



Evaluation of the Effect of recasting Nickel–chromium Base Metal Alloy on the Metal–ceramic Bond Strength: An *in vitro* Study

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ABSTRACT

Aim: The aim of this study was to evaluate the effect of recasting base metal alloy on the metal–ceramic bond strength.

Materials and methods: A total of 60 test samples were prepared from new and recast nickel–chromium alloy and divided into six groups. In group A0, test samples were prepared from 100% new alloy. Groups A1, A2, A3, A4, and A5 were prepared from 50% new alloy and 50% casting remnants (sprue and buttons) of the previous group by weight. All these samples were coated with ceramic (IPS d.SIGN and Ivoclar-Vivadent), and samples were then subjected to three-point bending test to evaluate metal–ceramic bond strength.

Results: The values were analyzed using one-way analysis of variance and Tukey's *post hoc* test. The mean bond strength of group A0 was higher than that of groups A1, A2, A3, A4, and A5.

Conclusion: Metal–ceramic bond strength decreased significantly with multiple recastings.

Clinical significance: Bond strength between metal and ceramic is a crucial factor for the clinical performance of metal–ceramic restorations. Recasting of alloys may affect the metal oxide layer composition and thickness of metal–ceramic interface, and thereby the metal–ceramic bond.

Keywords: Bond strength, Dental casting alloys, Laboratory research, Recasting.

How to cite this article: Meenakshi T, Bharathi M, Komala J. Evaluation of the Effect of recasting Nickel–chromium Base Metal Alloy on the Metal–ceramic Bond Strength: An *in vitro* Study. J Contemp Dent Pract 2017;18(9):837-841.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Due to good physical, economical, and biological properties, dental casting alloys are widely used in restorative dentistry. The ideal restorative material was gold alloy because of its excellent properties, such as tarnish and corrosion resistance, capacity to take high polish, castability, burnish ability, hardness, strength, and percentage elongation. However, due to high cost and unesthetic appearance, this alloy is not used now, which led to increase in demand for semiprecious and nonprecious base metal alloys.^{1,2} Most of the properties of the base metal alloys meet the requirements of gold alloy with added advantage of low cost and reduced specific gravity. Among them, cobalt–chromium and nickel alloys have become popular in restorative dentistry. Because of increased demand, there is a substantial rise in the cost of these alloys.^{1,2}

During the 1930s and 1940s, due to the low cost of these base metal alloys, the sprues and buttons remained after castings were discarded. Presently, due to rise in prices, most of the technicians and clinicians are reusing these base metal alloys. The reuse of casting surplus^{3,4} (sprue and metal remaining in the crucible former), either in part or complete, is a routine procedure in dental laboratories to reduce the price of restorations.^{5,6} Ideal cast restorations require certain optimum properties, and these properties should not be changed during various laboratory procedures as well as in oral environment.

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Therefore, recasting should not affect the optimum properties which are necessary for ideal restorations.⁷

Using metals and alloys alone leads to unesthetic appearance; therefore, a combination of metals and ceramics is being commonly used in dentistry to combine the esthetics of porcelain with the durability and strength of the metal.^{8,9} A strong bond between porcelain and metal is important for the longevity and clinical performance of prostheses.^{6,10} Recasting of alloys may affect the composition and thickness of the metal oxide layer at the metal–ceramic interface and thereby the metal–ceramic bond. Several studies showed that essential elements, such as Cu, Zn which are present in smaller quantities in the new alloy may be lost through evaporation or oxidation during first casting. The porcelain adherence may be decreased with proportional decrease in these elements. Hence, addition of 50% new alloy to previously melted alloy is recommended for recasting noble metal–ceramic restorations.¹¹ Ucar et al⁶ concluded that “durability of metal ceramic restoration depends on sufficient metal ceramic bond strength.” The bond strength will be decreased with increase in number of recastings. He suggested not using previously casted alloys to avoid potential reduction of bond strength between metal and porcelain.

Jochen et al¹² reported that once cast alloys with the addition of <50% new alloys produced significantly lower metal–ceramic bond strength.

This study aimed to evaluate the effect of recasting surplus base metal alloy on the metal–ceramic bond strength.

MATERIALS AND METHODS

In this study, a nickel–chromium alloy (4 all, Ivoclar-Vivadent – 61.4% nickel, 25.7% chromium, 11% molybdenum, 1.5% silica, <1% aluminum, carbon, manganese) was used. A total of 60 test samples of alloy were divided into six groups (A0, A1, A2, A3, A4, and A5). The groups are presented in Table 1. IPS d.SIGN (Ivoclar-Vivadent) ceramic was used for application on metal samples.

