

Effect of Recasting on Physical Properties of Base Metal Alloys: An *In Vitro* Study

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INTRODUCTION

The procedure of casting of a dental alloy involves the conversion of a wax pattern of a restoration into a replicate. It is used in restorations such as onlays, inlays, crowns, bridges, and removable partial dentures. More or less all casting procedures are prepared by usage of alteration of lost-wax technique of casting process.^[1,2] Cast gold alloy is regarded as an ideal restorative material as it has advantages such as resistant to tarnish and corrosion, hardness, percentage elongation, castability, burnishability, and capacity to take high polish. Whereas, its extremely discernible color and high cost are its disadvantages.^[1-3]

Recently, the usage of gold alloys is limited or eliminated due to its high cost. Base metal alloys satisfy properties

of gold alloys with further advantages of reduced specific gravity and less cost. Hence, cobalt–chromium (Co–Cr) and nickel–Cr (Ni–Cr) alloys are enormously well liked in restorative dentistry procedures.^[4,5]

Composition of noble gold alloys allows it to be recasted over and over again without any loss of their required properties. However, recasting of base metal alloys has not been suggested owing to the paucity of research, with manufacturers instructing their single usage only.^[5-7]

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ABSTRACT

Aims and Objectives: This study aims to establish the outcome of recasting on tensile strength, modulus of elasticity, and hardness of Nickel–chromium alloys.

Materials and Methods: Fifty wax patterns were fabricated, using the lost wax technique, the measurements of which were standardized. They were categorized into five groups of ten each. Group I included samples casted with new alloy alone. Group II samples consisted of 75% new alloy and 25% once casted alloy. Group III was casted with 50% of each. Group IV with 25% new metal and 75% previous alloy and samples of Group V samples were casted with once casted alloy alone. Modulus of elasticity and tensile strength were measured by universal testing machine, whereas hardness using microhardness tester. The values were statistically analysed. IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. IBM Corp, Armonk, NY, USA. for Windows software was used for analysis.

Results: We found a slight variation in mean tensile strength and modulus of elasticity, which was statistically insignificant variation among the groups. However, there was a significant difference in mean hardness between Groups III, IV, and V.

Conclusion: It is prudent to use pure alloy alone for casting. However, in view of environment and economical factors, addition of <50% reused alloy to pure alloy is satisfactory clinically.

KEYWORDS: *Hardness, lost-wax technique, microhardness tester, modulus of elasticity, tensile strength, universal testing machine*

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Metal wastes from laboratories are treated as health-care waste. They carry high potential for infection and injury. Hence, recycling or recasting alloys is an advantage, cost-wise and also environmentally.^[8,9]

We carried our study to gauge the characteristics of hardness, modulus of elasticity, and tensile strength of new alloy, and the same properties on different percentage permutations of new and once casted alloys.

MATERIALS AND METHODS

An *in vitro* study was carried on fifty specimens made from combining pure and once casted Ni–Cr alloy in different proportions, after obtaining institutional ethical committee clearance (number IEC/15/2016/MBDC). Sample size was determined from similar studies using the formula: $n = [(z\alpha + z\beta) \sigma d]^2$ Sample size of 50 was obtained with a confidence interval of 95% and power of 95% for the study. They were examined for hardness, tensile strength, and modulus of elasticity using microhardness tester [Figures 1 and 2] and universal

testing machine (Instron 3365, U.K with 5 KN load cell and a rate of 5 mm/min) [Figures 3 and 4], respectively.

FABRICATION OF WAX PATTERN OF THE TENSILE BAR

A tensile bar was made in wax with a diameter of 2.4 mm and a gauge length of 15.4 mm, same as Moffa *et al.*^[10] With a digital calliper patterns were standardized and were grouped into intogroups, each group of 10 samples were prepared the following manner.

- Group I: To be cast using new alloy alone
- Group II: To be cast using 75% new alloy and 25% once casted alloy
- Group III: To be cast using 50% of both
- Group IV: To be cast using 25% new alloy and 75% once casted alloy
- Group V: To be cast using once casted alloy alone.

