MPa (Noritake) and 24.11MPa (Vita VMK-68). The one-way ANOVA did not show statistically significant differences among the groups ($p<0.05$). The results showed that the three ceramic systems are suitable for the selected alloy.

UNITERMS: Metal-ceramic alloys, Ceramics, Compressive strength.

INTRODUCTION

Since its introduction in the 50s, the porcelain fused to metal restorations have been playing an important role in restorative dentistry because they allow efficient restorations with great color stability and resistance provided by the metallic framework. Along these years, many authors [1,4,27] have emphasized the importance to evaluate different alloys and ceramics, using physical tests [5,6,12-14,25,26,29]. Many tests were, thus, designed[5,6,12-14,25,26,28,29] in an attempt to reproduce the complex set of forces which act on the metal-ceramic interface[8,15,16,22,28]. Since that, there has been a great concern on the evaluation of bond strength between metal and ceramic, seeking the most ideal test to evaluate this interface, simulating the conditions observed in the oral cavity.

Several tests have been used for that purpose, including shear tensions[6,12,14,26,29], tensile tensions[25], flexure tensions[5,13,15] and torsion[10].

Regardless of the quantity of existent test types, according to Anusavice[1], a test must fulfill two basic requirements to provide precise results: (1) the concentration of stresses must take place only along the interface. If the test produces stresses concentrations outside of the interface, for example, at the end of the ceramic layer or thickness alterations of this layer, the obtained results will be lower than the actual metal-ceramic bond resistance; (2) the quantity of present tensions should be zero, because if this kind of force exists, there is a possibility of ceramic fracture and “contamination” of the test resulting values.

The circular-planar surface shear test proposed by Chong, Beech and Chem[6] provides easy fabrication and standardization of the specimens submitted to the tests. Furthermore, the matrix used in the specimen fabrication provides the execution only of shear strength tests. According to the requirements described by these authors [5,6,8,14,22,25-29], this type of test is highly reliable because of the metal-ceramic interface bonding is the only type of adhesion.

In the 80's, the palladium alloys were introduced and they were considered suitable for dental utilization by many studies[2,7,16,20,21,23]. This type of alloy presents particularities that, in spite of they not interfere with the porcelain to metal union, they deserve to be observed. The main path for bonding with these alloys is mechanical[1] and such condition has not been producing significant clinical failures. However, there are other elements in the alloy composition such as silver and tin, which are susceptible to oxidation. In this way, previous oxidation is an important procedure that may increase the bond strength of such metal-ceramic interface[2,9,16,23,30]. Moreover, the Pd-Ag alloy (Pors-On 4) presents much smaller grains than other Pd-Ag alloys. That provides better mechanical qualities, besides promoting a larger external contact surface [2,3].

According to some authors[2,9,16,21,23,30], previous oxidation may give rise to silver nodules emergence, which can undergo volatilization. The presence of silver vapors may, on the other hand, provoke ceramic spotting or darkening.

Another characteristic of the palladium alloys is the high sensitivity to the presence of carbon during the casting procedures. That may generate problems such as ceramic porosities and carbon contamination in the alloy[2,10,11,16,19,21]. The carbon promote the formation of carbon monoxide during the ceramic baking, originating bubbles and porosities, which can contribute to undesirable outcomes such as cracks or fractures.

Due to the constant seeking for the ideal type of ideal type of test and to the continuous development of new ceramics and an increase in the use of palladium alloys, this study aimed to test the bond strength of such metal/ceramic interfaces by means of a shear testing.

MATERIAL AND METHODS

A cylindrical stainless steel matrix (Figure 1-A) was used to obtain the specimens. The same matrix was used for ceramic layering and to perform the shear strength tests. The matrix had a central hole with 6.5mm in depth and 6.0mm in diameter, and an auxiliary 2.0mm diameter perforation across the matrix (Figure 1-B) up to the bottom of the central perforation. That was used to remove the dies and specimens using a metallic pin (Figure 1-C).

The set of matrix components also includes a metallic base (Figure 1-B) to which the matrix is screwed to adapt to the testing machine and a 6.0mm diameter, 1.5mm thick disc used as a spacer for standardizing the thickness of the ceramic layer (Figure 1-D).