Recast Alloy Preparation

Sprues and buttons were cut from the castings. Remnants of any investment material were removed by sandblasting with 50 μm Al_2O_3 . Then, sprues and buttons were cut into pieces and weighed to be mixed with new alloy in appropriate proportion.

Metal samples were prepared in accordance with International Organization for Standardization 9693:2000 specifications (25 mm \times 3 mm \times 0.5 mm). Wax patterns were prepared from casting wax sheets of 0.5 mm thickness with 25 mm length and 3 mm width. Sprues were

Table 1: Different groups in the study

Groups	Proportions of new and recast alloy by weight
A0	100% new alloy
A1	50% new alloy and 50% remnants from group A0
A2	50% new alloy and 50% remnants from group A1
A3	50% new alloy and 50% remnants from group A2
A4	50% new alloy and 50% remnants from group A3
A5	50% new alloy and 50% remnants from group A4

attached to wax strips, invested and casted following routine casting procedure. Castings were bench cooled to room temperature, divested, and sandblasted with 50 μm Al_2O_3 and steam cleaned to remove aluminum oxide particles and other contaminants. Thickness of each sample was measured using digital vernier calipers. Then, two layers of opaque porcelain were applied to a rectangular area of 8.0 mm \times 3.0 mm in the center of each sample with a thickness of 1.0 mm. Thickness of ceramic layer was determined by measuring the metal strip thickness before and after applying ceramic (Fig. 1).

Samples were subjected to three-point bending test using a universal testing machine to measure the flexural bond strength (Fig. 2). Each sample was placed on the testing apparatus where the distance between two supports was 20 mm. The ceramic surface was placed facing down and opposite to the applied load. The force was applied at a rate of 1.5 mm/minute and recorded up to failure. The failure load was recorded digitally using software provided by the manufacturer of the universal testing machine. The minimum load at which bond failure occurred was recorded in Newton and bond strength (Table 2) was calculated by the given formula:

$$\Sigma = 3PI/2bd^2$$

where Σ = bond strength (MPa), P = load (N), I = distance between the supports in mm, b = width of the sample in mm, d = thickness of the sample in mm.



Fig. 1: Test samples

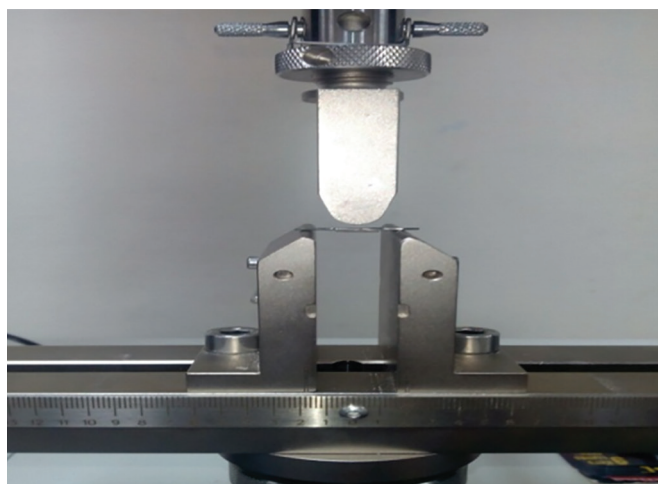


Fig. 2: Samples subjected to three-point bending test

RESULTS

The values were statistically analyzed using one-way analysis of variance (Table 2) and Tukey’s *post hoc* test (Table 3). The mean bond strength of group A0 was significantly higher than that of groups A1, A2, A3, A4, and

A5 respectively. Lowest mean bond strength was found for group A5.

