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Effect of Different Casting Techniques on the Castability of Nickel-Chromium Alloy

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Authors' contributions

This work was carried out in collaboration between all authors. Authors VKM and RPN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author RP managed the analyses and literature searches of the study. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Statement of Problem: Castability plays an important role in success and failure in the field of restorative and prosthetic dentistry. Recasting of base metal alloys can alter its castability value and some of its physical properties.
Aim: To evaluate the castability of new and recasted Ni-Cr alloy using conventional ring and ringless casting system and compare the results.
Place and Duration of Study: Department of Prosthodontics and crown and bridge, KLE V.K. Institute of Dental Sciences, Belagavi, KLE University, between August 2016 and February 2017.
Materials and Methods: Thirty identical mesh - runner bar - sprue patterns were prepared and divided into 2 different groups of 15 each, namely; Group 1 – Metal ring casting system and Group 2 – Ringless casting system. Each group was further divided into 3 sub-groups based on weight percentage of new-recasted Ni-Cr alloy; Group 1A and 2A – 100% new Ni-Cr alloy, Group 1B and 2B – 50% new and 50% recasted Ni-Cr alloy, and Group 1C and 2C – 100% recasted Ni-Cr alloy. Castability of the alloy was tested using modified Whitlock's method.
Results: The results of this study revealed that the mean castability values ranged from 99.64% –

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99.86%, and there is no significant difference ($p > 0.05$) between the castability of new alloy and recasted alloy using ring and ringless casting techniques.
Conclusions: Ring and ringless casting techniques have comparable accuracy and can produce clinically acceptable castings.

Keywords: Base metal alloys; nickel-chromium alloy; recasting; whitlock's castability test; RINGLESS casting system.

1. INTRODUCTION

Casting is commonly used procedure in the field of restorative and prosthetic dentistry. Application of casting procedure in dentistry has changed the scope of prosthetic rehabilitation. High cost of gold has not only led to its elimination but also resulted in introduction and widespread use of base metal alloys in dentistry. In 1930s, base metal alloys were introduced to dentistry by Eardle and Prange.

Compared to noble metal alloys, base metal alloys feature lower cost, lower density, greater stiffness, higher hardness, rigidity even in small thickness, and comparable clinical resistance to tarnish and corrosion. But, at the same time, they are difficult to cast and solder [1]. High nobility makes gold alloys available for recasting without losing any of its desired properties [2]. However, the same cannot be justified for the base metal alloys, as the literatures have suggested the deterioration of their constituents due to recasting. Dental alloy manufacturers have advised against the reuse of previously casted alloy [2]. However, dental laboratories often reuse these castings in the form of sprue and the casted metal remaining in the crucible former. Various studies have reported the effects of recasting noble and predominantly base alloys on properties such as corrosion, cytotoxicity resistance, and the elements released. The impurities from previously casted buttons and sprues may result in changes in the properties of dental alloy castings [2,3,4,5]. It will be of great advantage, both economically and environmentally, to recycle or to recast the alloy again and again with or without adding new alloy [5]. There is limited information available regarding castability of Ni-Cr alloy using varying alloy proportion and using different casting techniques. This will be of a definite scientific advantage if the properties of the recast alloys are studied in detail, which will help to formulate suitable recommendations to prosthodontist and laboratory technicians regarding the casting technology.

2. MATERIALS AND METHODS

The different armamentariums used in the study were shown in (Fig. 1). The acrylic-wax mesh (Polywax) of 28 mm x 28 mm containing 100 square-shaped spaces, each of 1.5 mm x 1.5 mm and filament size of 1 mm, were used. A runner bar of 2 mm in diameter and 28 mm in length was attached to one half of the mesh. A sprue of 4 mm in diameter and 5 mm in length was attached to this runner bar (Fig. 2). Thirty identical mesh - runner bar - sprue patterns were prepared and divided into 2 different groups of 15 each, namely; Group 1 – metal ring casting system and Group 2 – ringless casting system. These groups were further divided into 3 sub-groups based on weight percentage of new-recasted alloy used; Group 1A and 2A – 100% new Ni-Cr alloy, Group 1B and 2B – 50% new and 50% recasted Ni-Cr alloy (by wt %), and Group 1C and 2C – 100% recasted Ni-Cr alloy (Fig. 3).