SPRUE FORMING OF THE WAX PATTERN

A preformed sprue wax wire (Renfert-Germany) of 3 mm diameter and 5 mm length was used for sprue



Figure 1: Microhardness tester



Figure 2: Specimen in microhardness tester



Figure 3: Instron Universal Testing Machine

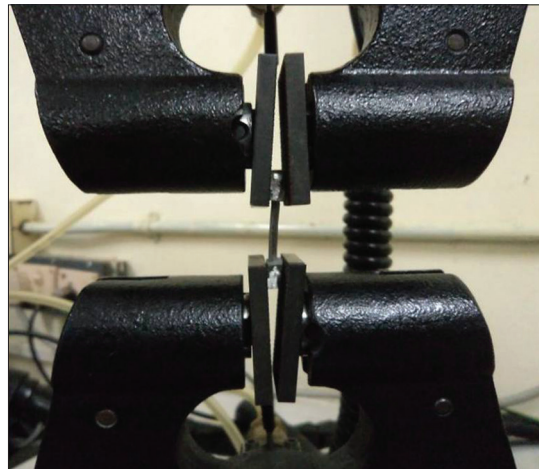


Figure 4: Tensile bar loaded in Instron Universal Testing Machine

forming. The patterns highest point was placed about 6 mm below the casting ring open end, so as to permit escape of gases throughout burnout stage and avert investment fracture owing to molten metal impact all through the casting process [Figure 5].

INVESTING OF WAX PATTERN

Ringless technique was used for investing wax pattern. Investment of wax patterns was carried with carbon-free, phosphate-bonded investment material, Bellavest SH (Bego, Germany), immediately, based on the manufacturer's instructions. The material was mixed in a vacuum mixer (Renfert, Germany) for a time period of 90 s. A fine hair brush was used to paint the wax patterns with mixed investment. Then, casting rings were filled under mechanical vibration with investment material and allowed to bench set for 1 h.

BURNOUT OF WAX PATTERNS

Specimens were kept in a burnout furnace (Sirodental, Italy) and the temperature of the furnace was gradually increased from room temperature to 5700°C with a holding time of 20 min and from 5700°C to 9800°C with a holding time of 20 min.

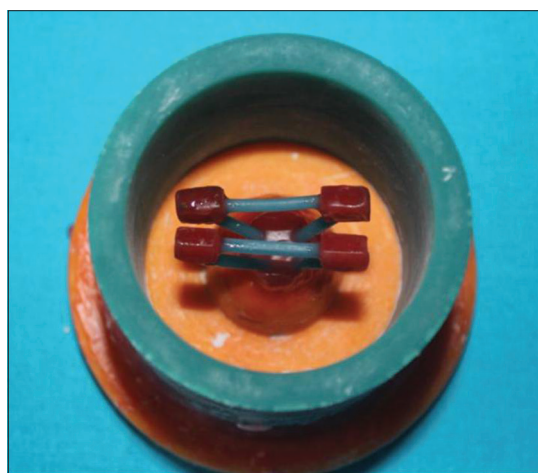


Figure 5: Sprued wax pattern

CASTING

Casting was accomplished in an induction centrifugal casting machine (Fornax-T-Bego, Germany) with a base metal alloy (Girobond) with a composition of Ni 63.5%, Cr 24%, and Molybdenum 10%.

DIVESTING, FINISHING, AND POLISHING OF METAL COPINGS

Castings were divested, cleaned, and air abraded by sandblasting with 250 μ aluminum oxide powder at 0.6 MPa, (Cobra-Renfert) followed by steam cleaning using steam cleaner (Triton, Bego, Germany). Sprues were removed with carbide disks. The castings were observed under magnification and good illumination.

MEASUREMENT OF MICROHARDNESS

One end of the fractured bar was prepared for microhardness evaluation. Each specimen was embedded in acrylic resin. After polishing, Vickers hardness testing was accomplished using a 136° diamond in a microhardness tester (HMV-2 Microhardness tester, Shimadzu, Japan).

STATISTICAL ANALYSIS

Results were plotted with a mean and standard deviation. The variance was analyzed using ANOVA. The difference between groups was detected by *post hoc* Tukey's test.

RESULTS

Comparison of tensile strength of five groups (ANOVA) demonstrated statistically insignificant difference between the Groups I, II, III, IV, and V [$P = 0.081$, i.e. $P > 0.05$, Table 1]. For pairwise comparison of all groups, a *post hoc* Tukey test was done. There was insignificant variation among the groups [$P > 0.05$, Table 2].

Comparison of modulus of elasticity of five groups (ANOVA) revealed statistically insignificant difference between the groups [$P = 0.9789$, i.e. $P > 0.05$, Table 3]. *Post hoc* Tukey test showed insignificant difference between the groups [$P > 0.05$, Table 4].

