



## Evaluation of the shear bond strengths between two alternative metal alloys and porcelain

**Dr. Haider H. Jassim** B.D.S. M.Sc.

### Abstract

The success of metal-ceramic restorations is influenced by the compatibility between base metal alloys and porcelains. Although porcelain manufacturers recommend their own metal systems as the most compatible for fabricating metal-ceramic prostheses, a number of alloys have been used. The purpose of this study was to evaluate the bond strength of CoCr alloy (Wironbond C) and NiCr alloy (Wiron 99) 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. Ten metal dies of each alloy were made for each alloy, and the metallic portion was obtained with the lost wax casting technique with standardized waxing of 6.5mm of height and of 6mm of diameter. The ceramic was applied according to the manufacturer's recommendations with the aid of a Teflon matrix that allowed its dimension to be standardized in the same size as the metallic portion, 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 53.06MPa for Wironbond C alloy, with standard deviation of 10.67, and 45.38MPa for Wiron 99, with standard deviation of 9.01. No statistically significant difference was observed between the shear strength of the two metal-ceramic alloys.

### Introduction

For decades dentistry has used metal-ceramic prostheses with good clinical performance, esthetics, and durability. The aim of these restorations is to combine the fracture resistance of the metal substructure with the esthetics properties of the porcelain <sup>(1)</sup>. The oral rehabilitation, besides reestablishing function and esthetics, must respect the patient's financial capacity. Therefore, the use of noble alloys for fabrication of ceramometal dentures should be avoided in many cases because of their high cost <sup>(2)</sup>. The use of alternative metal alloys is an unquestionable need, and the use of CoCr and NiCr alloys in

particular have permitted high quality treatment for a large number of patients with limited financial means in developing countries <sup>(3)</sup>. These and other non-precious alloys have been developed and have become superior to the gold-based metals in several aspects, including hardness, elasticity modulus and tensile strength <sup>(4)</sup>. Thinner infrastructures became viable, with a smaller volume of material, but with the necessary rigidity for extensive fixed partial dentures <sup>(5)</sup>.

These alloys also have several negative characteristics, however: markedly higher corrosion in acidic environments; difficult finishing and

polishing; dark, thick oxides; risk of patient allergy; and difficult soldering. Furthermore, their liquidus temperatures are the highest among all prosthodontic alloys, making it harder to cast them and ensure appropriate marginal fit of restorations<sup>(6)</sup>.

However, such disadvantages may be minimized due to changes in technology, material properties, and design advantages of these alternative alloys for metal-ceramic restorations<sup>(7)</sup>.

The longevity of the metal-ceramic restorations depends on the formation of a stable adhesive layer between the 2 materials<sup>(8)</sup>. The adhesion mechanism between the metal and porcelain has not been completely defined, but it is believed to generally result from suitable oxidation of the metal<sup>(9)</sup> and inter diffusion of ions between the metal and porcelain<sup>(10)</sup>.

Evaluation of the resistance of the interface between two base metal alloys and ceramics is performed by the shear test, which allows evaluation of the metal/ceramic adhesion by inducing tension on the interface, so that the crack initiates at the most fragile point<sup>(11, 12)</sup>.

## Materials 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 type II blue inlay wax (Degussa, Germany) was liquefied at 75°C 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.

Twenty metallic dies were obtained. Ten dies were made using a NiCr alloy (Wirron 99; Bego, Bremen, Germany) and the other ten dies were made using CoCr alloy (Wirobond C, Bego; Germany) whose composition is presented in table 1. The investment and casting procedures were performed according the manufacturer's specifications.

After checking for adaptation in the matrix, the metallic cylinders were washed in water, sandblasted with 150µm aluminum oxide (for 10 seconds at 2cm distance, 2-bar pressure, and 45° approximate angulations) and then 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 ceramic (Vita 95, 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 (figure 2).

Shear bond strength was evaluated with Instron testing machine using a stainless steel chisel-shaped rod with 0.5 mm thickness applied at the metal-ceramic interface until failure, the load cell was set at 100 kg.

## Results

The means and standard deviations obtained from the data of the shear bond strength test for each alloy investigated can be seen in Table 2. *t*-test between CoCr and NiCr alloy values was performed. No statistically significant difference was observed between groups at a significance level ( $p=0.05$ ), (Table 3).

## Discussion

Nowadays, the use of alloys, especially NiCr with and without Be, represents the largest amount of alloys used in ceramometal prosthesis. On the other hand, questions about toxic and allergenic elements and even on the carcinogenic potential of these alloys have been raised<sup>(13)</sup>. The biological characteristics of these alloys should also be taken into consideration when selecting the material<sup>(14)</sup>, considering that their use could harm the health of patients and professionals involved in fabrication of the prosthesis. The Ni is considered one of the most common causes of allergic dermatitis<sup>(3)</sup>, appearing in researches as a component with the higher allergenic<sup>(13)</sup> and toxic potential together with Be<sup>(15)</sup>. Therefore, the CoCr alloys were developed to become an option to the Ni-based alloys, and are considered secure substitutes for clinical use with favorable physical and mechanical properties<sup>(13,16)</sup>. Thus, the performance of the metal ceramic interface of these

alloys must be evaluated and, in the present study, CoCr alloy was evaluated and compared with NiCr alloy.

The success of a metal-ceramic restoration depends primarily on strong adhesion between the porcelain and alloy. Many methods have been proposed to quantify such adhesion, but none is completely exempt from errors, due to the complexity of the ceramic/metal bonding<sup>(17)</sup>. According to Anusavice<sup>(18)</sup>, the metal and porcelain must have similar coefficients of thermal contraction, and metal must have a slightly higher value to avoid undesirable tensile loading at the interface. All of the metals tested in this study were considered thermally compatible with the porcelain, as they have the following coefficients of thermal expansion purported by the manufacturers: Wiron 99 ( $14.0 \times 10^{-6} \text{K}^{-1}$ ) and Wirobond C ( $14.2 \times 10^{-6} \text{K}^{-1}$ ).