The wax patterns were made with the disk positioned inside the perforation. The wax (Green Regular Wax - Kota Ind. Ltd., São Paulo, Brazil) was liquefied at 75ºC and flowed with the aid of a dropper inside the perforation. After the cooling of the wax, the patterns were removed by the introduction of the metallic pin in the auxiliary perforation and stored in a container with water until the investment and casting procedures.

Thirty metallic dies were obtained using a palladium-silver alloy (Pors-on 4, Degussa S.A., São Paulo, Brazil). The investment and casting

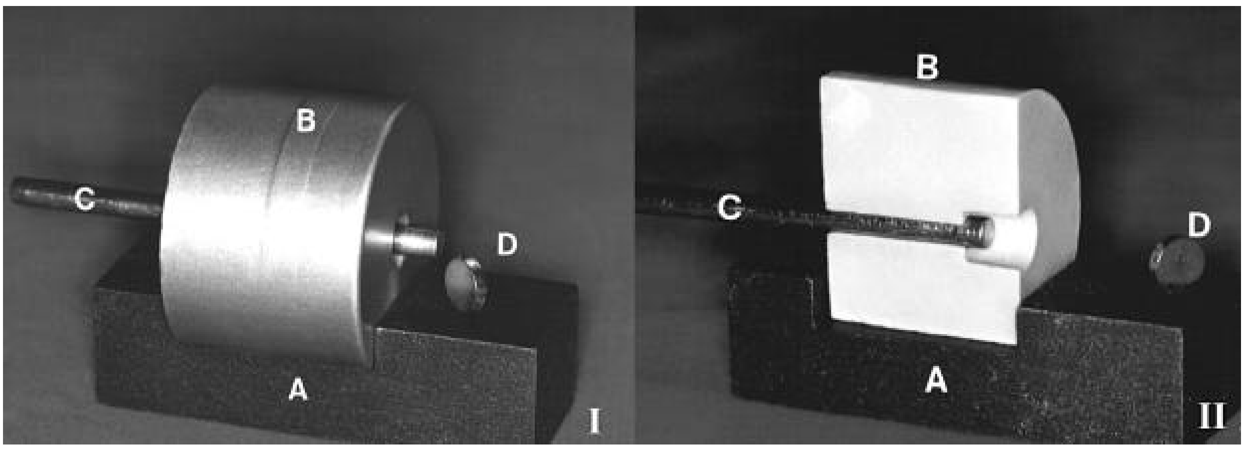

FIGURE1- Matrix's set components – (I – actual view; II – schematic view)
A – Matrix
B – Base
C – Pin – specimen removal
D – Spacing disk

procedures were performed according the manufacturer's specifications.

After checking for adaptation in the matrix, the metallic cylinders were ultrasonically cleaned, washed in water, sandblasted with 50µm aluminum oxide and oxidized according to the manufacturer's instructions. They were further washed in distilled water, dried, and kept free of touch until ceramic application. They were "coated" with three ceramics: Ceramco (Ceramco Inc., Burlington, NJ, USA), Noritake Super Porcelain EX-3 (Noritake Kizai Co., Ltd., Nagoia, Japan) and Vita VMK-68 (Vita Zahnfabrik, Säckingen, Germany).

The metallic die was positioned inside the perforation, without the disk, leaving a 1.5mm space for ceramic application. Each ceramic was applied according to the manufacturer's instructions for mass preparation, condensing, baking temperature and time.

After application of porcelain, all samples were positioned to the matrix with the disk at the bottom of perforation, leaving the ceramic layer showing outside the matrix, in order to apply forces only at the metal/ceramic interface.

The shear tests were conducted in a universal testing machine (Kratos 2000 – Kratos Dynamometers, São Paulo, Brazil) with a beveled shaped rod with 0.5 mm thickness applied at the metal-ceramic interface until failure (Figure 2).

RESULTS

The results of shear strength tests are presented in Table 1.