HARDNESS

ANOVA showed a statistically significant variation between all the groups [$P < 0.001$, Table 5]. *Post hoc* Tukey test revealed insignificant variation among Groups I and II. However, when Group I was compared

Table 1: One-way ANOVA: Comparison of the five groups - tensile strength in MPa

Dependent variable	Group	n	Mean	SD	Statistic	df1	df2	Significance
Tensile strength	Group 1	10	1059.2	72.217	2.415	4	2.223	0.081
	Group 2	10	1059.2	65.337				
	Group 3	10	1040.7	69.191				
	Group 4	10	1020.2	61.763				
	Group 5	10	1001.9	27.723				
	Total	50	1034.98	62.634				

$P > 0.05$, not significant. SD=Standard deviation

Table 2: Post hoc Tukey test - tensile strength in MPa

Dependent variable	Group (I)	Group (J)	Mean difference	SE	P
Tensile strength	Group 1	Group 2	6.3	27.463	0.999
		Group 3	18.5	27.463	0.961
		Group 4	39	27.463	0.618
		Group 5	57.3	27.463	0.244
	Group 2	Group 3	12.2	27.463	0.992
		Group 4	32.7	27.463	0.757
		Group 5	51	27.463	0.355
	Group 3	Group 4	20.5	27.463	0.944
		Group 5	38.8	27.463	0.623
	Group 4	Group 5	18.3	27.463	0.963

$P > 0.05$, not significant. SE=Standard error

Table 3: One-way ANOVA: Comparison of the five groups - modulus of elasticity in MPa

Group	Mean	SD	df	MS	F	P
Group 1	223.6	8.289	4	2.83	0.1087	0.9789
Group 2	223.1	4.332				
Group 3	222.8	3.882				
Group 4	222.4	4.115				
Group 5	222.3	3.268				

$P > 0.05$, not significant. SD=Standard deviation, MS=Mean of square

Table 4: Post hoc Tukey's test - modulus of elasticity in MPa

Tukey's multiple comparison test	Mean difference	q	P
Group 1 versus Group 2	0.5	0.3099	>0.05
Group 1 versus Group 3	0.8	0.4958	>0.05
Group 1 versus Group 4	1.2	0.7438	>0.05
Group 1 versus Group 5	1.3	0.8057	>0.05
Group 2 versus Group 3	0.3	0.1859	>0.05
Group 2 versus Group 4	0.7	0.4339	>0.05
Group 2 versus Group 5	0.8	0.4958	>0.05
Group 3 versus Group 4	0.4	0.2479	>0.05
Group 3 versus Group 5	0.5	0.3099	>0.05
Group 4 versus Group 5	0.09999	0.06197	>0.05

$P > 0.05$, not significant

Table 5: One-way ANOVA: Comparison of the five groups - hardness in MPa

Group	n	Mean	SD	Statistic	df1	df2	Significance
Group 1	10	505.3	12.037	619.32	4	19.9	<0.001
Group 2	10	499.7	4.029				
Group 3	10	486.2	1.687				
Group 4	10	461.8	9.624				
Group 5	10	383.2	6.391				
Total	50	467.24	45.673				

$P < 0.05$, highly significant. SD=Standard deviation

with Groups III, IV, and V, a significant difference was found [Table 6].

DISCUSSION

Casting is a complex procedure, with many stages, each affecting the dimensions and hence the accurateness of the final casting, which has to endure the rigors of the oral environment. The dimensional accuracy of the casting depends on the method employed and also on the various materials involved in its fabrication. Introduction of new materials and techniques so as to enhance the quality of these restorations warrants necessitating a constant monitoring of the entire process to ensure success.

The dental gold alloys contain all noble metals (except copper). Hence, sprues and buttons remaining after casting were used again for casting with addition of copper lost during the casting process. Presswood^[11] reported a 0.01%–0.1% loss of component metals with each generation of the recast. According to him, recasting will not bring out any difference in alloy properties including hardness. He suggested that recasted alloy can be used at least once again.

According to Harcourt and Cotterill,^[12] recasting may be carried out up to 13th generation without any loss of any physical properties of the alloy. He also suggested that entirely cleaned and deoxidized cast alloy need not be added with new alloy in any quantity. They evaluated the outcome of remelting of Co–Cr on their physical and chemical properties and found that remelting causes changes in the chemical composition of alloy that further results in reduction of fluidity and easiness of melting.