DISCUSSION

This study was done to evaluate the metal–ceramic bond strength of ceramic with new and recast nickel–chromium alloy. The findings of this study showed that there was a significant reduction in bond strength with each recasting. Several studies in the literature evaluated the bond strength by adding new and recast alloy in various proportions of 25, 50, 75, and 100%. In this study, the first group was cast from 100% new alloy and served as control. The other groups were prepared with the addition of 50% new alloy each time to the remnants of the previous group. The mean bond strength of group A0 was significantly higher than that of groups A3, A4, and A5. The mean bond strength of group A1 was significantly higher than that of groups A4 and A5. The mean bond strength of group A2 was significantly higher than that of group A5. No statistically significant difference was found between groups A3, A4, and A5. The findings

Table 2: Comparison of bond strength between the study groups using analysis of variance (ANOVA)

Groups	n	Mean ± SD	Minimum	Maximum	Analysis of variance	
					F	p-value
A0	10	29.61 ± 2.37	26.84	34.18	10.10	<0.001*
A1	10	29.02 ± 1.19	26.82	30.56		
A2	10	28.33 ± 0.47	27.46	28.96		
A3	10	27.57 ± 0.33	26.98	27.92		
A4	10	27.11 ± 0.52	26.46	27.89		
A5	10	26.60 ± 0.49	25.98	27.64		

*p<0.05 statistically significant; p>0.05, nonsignificant; SD: Standard deviation

Table 3: Pair-wise comparison of bond strength between the study groups using Tukey *post hoc* test

(I) Groups	(J) Groups	Mean difference			95% CI	
		(I – J)	SE	p-value	Lower bound	Upper bound
A0	A1	0.59	0.51	0.86 (NS)	-0.93	2.11
	A2	1.28	0.51	0.15 (NS)	-0.24	2.79
	A3	2.03	0.51	0.003*	0.52	3.55
	A4	2.50	0.51	<0.001*	0.98	4.01
	A5	3.01	0.51	<0.001*	1.49	4.52
A1	A2	0.69	0.51	0.76 (NS)	-0.83	2.20
	A3	1.44	0.51	0.07 (NS)	-0.07	2.96
	A4	1.91	0.51	0.006*	0.39	3.42
	A5	2.42	0.51	<0.001*	0.90	3.93
A2	A3	0.76	0.51	0.68 (NS)	-0.76	2.27
	A4	1.22	0.51	0.18 (NS)	-0.30	2.74
	A5	1.73	0.51	0.02*	0.21	3.24
A3	A4	0.46	0.51	0.94 (NS)	-1.05	1.98
	A5	0.97	0.51	0.42 (NS)	-0.54	2.49
A4	A5	0.51	0.51	0.92 (NS)	-1.01	2.03

*p<0.05, statistically significant; p>0.05, NS; CI: Confidence interval; NS: Not significant; SE: Standard error

of the present study showed that there was a significant reduction in bond strength with each recasting. The findings were not new since it is reported in the literature that recasting of the same alloy multiple times may interfere with the compositional stability of the alloy.¹³⁻¹⁵ After multiple castings, a change in minor and trace elements (Al, Be, C, Si, Fe, and Sn) is expected.¹⁶⁻¹⁸ This results in decreased bond between the metal and ceramic since chemical bond is affected by these elements. Study by Tucillo et al¹⁹ investigated that due to multiple castings, bond strength will be reduced and this might be because of changes in thickness of the oxide layer formed on the metal surface. The effect of various percentages of reused silver-palladium alloy on the bond strength of porcelain was studied by Hong et al,²⁰ and they found that 50% new alloy should be added to each casting. Ucar et al⁶ studied the metal-ceramic bond strength of Ni-Cr alloy and documented a value of 39.8 MPa for castings containing 100% new alloy and for castings containing 100% recycled alloy; the value was 24.4 MPa. Rasmussen and Doukoudakis²¹ evaluated the effect of recasting gold alloy on the metal-ceramic bond and reported that there was no adverse effect when 75% recast metal was used. Another study investigated that metal-ceramic bond strength will be influenced by the properties of oxide layer on metal surfaces, which is better with high noble and noble alloys than with predominantly base metal alloys.¹¹

Papazoglou and Brantley¹⁸ compared high Pd alloys after recasting three times by evaluating porcelain adherence and bond failure force and found no correlation between porcelain adherence and bond failure force. Liu et al²² reported that after three castings all three noble alloys showed satisfactory bonding compatibility with porcelain. Kul et al²³ reported that noble alloys can be reused because there is no problem with porcelain. However, the same cannot be said for base metals, because after the second and third casting, the bonding compatibility with porcelain was not satisfactory. Borom and Pask²⁴ noted the importance of adherence of oxides on the formation of a strong bond between metal and porcelain.

The bond strength values obtained in this study were consistent with those of previous studies.^{25,26}

CONCLUSION

Considering the decreased cost of base metal alloys when compared with high noble and noble alloys, the addition of previously cast alloy is not crucial and should be avoided.

Further studies are required to investigate the depth of the oxide layer into the casting and its effect on bond strength.

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