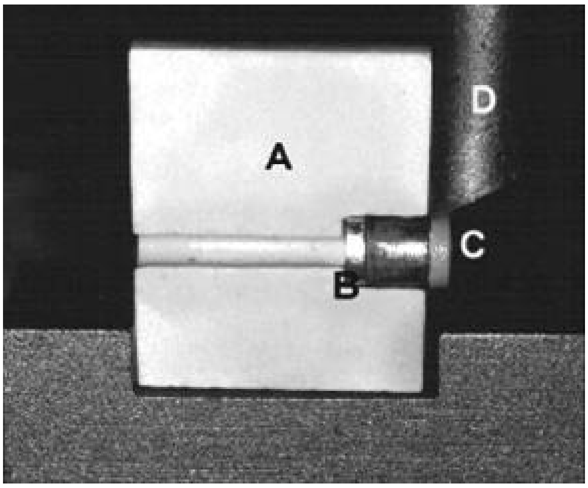

FIGURE 2- Schematic view of the shear test:
A - Matrix
B - Spacer disk in position
C - Ceramic portion
D - Active point

The results were analyzed by the One-Way ANOVA at á=0.05.

Table 2 shows the One Way ANOVA results for shear bond strengths. The analysis indicated that the bond strengths had no significant differences ($p<0.05$).

Besides, the fracture type between porcelain and metal was observed. Of the thirty specimens, twenty-seven showed adhesive fractures, and the remaining three, adhesive and cohesive fractures. The relationship among the test, material and fracture type, will be discussed further.

DISCUSSION

According to the literature, there is no test that can be considered as ideal for the evaluation of the shear bond strength between metal and ceramics. There are many tests that have been used frequently with the ceramic applied around metallic patterns in a semi-circle shape, or applied over a flat metal surface, in order to avoid tensions on ceramic.

However, these shear tests were criticized because of the influence of metal surface texture and the possible effect of residual stress from mismatches of thermal expansion or the hoop-stress phenomenon [8]. There are still other types of tests that have been used, however, none of them was considered ideal, due to their inherent problems.

Thus, the option was for the circular-planar interface shear test[6,8], which provides easy fabrication and standardization of the specimens submitted to the tests. Furthermore, the matrix used in the fabrication of the specimens provides the execution only of shear strength tests. According to the requirements described by these authors, this type of test is highly reliable, because it is based on minimal experimental variables and least residual stresses at metal-ceramic interface.

With the same test type, Chong et al.[6] obtained shear bond strength values of 30MPa using Ni-Cr alloys.

Other authors[5,8,12,14,18,24], using the same test type, just with small methodology alterations, obtained results varying from 15MPa to 60MPa. It can be observed that even when a similar test is used, the variation of the results is very high, due mainly to the inexistence of a standardization of the methodology to be used for evaluation of the porcelain fused to metal union.

The data from this study did not show significant differences for any ceramic systems ($p=0.299$),

TABLE 1 - MPa±SD(n).

Material	MPa±SD	n
Noritake	28.96±6.92	10
Ceramco	28.20±8.65	10
Vita VMK 68	24.11±6.27	10

TABLE 2 - One-Way ANOVA results.

Source of variation	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Between treatments	2	136.473	68.237	1.262	**0.299***
Residual	27	1460.152	54.080		
Total	29	1596.625			

*not significant ($p<0.05$)

although the results of the Noritake system (28.96 MPa) were about 2.63% higher than those of the Ceramco system (28.20 MPa) and 16.75% higher than those of the Vita VMK-68 system (24.11 MPa). Clinically, the interpretation of these results suggests that all ceramics present enough bond strength and can be used routinely.

Furthermore, according to some authors[1,2,6,8,17,19,22-24,26], shear bond strength values greater than 10MPa indicate clinically satisfactory results, representing a better bond strength than the necessary to provoke the clinical flaw of union between metal and ceramic.

With regard to the fracture type observed, most of the specimens presented fracture of the adhesive type. Only 1% of the specimens presented combined fractures, that is, adhesive and cohesive. Small ceramic portions stayed adhered to the metallic surface. According to some authors[2,3,8,15,17,21], it should not be considered as cohesive fracture. So that it happens this fracture type, it is necessary that the ceramic portion stays adhered in the whole extension of the metallic surface and the fracture line travels the portion of "body" porcelain. In agreement with Chong et al.[6], Mackert et al.[15], Papazoglou et al.[21], the presence of these porcelain "islets" can be considered as an undesirable result of the test type, and not as cohesive fracture.