Fig. 1. Armamentarium used in the study

2.1 Investing Burnout and Casting

These wax mesh pattern were attached to crucible former (Fig. 4) and coated with surface tension reducing agent (Waxit, Degudent). Asbestos-lined casting ring of 50 mm diameter was placed over this crucible former for the specimens in Group 1 and the ringless casting system was used for specimens in Group 2 (Fig. 5). The Phosphate-bonded investment

material (Bellasun, BEGO) was manipulated according to manufacturer's instructions and patterns were invested. After initial setting, the molds for the ringless group were removed from the plastic rings. Following 1 hour of air drying, both the molds were subjected to wax elimination procedure. For burnout procedure, the temperature of the wax elimination furnace was raised to 250℃ and maintained for 1 hr and then was raised to 950℃ and maintained for 1 hr for complete elimination of wax. These molds were then immediately transferred to induction casting machine (BEGO), followed by casting using Ni-Cr alloy (Girobond CBS). After casting, ring was allowed to cool at room temperature. Specimens were retrieved and sandblasted with 50-μm alumina particles (Fig. 6). The buttons of the castings from Group 1 were separated from its sprue and cut into different portions so as to mix it with new alloy by weight in proper proportions. The investing, wax elimination, and casting procedures were done for the specimens in Group1, Group 2 and all sub-groups using ring and ringless casting techniques (Figs. 7 and 8).

