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Original Research

Comparative Evaluation of Metal-ceramic Bond Strengths of Nickel Chromium and Cobalt Chromium Alloys on Repeated Castings: An *In vitro* Study

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Abstract:

Background: Recasting the base metal alloys is done as a routine procedure in the dental laboratories whenever there is casting failure or to decrease the unit cost of a fixed partial denture. However, this procedure may affect the metal ceramic bond. Furthermore, it is unclear, as to which test closely predicts the bond strength of metal-ceramic interface. The aim was to compare the bond strength of nickel chromium (Ni-Cr) and cobalt chromium (Co-Cr) alloys with dental ceramic on repeated castings using shear bond test with a custom made apparatus.

Materials and Methods: Sixty metal ceramic samples were prepared using Wiron 99 and Wirobond C, respectively. Three subgroups were prepared for each of the groups. The first subgroup was prepared by casting 100% fresh alloy. The second and third subgroups were prepared by adding 50% of fresh alloy and the remnants of the previous cast alloy. The bond load (N) between alloy and dental porcelain was evaluated using universal testing machine using a crosshead speed of 1 mm/min, which had a 2500-kgf load cell. Mean values were compared using oneway analysis of variance with post-hoc Tukey's test and Student's t-test.

Results: The mean shear bond load of A0 (842.10N) was significantly higher than the load of A1 (645.50N) and A2 (506.28N). The mean shear bond load of B0 (645.57N) was significantly higher than the load of B1 (457.35N) and B2 (389.30N).

Conclusions: Significant reduction in the bond strength was observed with the addition of the first recast alloy (A1 and B1) compared with the addition of second recast alloy (A2 and B2). Ni-Cr alloys (664.63N) showed higher bond strengths compared to that of Co-Cr alloys (497.41N). The addition of previously used base metal dental alloy for fabricating metal ceramic restorations is not recommended.

Key Words: Cobalt chromium alloys, custom made apparatus, metal-ceramic bond, nickel chromium alloys, recasting

Introduction

Base metal dental alloys are often used as alternatives to precious alloys due their cost considerations, mechanical properties, and low density.[1,2] Currently, there is growing concern about nickel (Ni) being an allergen and beryllium (Be) being a toxic element.[3,4] Therefore, cobalt chromium (Co-Cr) alloys may serve as an alternative to nickel chromium (Ni-Cr) alloys, due to the allergic concerns of Ni and Be.[5-7] Remelting the casted metal is usually done whenever there is a casting failure or as a routine procedure where dental laboratories want to decrease the unit cost of a fixed partial denture.

Hong *et al.* studied the effect of various percentages of reused silver-palladium alloy on the bond strength of porcelain and concluded that, 50% new alloy should be added to each casting button.[8] de Melo *et al.* evaluated the shear bond strength between a porcelain system and 4 alternative alloys (2 Ni-Cr alloys and 2 Co-Cr alloys) and reported bond strength values ranging between 54 MPa and 71.7 MPa.[9]

However, none of these studies compared the effects of recasting on the bond strength of porcelain to both the Ni-Cr and Co-Cr alloys. Furthermore, it is unclear from the literature, as to which bond strength test closely predicts the bond strength of metal-ceramic interface. Therefore, this study was designed to compare the bond strength of Ni-Cr and Co-Cr alloys with dental ceramic on repeated castings using shear bond test with a custom made apparatus.