The previous oxidation may give rise to silver nodules emergence, which promotes adhesion, but can undergo volatilization. The presence of silver vapors may, on the other hand, provoke ceramic spotting or darkening. Such outcomes were not observed in this study.

In the same way, the use of a ceramic based investment, impeded any superficial contamination of the metal by carbon.

Moreover, there is a constant improvement of the ceramics, which present resistance values more and more elevated when they are submitted to the most varied types of tests. Meanwhile, these ceramics have always been improved, with few occurrence of failures related to fracture, which is undoubtedly the most undesirable characteristic that may exist in this material.

However, to obtain a satisfactory result, the framework must have a correct and properly shape, permitting a uniform thickness of the ceramic layer in order to receive just compressive forces. These compressive forces will provide an additional way of resistance.

Although the main cause of failure of porcelain fused to metal restoration can be attributed to secondary caries, the success of this kind of work depends greatly on the union resistance between metal and ceramic.

CONCLUSIONS

According to the obtained results, the systems presented no statistically significant differences between them and are in accordance with the literature data, serving as a subside for the utilization of any of the three systems in association with the studied alloy. It is concluded that the porcelain fused to metal restoration depends fundamentally on the union ability between the two materials, not suffering from fatigue or fractures, under different conditions.

RESUMO

Muitos dentistas e técnicos usam cerâmicas dentais com diferentes ligas sem se preocupar com as características de compatibilidade desses materiais. É muito importante para o profissional, conhecer as propriedades das ligas e cerâmicas utilizadas em restaurações metalocerâmicas. O objetivo deste estudo foi de avaliar a resistência de união de uma liga de paládio-prata (Pors-On 4) com três cerâmicas (Ceramco, Noritake e Vita VMK-68) utilizando forças de cisalhamento na interface meta/cerâmica, além de testar a metodologia e as características de manipulação dos materiais estudados. Uma matriz cilíndrica foi utilizada para a preparação dos padrões metálicos, aplicação das cerâmicas e execução dos testes de cisalhamento. Trinta padrões metálicos receberam duas camadas de opaco e duas camadas de porcelana de corpo. Os testes de cisalhamento foram executados em uma máquina de ensaios universal a uma velocidade de 0.5mm/min. Os valores de resistência de união foram: 28.21MPa (Ceramco), 28.96MPa (Noritake) e 24.11MPa (Vita VMK-68). A ANOVA a um critério determinou não existirem diferenças estatisticamente significativas entre os grupos ($p<0.05$). Os resultados mostraram que os três sistemas cerâmicos são satisfatórios para a utilização com a liga selecionada.

UNITERMOS: Ligas metalocerâmicas; Cerâmicas; Forças compressivas.

ACKNOWLEDGEMENTS

This study was supported by FAPESP – grant n. 98/06880-0

REFERENCES

1- Anusavice KJ. Noble metal alloys for metal-ceramic restorations. Dent Clin N Amer 1985;29:789-803.

2- Böning K, Walter M. Palladium alloys in prosthodontics: selected aspects. Int Dent J 1990;40: 289-97.

3- Brantley WA, Cai Z, Papazoglou E, Mitchell JC, Kerber SJ, Mann GP, Barr TL. X-ray diffraction studies of oxidized high-palladium alloys. Dent Mater 1996;12:333-41.

4- Brecker SC. Porcelain baked to gold: A new medium in prosthodontics. J Prosthet Dent 1956;6:801-10.

5- Caputo AA, Dunn B, Reisbick MH. A flexural method for evaluation of metal-ceramic bond strengths. J Dent Res 1977;56:1501-6.

6- Chong MP, Beech D, Chem C. A simple shear test to evaluate the bond strength of ceramic fused to metal. Aust Dent J 1980;25:357-61.

7- Cohen SM, Kakar A, Vaidyanathan TK, Viswanadhan T. Castability optimization of palladium based alloys. J Prosthet Dent 1996;76:125-31.

8- Hammad, IA Talic, YF. Designs of bond strength tests for metal-ceramic complexes: review of the literature. J Prosthet Dent, 1996;75:602-8.