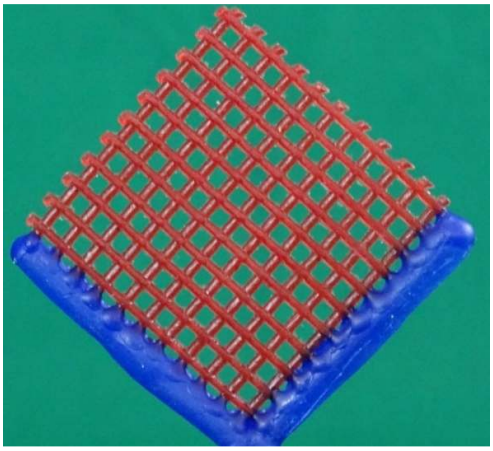

Fig. 2. Acrylic-wax mesh

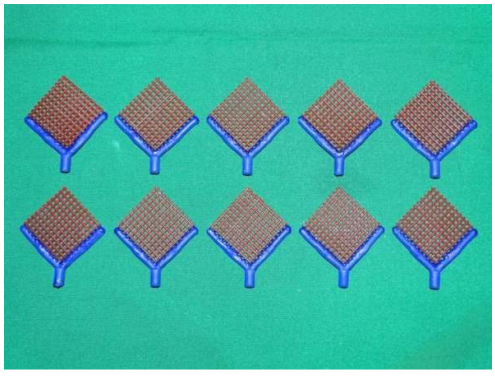

Fig. 3. Identical mesh - runner bar - sprue patterns

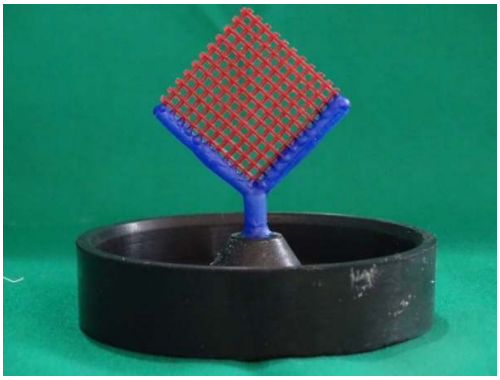

Fig. 4. Wax mesh pattern attached to crucible former

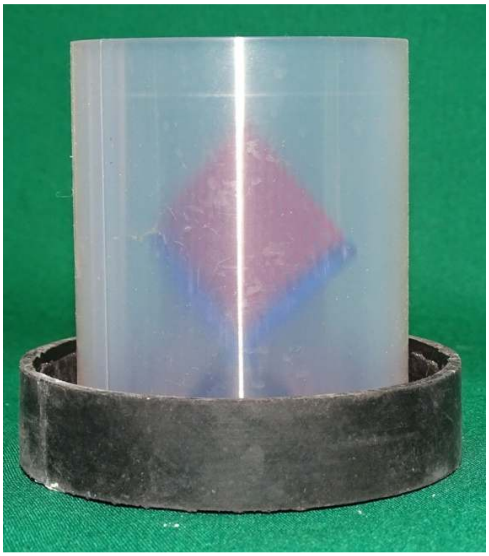

Fig. 5. Ringless casting technique

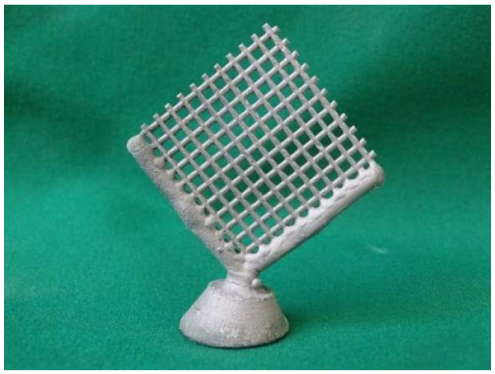

Fig. 6. Casted specimens retrieved and sandblasted

In this study, castability of the alloy was tested using modified Whitlock's method [3-6].

Castability value was calculated for all the specimens from both the groups. A grid with 100 square spaces will provide 220 segments. The numbers of completely cast segments were counted. Percentage castability value (C_v) was calculated using a formula:

Cv = No. of completely cast segments / 220 x 100

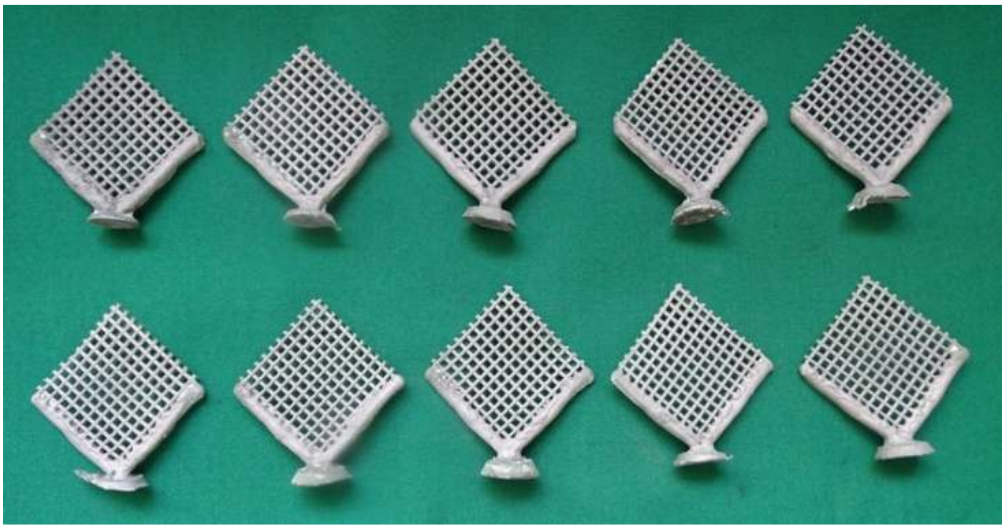

Fig. 7. Casted specimens of group 1A and 2A

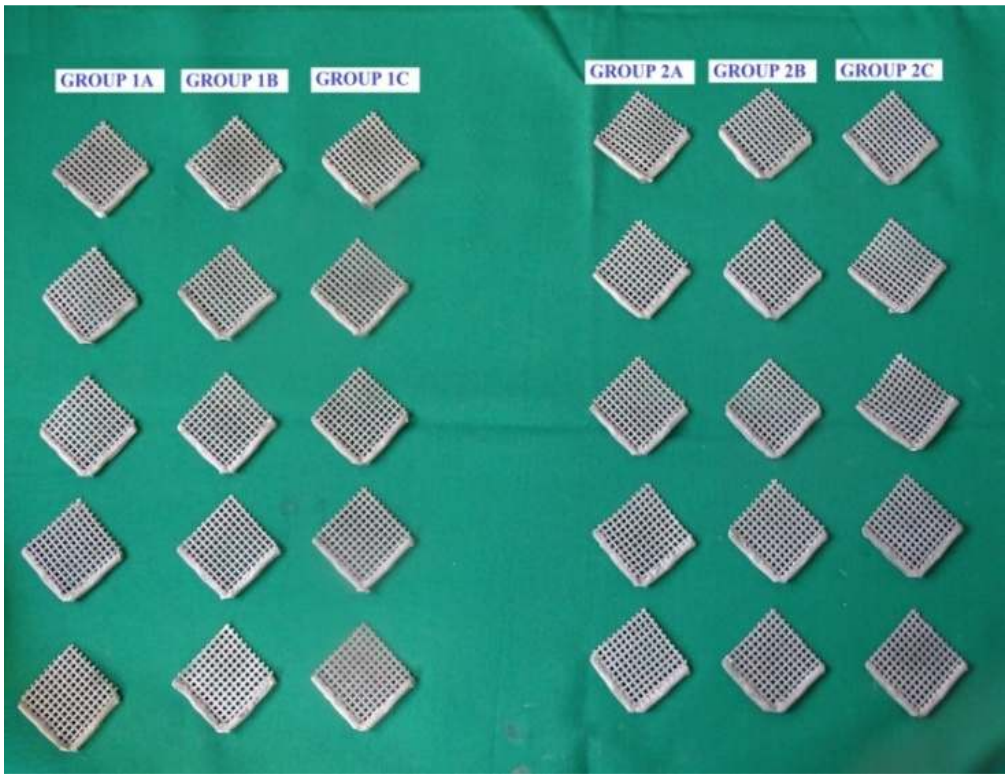

Fig. 8. Casted specimens of groups (1 and 2) and sub-groups (A, B, and C)

3. RESULTS

The resultant values of modified Whitlock's method to assess the castability of Ni- Cr alloy by varying the alloy ratio using ring and ringless casting techniques in specimens group 1 and group 2, were subjected to statistical comparison to draw the conclusions. Descriptive statistical measures such as mean and standard deviation values were computed for all the study groups. In order to collectively compare the means of the study groups, two-way ANOVA test was used ($p<0.05$), pair-wise comparison of the test group were done using Tukey's multiple post hoc procedures ($p<0.05$).

The mean number of completely casted segments, castability values, and standard deviation were calculated for Group 1 (number of specimens (n) =15) and 2 (number of specimens (n) =15) specimens and each of the three sub-groups (Table 1). The mean C_v value (in %) for Group 1A was 99.86 (± 0.22), which was slightly higher than for Group 1B – 99.82 (± 0.24) and Group 2C – 99.64 (± 0.36), within Group 1 and the mean C_v value (in %) for Group 2A and 2B was 99.82 (± 0.32), which were slightly higher than for Group 2C – 99.55 (± 0.37), within Group 2.

Two-way Analysis of Variance (ANOVA) for significance ($p<0.05$) of two groups indicated that there were no significant difference in C_v values (in %) between the group 1 and 2 ($p<0.05$). (Table 2).

Table 1. Mean percentage castability values of two main groups (1 and 2) and three sub-groups (A, B, C)

Groups with sub groups	No. of completely casted segments (mean)	C_v (in %)	SD
Group 1A	219.70	99.86	0.22
Group 1B	219.60	99.82	0.24
Group 1C	219.20	99.64	0.36
Group 2A	219.60	99.82	0.24
Group 2B	219.60	99.82	0.24
Group 2C	219.00	99.55	0.37

SD: Standard deviation

Table 2. Comparison between two main groups (1 and 2) and three sub-groups (A, B, C) with mean scores by two-way ANOVA

Sources of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	p-value
Main effects					
Main groups	1	0.15	0.15	0.3537	0.5545
Sub-groups	2	3.70	1.85	4.3624	0.0175*
2-way interactions					
Main groups x Sub-groups	2	0.10	0.05	0.1179	0.8890
Error	54	22.90	0.42		
Total	59	26.85			

p<0.05: suggest the level of significance, F value: suggest the mean variations between or within the samples.
**0.0175: Indicates that there is a statistical significance within the compared sub-groups*

Table 3. Pair-wise comparisons between two main groups (1 and 2) and three sub-groups (A, B, C) with mean scores by Tukey's multiple posthoc procedures

Main groups with sub groups	Group 1A	Group 1B	Group 1C	Group 2A	Group 2B	Group 2C
Mean	99.86	99.82	99.64	99.82	99.82	99.55
SD	0.22	0.24	0.36	0.32	0.24	0.37
Group 1A	-					
Group 1B	p=0.9860	-				
Group 1C	p=0.4326	p=0.1754	-			
Group 2A	p=0.9372	p=0.9999	p=0.3619	-		
Group 2B	p=0.7328	p=0.9999	p=0.5213	p=0.9999	-	
Group 2C	p=0.1734	p=0.1080	p=0.4953	p=0.1794	p=0.2524	-

On pair-wise comparison of two Groups (1 and 2) by Tukey's multiple post hoc procedures, no statistically significant differences were found in C_v values amongst both the groups and within the sub-groups (A, B, and C) ($p<0.05$) (Table 3).