Scolaro and Valle<sup>(19)</sup>, in 2002, measured the bond strength of a palladium-silver alloy to three ceramics (Ceramco, Noritake and Vita VMK-68) using shear forces at the metal-ceramic interface. The mean shear bond strength values were: 28.21MPa (Ceramco), 28.96MPa (Noritake) and 24.11MPa (Vita VMK-68). The results did not show statistically significant differences among the groups ( $p<0.05$ ). They concluded that the three ceramic systems are suitable for the selected alloy.

Pretti et al.<sup>(20)</sup> showed that shear bond strength of the metal-ceramic union of two Co-Cr alloys (Wirobond C, Bego; Remanium 2000, Dentaaurum) combined with Omega 900 ceramic (Vita Zahnfabrik). The mean resistance was 48.387MPa for Wirobond C alloy, with standard deviation of 17.718, and 55.956MPa for Remanium 2000, with standard deviation of 17.198. No statistically

significant difference was observed between the shear strength of the two metal-ceramic alloys.

De Melo, Travassos and Neisser<sup>(21)</sup>, 2005, they evaluated the shear bond strengths between a porcelain system and NiCr and CoCr alloys, the results were 58.5 MPa and 63.4 MPa respectively, with no significant differences were found among the shear bond strength values for the metal-ceramic specimens tested. These results are in Consistent with the results of the present study. All these studies used the same type of shear test as the present work.

The data from this study did not show significant differences between the two metal-ceramic alloys used, although the results of the CoCr alloy (53.06) were higher than those of the NiCr alloy (45.38). Clinically, the interpretation of these results suggests that both metal-ceramic alloys present enough bond strength and can be used routinely.

According to some authors<sup>(22,23,24,25)</sup>, shear bond strength values greater than 10 MPa indicate clinically satisfactory results, representing a better bond strength than the necessary to provoke the clinical flaw of union between metal and ceramic.

## Conclusions

Shear bond strength evaluation of the interface formed by base metal alloys (Co-Cr, Ni-Cr) with a dental porcelain product revealed no statistically significant differences in bond strength for the two alloys and single ceramic tested. Based on the present results, it is possible to conclude that the tested CoCr alloy presented similar characteristics as to the interface adhesion aspects with covering ceramic. However, tests are still required because of the small range of research on the subject.

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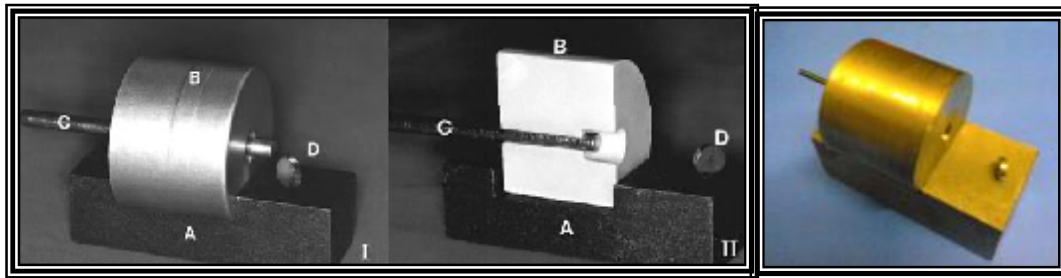


Figure 1. Matrix's set components A - Matrix. B - Base.  
C - Pin - specimen removal. D - Spacing disk

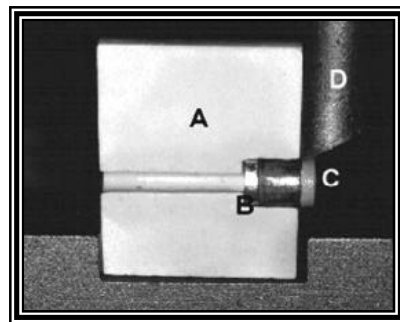


Figure 2 Schematic view of the shear test:

- A - Matrix  
B - Spacer disk in position  
C - Ceramic portion  
D - Active point

Table 1- Composition of NiCr, CoCr alloys given by manufacturers

<b>Alloy</b>	<b>Composition in % by weight</b>
<b>Wirron 99</b>	Ni 65, Cr 22.5, Mo 9.5, Nb 1, Si 1, Fe 0.5,Ce 0.5 C max. 0.02
<b>Wirobond C</b>	Co 61, Cr 26, Mo 6,W 5, Si 1, Fe 0.5,Ce 0.5, C max. 0.02

Table 2- Descriptive table.

<b>CoCr</b>	<b>Min</b> <b>40.73</b>	<b>Max.</b> <b>74.52</b>	<b>Mean</b> <b>53.06</b>	<b>SE</b> <b>3.410</b>	<b>SD</b> <b>10.67</b>
<b>NiCr</b>	<b>Min.</b> <b>32.5</b>	<b>Max.</b> <b>55.73</b>	<b>Mean</b> <b>45.38</b>	<b>SE</b> <b>2.850</b>	<b>SD</b> <b>9.01</b>

Table 3- *t*-test

<b>CoCr</b>	<b>Mean</b> <b>53.06</b>	<b>SD</b> <b>10.67</b>	<b>t-test</b> <b>1.339</b>	<b>P-value</b> <b>0.214</b>	<b>Sig.</b> <b>NS</b> <b>P&gt;0.05</b>
<b>NiCr</b>	<b>Mean</b> <b>45.38</b>	<b>SD</b> <b>9.01</b>			