Materials and Methods

The Ni-Cr alloy used in this prospective study was Wiron 99 (BEGO Ltd., Germany) composed of Ni 65, Cr 22.5, Mo 9.5, Nb 1, Si 1, Fe 0.5, Ce 0.5 and C max. 0.02. The Co-Cr alloy used was Wirobond C (BEGO Ltd., Germany) composed of Co 61, Cr 26, W 5, Nb 1, Si 1, Fe 0.5, Ce 0.5 and C maximum 0.02 (in % by Wt.). These alloy brands were selected for the study due to their biocompatibility, long-term clinical usage and reliable processing methods. Ethical clearance from the institutional review board was obtained for the study. A rod with a length and diameter of 5 mm was machined to the sample dimensions used by de Melo *et al.* to prepare a metal die[9] (Figure 1). The machined die was embedded in a putty silicone impression material (polyvinyl siloxane, aquasil soft putty, dentsply) to prepare a silicone index. Casting wax (thowax, yeti dental) was used to prepare the wax duplicates. All the wax duplicates were then sprued and invested in a phosphate bonded investment material (Bellasun, Bego) (Figure 2). Lost wax technique was followed, and samples were cast using centrifugal casting machine (OKAY PLUS, Galoni, Italy). After casting, samples were devested and sandblasted (Renfert, Basic master, TBS Pvt. Ltd). Metal samples that are free of voids and meeting the specimen dimensions were only considered for porcelain application. Following the manufacturer's recommendations, opaque porcelain was applied to a clean metal surface using a brush. Dentine porcelain (VMK 95 Metal Ceramic; VITA Zahnfabrik, Bad Säckingen, Germany) was condensed into the putty index, which was used to standardize the porcelain thickness (Figure 3). The samples were removed from the index and fired in a porcelain furnace (Vacumat 40, VITA Zahnfabrik, Germany) (Figure 4). Sample size (n = 10) was determined from similar studies on metal ceramic bond and to get significant values.[9-12] Sixty metal-ceramic samples were prepared out of which thirty samples were cast using Wiron 99, which constituted the Group A and the rest were casted using Wirobond C, which constituted the Group B. Three subgroups were prepared for each of the above groups. The subgroups A0 and B0 were prepared by casting 100% fresh alloy and served as the controls for both the A and B groups, respectively. The subgroups A1 and B1 were prepared by adding 50% of fresh alloy and the remnants of the already cast alloy of A0 and B0, respectively. The subgroups A2 and B2 were prepared by adding 50% of fresh alloy and remnants of their cast alloy of A1 and B1, respectively. The study design is depicted in Table 1.

To measure the mechanical shear bond test, a custom made apparatus made of steel was specially designed for the purpose of the study. This apparatus is made up of two independent pieces. The first Part A is a flat cylindrical shape to fit into the second Part B (Figure 1). The second part, also cylindrical used as a piston during mechanical evaluation. 4 mm diameter perforations are present for proper seating of both parts together. In Part A, the metallic component is lodged and the ceramic portion in Part B. The set was placed in a universal testing machine and on the upper cylindrical prolongation of Part B. Using a crosshead speed of 1 mm/min, the shear bond test was conducted in Instron Universal testing machine (Instron 3366, Norwood, USA), which had a 2500-kgf load cell (Figure 5) and porcelain fracture for minimum load was recorded for each sample.

Statistical analysis

Subgroup was the independent variable, and measured strength was the dependent variable for both the groups. One-way analysis of variance, followed by Tukey multiple comparison test was used for statistical analysis of the data (α = 0.01). An alpha level of 0.01 rather than the more traditional 0.05 was selected to decrease the Type 1 error rate. A statistical software package (SPSS 15.0; SPSS, Inc., Cary, NC, USA) was used for the analysis.

Results

Shear bond load between cast alloys and dental porcelain was compared among the groups. The mean shear bond load of Ni-Cr (664.63N) was significantly higher than the load of

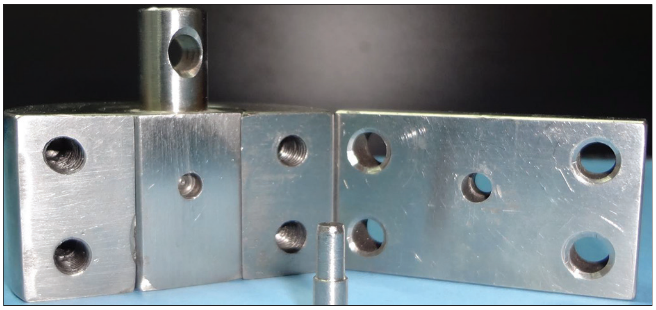


Figure 1: Metal die and custom made apparatus.

Figure 2: Spruing and investing of metal-ceramic samples.