9- Hautaniemi JA, Juhanoja JT, Suoninen EJ, Yli-Urpo AU. Oxidation of four palladium-rich ceramic fusing alloys. Biomater 1990;11: 62-72.

10- Herø H, Syverud M. Carbon impurities and properties of some palladium alloys for ceramic veneering. Dent Mater 1985;1:106-10.

11- Johnson A, Winstanley RB. The evaluation of factors affecting the castability of metal ceramic alloy-investment combinations. Int J Prosthodont 1996;9:74-8.

12- Knap FJ, Ryge G. Study of bond strength of dental porcelain fused to metal. J Dent Res 1966;45:1047-51.

13- Lavine MH, Custer F. Variables affecting the strength of bond between porcelain to gold. J Dent Res 1966;45:32-6.

14- Lubovich RP, Goodkind RJ. Bond strength studies of precious, semiprecious and nonprecious ceramic-metal alloys with two porcelains. J Prosthet Dent 1977;37:288-99.

15- Mackert JR, Parry EE, Hashinger DT, Fairhust, CW. Measurement of oxide adherence to PFM alloys. J Dent Res 1984;63:1335-40.

16- Mackert JR, Ringle RD, Fairhurst CW. High-temperature behavior of a Pd-Ag alloy for porcelain. J Dent Res 1983;62:1229-35.

17- O'Connor RP, Mackert JR , Myers ML, Parry EE. Castability, opaque masking, and porcelain bonding of 17 porcelain-fused-to-metal alloys. J Prosthet Dent 1996;75:367-74.

18- Pang IC, Gilbert JL, Chai J, Lautenschlager EP. Bonding characteristics of low-fusing porcelain bonded to pure titanium and palladium-copper alloy. J Prosthet Dent 1995;73:17-25.

19- Papazoglou E, Brantley WA, Johnston WM, Carr AB. Effects of dental laboratory processing variables and in vitro testing medium on the porcelain adherence of high-palladium casting alloys. J Prosthet Dent 1998;79:514-9.

20- Papazoglou E, Brantley WA, Johnston WM. Evaluation of high-temperature distortion of high-palladium metal-ceramic crowns. J Prosthet Dent 2001;85:133-40.

21- Papazoglou E, Brantley WA, Mitchell JC, Cai Z, Carr AB. New high-palladium casting alloys: studies of the interface with porcelain. Int J Prosthodont 1996;9:315-22.

22- Papazoglou E, Brantley WA. Porcelain adherence versus force to failure for palladium-gallium alloys: A critique of metal-ceramic bond testing. Dent Mat 1998;14: 112-9.

23- Papazoglou E. Porcelain adherence to high-palladium alloys. J Prosthet Dent 1993;70:386-94.

24- Poljak-Guberina R, Catovic A, Jerolimov V, Franz M, Bergman V. The fatigue strength of the interface between Ag-Pd alloy and hydrothermal ceramic. Dent Mater 1999;15:417-20.

25- Sced IR, Mclean JW. The strength of metal/ceramic bonds with base metals containing chromium. Brit Dent J 1972;32:232-4.

26- Shell JS, Nielsen JP. Study of the between bond gold alloys and porcelain. New Rochelle, J. F. Jelenko, 1963.

27- Silver M, Klein G, Howard MC. Platinum-porcelain restorations. J Prosthet Dent 1956; 6:695-705.

28- Suansuwan N, Swain MV. New approach for evaluating metal-porcelain interfacial bonding. Int J Prosthodont 1999;12:547-52.

29- Vickery RC, Badinelli LA. Nature of attachment forces in porcelain-gold systems. J Dent Res 1968;47:683-9.

30- Wu Y, Moser JB, Jameson LM, Malone WF. The effect of oxidation heat treatment on porcelain bond strength in selected base metal alloys. J Prosthet Dent 1991;66:439-44.

ENDEREÇO PARA CORRESPONDÊNCIA:
Faculdade de Odontologia de Bauru
Departamento de Prótese
Al. Octávio Pinheiro Brisola, 9-75
Cep.: 17012-901 - Bauru - SP
e-mail: jmscolaro@uol.com.br
al-valle@fob.usp.br