Nelson *et al.*^[13] showed no notable degenerative changes in Ni–Cr alloy after recasting for ten generations. They also observed that combining used alloy with new alloy and recasting for 100 times revealed no significant changes in properties, microstructure, or clinical characteristics.

Hong *et al.*^[14] confirmed that the repeated remelting of four generations of palladium-silver alloys introduced an alteration of the chemical composition and/or microstructure of the alloys. Sheffick^[15] concluded that Co–Cr and Ni–Cr behaved inferiorly than the gold Type III alloys with inconsistent behavior in the compositions with remelting procedures. They stated that the first remelting of these alloys must be done by adding 50% by weight of new alloy, to enhance the castability and the percentage of constituents of these alloys.

Khamis and Seddik^[16] observed Ni–Cr and Co–Cr commercial dental alloys on their corrosion behavior and

Table 6: Post hoc Tukey test - hardness in MPa

Dependent variable	Group (I)	Group (J)	Mean difference	SE	P
Hardness	Group 1	Group 2	5.6	3.449	0.491
		Group 3	19.1	3.449	<0.001
		Group 4	43.5	3.449	<0.001
		Group 5	122.1	3.449	<0.001
	Group 2	Group 3	13.5	3.449	0.003
		Group 4	37.9	3.449	<0.001
		Group 5	116.5	3.449	<0.001
	Group 3	Group 4	24.4	3.449	<0.001
		Group 5	103	3.449	<0.001
	Group 4	Group 5	78.6	3.449	<0.001

$P < 0.05$, highly significant. SE=Standard error

stated that the corrosion resistance of alloy containing Co and molybdenum was not influenced by consecutive melting and recasting.

Mosleh *et al.*^[17] revealed that the castability values for Ni–Cr alloy were insignificantly affected. Al-Hiyasat and Darmani^[18] stated that reuse of base metal alloys at 50% and 100% significantly increased the cytotoxicity of the alloys studied (2 Ni–Cr, a Ni–Cr with Copper, a Copper–Cr, and a Copper–base). Furthermore, the amount of element released was seen to increase in ratio with the percentage of the recast alloys used.

TENSILE STRENGTH

Hesby *et al.* demonstrated no major variations among the four generations of castings regarding hardness and tensile strength. Although tensile strength was affected insignificantly, it was found to be lesser than the minimum American with Disabilities Act (ADA) specification. They explained that the decreased tensile strength values are attributed to the difference in the sprue size and tensile bar which caused the bar to become prestressed during cooling.^[19]

In this study, physical specifications for individual tensile strength were standardized, the dimensions of which were comparable to those suggested by Moffa *et al.*^[10] The tensile strength values were greater than the calculated minimum specification for Ni–Cr alloys.

MODULUS OF ELASTICITY

Nelson *et al.*^[13] after recasting Ni–Cr alloy for ten generations found the mean modulus of elasticity values to be greater than the minimum ADA specification of 1.54 MPa × 106 MPa. In our study, the values of modulus of elasticity were 212–235 MPa.

HARDNESS

Hesby *et al.*^[19] and Nelson *et al.*^[13] did not find any significant difference in hardness values on recasting. Presswood^[11] indicated that in each generation of

recast, 0.01%–0.1% loss of components will be present. However, it does not contribute to any change in hardness. In our study, the values of hardness were greater than minimum specification for Ni–Cr alloys.

We suggest that it is prudent to use new alloy alone for casting. But considering economic and environmental factors, adding <50% reused alloy to new alloy is clinically acceptable.

LIMITATIONS

1. Exclusion of recasting effect on biocompatibility of Ni–Cr alloy
2. Even though airborne contamination was minimized throughout the investigation by cautious concentration on detail in all phases of the technique, it might also have a say in difference observed between and within the groups
3. Lack of application to *in vivo* conditions.

Future studies with a larger sample and more parameters might confirm the fact that adding of <50% reused alloy to pure alloy is satisfactory clinically, other benefits being cost effectiveness and environment-friendly.

CONCLUSION

There was an insignificant difference in modulus of elasticity and tensile strength, and a significant variation in the hardness among the groups casted using various percentage combinations of Ni–Cr alloys.

Addition of reused alloy up to 50% was seen as clinically acceptable due to insignificant statistical variation among Groups I and II. However, significant statistical variation was noticed between Group III, IV, and V, indicating deterioration of properties when the content of reused alloy is 50% or more.

FINANCIAL SUPPORT AND SPONSORSHIP

Nil.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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