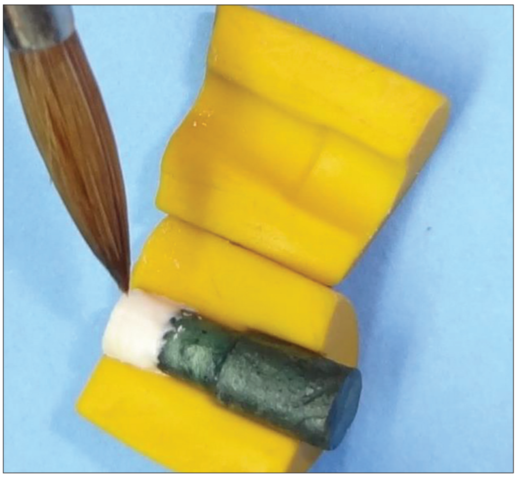


Figure 3: Putty index used to standardize porcelain application.

Figure 4: Porcelain firing on the metal samples.

Figure 5: Custom made apparatus mounted in instron for testing samples.

Co-Cr (497.41N). Means and standard deviations of shear bond load results with Tukey analysis be given in Tables 2-4.

Discussion

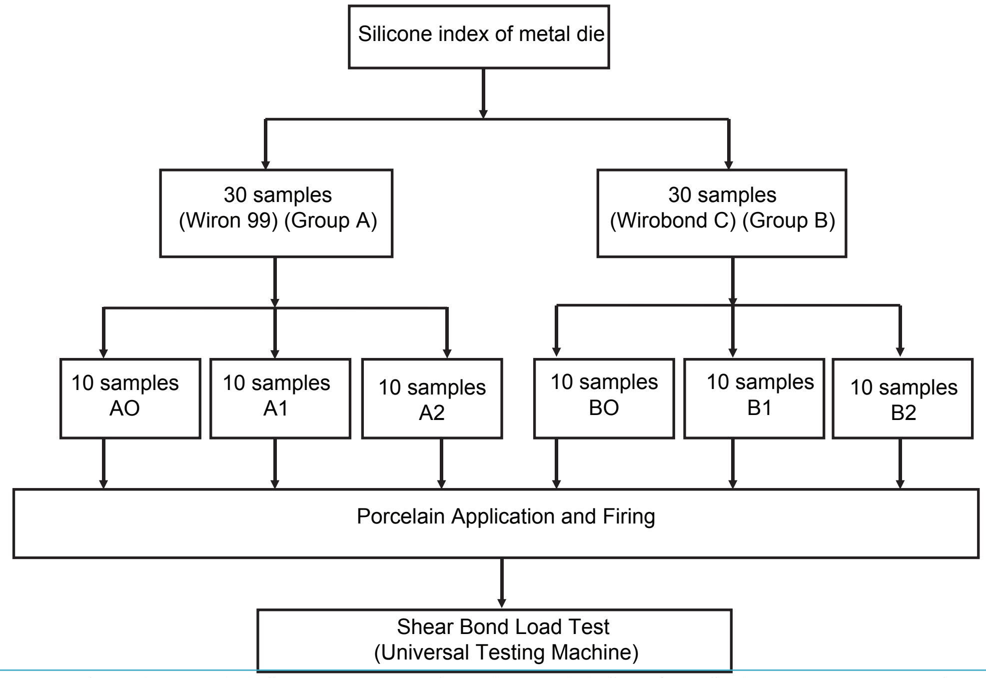
This study was carried out to compare the bond strength of Ni-Cr and Co-Cr alloys with dental ceramic on repeated castings using shear bond test with custom made apparatus. Studies showed that the bond strength of ceramic to Co-Cr and Ni-Cr alloys ranges from 35 to 95 MPa.[13,14] The bond strength values obtained in this study for the Ni-Cr alloys were consistent with those of previous studies.[10-12,15,16] The findings of the present study showed that there was significant reduction in the metal-ceramic bond strength for each of the Ni-Cr (664.63N) and Co-Cr alloys (497.41N) with the addition of recast alloy to the fresh alloy.