The results of this study revealed that the mean castability values ranged from 99.64% – 99.86%, and there is no significant difference ($p > 0.05$) between the castability of new alloy and recasted alloy using ring and ringless casting techniques.

4. DISCUSSION

Although the ringless casting technique is in use in fixed prosthodontics, the information related to the same is at sparse. The metal ring casting technique is clinically acceptable and allows for the fabrication of accurate castings, but the metal ring restricts the setting and thermal expansion of the investment, which is necessary to compensate for the shrinkage of the metal on solidification. With the use of a ringless casting technique, the restriction of thermal expansion that is associated with the presence of the metal ring is avoided [7].

In this study, effects of recasting Ni-Cr alloy was tested using metal ring and ringless casting techniques and the results were compared. It was found that there is no statistically significant difference in castability of Ni-Cr alloy between ring and ringless casting system.

Some of the problems associated with recasting includes decrease in the fluidity of the alloy, contamination of the surface of alloy, increased grain dimensions, impurities, elemental release causing cytotoxicity of adjacent cells and tissues, affect ceramo-metal bonding and microporosities [1,2]. According to Bessing [8] and Johnson and Winstanley [9], the castability of an alloy may be affected by several factors, including composition, density, surface tension, type of investment, cast temperature, casting machine, positioning of the wax pattern and vent sprue shape [1].

Apart from the cost, every material should be recycled as far as possible to conserve resources and protect the environment [4]. The practicality of recasting base metal alloys as an economic measure comes under close scrutiny because the remelting of base metal alloys introduces the opportunity to alter chemical composition and physical properties thereby altering the biocompatibility and cytotoxic properties of the alloy. Nevertheless, it is very clear that recasting should not be done at the expense of the properties of the alloy, and its biocompatibility should be evaluated [4,5,10].

Published reports on the recasting of dental alloys vary widely, with opinions ranging from the complete avoidance of recasting and recasting up to 10 times without any changes in the alloy's quality [2]. Few studies have suggested that base metals alloys should not be recasted [11,12]. Hesby et al. studied the effect of recasting a nickel-chromium alloy routinely used for fixed partial denture castings through four generations. They found no significant alteration in the physical properties of the alloy after multiple recasting [10].

There are some guidelines that have been proposed on the feasibility of recasting dental alloys. The first is that no new metal should be added at successive recastings of predominantly base alloys, and the second is that 50% new metal can be added to previously melted alloys [2].

The present study showed no statistically significant differences in mean C_v values between 100% fresh alloy, 50% fresh and 50% once casted alloy and 100% once casted alloy. The results of this study are in agreement with the studies done by Palaskar et al. [5] Nakhaei et al. [13] and Mosleh et al. [14] who suggest that recasting will not affect the castability of Nickel‑Chromium alloy.

In this study, modified Whitlock's method was used. The filaments of wax mesh were very fine and the size were comparable to that of sieve cloth used by Whitlock. The percentage castability value were attributed to the specimens by counting the number of complete segments of the cast grid, which indicated the accuracy of the alloys to reproduce details. Advantages of this method are the ease of preparation of the casting pattern; the pattern can be burned out in an oven using the usual procedure for wax elimination; size and shape of specimens can be standardized; the casting pattern can be adjusted accordingly to evaluate specific characteristics, depending on the purpose of each study; and castability is evaluated by simply counting the number of completely formed cast segments [6].

Based on the findings of this study, it can be advocated that recasted alloy can be used atleast once provided they are sandblasted and

cleaned properly after casting. Also, there is no difference in the castability of Ni-Cr alloy using metal ring and ringless casting system.

5. CONCLUSIONS

Within limitations of the study, it was concluded that:

1. Both, ring and ringless casting techniques have comparable accuracy and can produce clinically acceptable castings.
2. There is no significant difference in the castability among the three sub-groups with different percentage of new and recasted Ni-Cr alloy upto 2nd generations of the recasted alloy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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