This reduction in the bond strength can be attributed to an increase in the frequency of interfacial voids as the percentage of recast metal is increased. Another possible reason for the failure of recast alloy may be the compositional change that occurs after multiple castings.[17] This results in a decreased bond between the metal and the ceramic, since the chemical bond is affected by these elements. Tucillo reported that the thickness of the adherent oxide layer formed at the metal surface might decline due to multiple castings, and result in decreased bond strength.[18]

Several tests were reported in the literature which evaluated the metal-ceramic bond strength, such as twist, shear, tension, flexural mode or the combination of flexural and twist modes all showing advantages and disadvantages.[7] The shear test is considered by some authors as the most adequate method to measure bond between two materials.[10,19-22] The dominant stress in the shear bond test is shear stress, whereas in the 3-point bending test; tensile stress predominates.[19] Therefore, in the present study shear bond was tested using the universal testing machine to evaluate the bond at the metal ceramic interface. In this study, a custom made apparatus was devised so as to concentrate the load predominantly on the metal-ceramic interface and achieve accurate interfacial shear bond results.

When high gold alloys are used, the addition of up to 50% remnant alloy from previous castings is acceptable. However, results from the current study suggest that the addition of previously cast alloy should be avoided if base metal dental alloy is selected for metal ceramic restorations. A significant decrease in the metal ceramic bond after the addition of recast alloy is confirmed with the shear bond test citing to be of the reasons for the clinical fractures observed on metal ceramic

Table 1: Study design.



Sub group designation: A0: Wiron 99 samples cast from 100% fresh alloy; A1: Wiron 99 samples cast from 50% fresh alloy and 50% alloy from A0; A2: Wiron 99 samples cast from 50% fresh alloy and 50% alloy from A1; B0: Wirobond C samples cast from 100% fresh alloy; B1: Wirobond C samples cast from 50% fresh alloy and 50% alloy from B0; B2: Wirobond C samples cast from 50% fresh alloy and 50% alloy from B1

Table 2: Mean maximum loads (SD) between the sub-groups of Group A using ANOVA with *post-hoc* Tukey's test (*n*=10 in each sub-group).

Group	Mean	SD	*P* value	*Post-hoc* test
A				
A0	842.10	81.30	<0.001 S	A0>A1>A2
A1	645.50	38.49		
A2	506.28	20.42		

SD: Standard deviation, ANOVA: Analysis of variance, S: Significant

Table 3: Mean maximum loads (SD) between the sub-groups of Group B using ANOVA with *post-hoc* Tukey's test (*n*=10 in each sub-group).

Group	Mean	SD	*P* value	*Post-hoc* test
B (Co-Cr)				
B0	645.57	32.59	<0.001 S	B0>B1>B2
B1	457.35	11.26		
B2	389.30	9.23		

SD: Standard deviation, ANOVA: Analysis of variance, Co-Cr: Cobalt chromium, S: Significant

Table 4: Results of ANOVA used to compare the shear bond strengths in different groups.

Degrees of freedom	Between groups A and B	Within sub-groups (A0B0), (A1B1), (A2B2)	Total
	4	55	59

ANOVA: Analysis of variance

restorations. Considering the decreased cost of base metal dental alloys, when compared to noble and high noble alloy alternatives, the addition of previously used alloy is not crucial and should be avoided.

Further studies should be conducted to evaluate the effect of multiple firings on the metal-ceramic bond strength and the variation of bond strength with thermocycling of the samples. The coefficient of thermal expansion (CTE) of the dental alloys used is also altered after multiple castings.[23] Additional researches is needed to evaluate the changes in CTE after multiple castings and cytotoxicity of base metal alloys.[24] Also, other key structural factors such as grain size, porosity, and oxide thickness need further studies using scanning electron microscopy.

Conclusion

Within the limitations of the present study, the following can be concluded that Ni-Cr alloys (664.63N) showed higher bond strengths than that of Co-Cr alloys (497.41N). Significant reduction in the bond strength was observed with the addition of the first recast alloy (A1 and B1) compared with the addition of second recast alloy (A2 and B2). The addition of previously used base metal dental alloy for fabricating metal ceramic restorations is not recommended.

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