Evaluation of Surface Roughness and Tensile Strength of Ni-Cr Alloys Used for Fixed Partial Prosthesis on Recasting (Recycling)- An in-Vitro Study

Original Research Article

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ABSTRACT

Casting is one of the primary techniques for producing shaped metals and alloys. Investigators had been making effort to recast the alloy up to many generations. The aim of present study was evaluation of surface roughness and tensile strength of Ni-Cr alloys used for Fixed Partial Denture on recasting. The alloys are divided into four groups: Group A- Pure Alloys100%, Group B-75% New + 25% Once recast alloy, Group C-50% New +50% Once recast alloy and Group D-100% Once Recast alloy. Identical test specimens were prepared with the use of metal mold. The entire specimens were tested first for the surface roughness test by surface roughness tester and later for tensile strength test by UTM machine. ANOVA test (Analysis of Variance) was used for analyzing the result. Tensile strength of new alloy showed no statistically significant difference (p-value>0.05) from recast alloy whereas new alloy had statistically significant surface roughness (Maximum and Average surface roughness) difference (p-value<0.01) as compared to recast alloy. It is concluded that the tensile strength will not be affected by recasting of nickel-chromium alloy whereas surface roughness increases markedly.

KEY WORDS: tensil strength, recasting, surface roughness

INTRODUCTION:

Dental casting alloys play a prominent role in treatment of the dental diseases. This role has changed significantly in recent years with the improvement of all-ceramic restorations and the development of more durable resin-based composites. Though, alloys keep on being utilized as the primary material for fixed restorations and will probably be the main material for a considerable length of time to come. No other material has the combination of strength, modulus, wear resistance, and biologic compatibility that a material must have to survive long term in the mouth as a fixed prosthesis. Casting alloys have to survive long term in the mouth and also have the combination of structure, molecules, wear, resistance and biologic compatibility[1].

The escalating cost of gold has contributed to the widespread use of base metal alloys for fabrication of removable partial demure frameworks. In 1930's base metal alloys were introduced to dentistry by R. W. Eardle and C. H. Prange. The popularity of base metal alloys in comparison to other alloys is further enhanced by their resistance to corrosion, reduced weight, less cost and generally more favorable physical properties than those of gold[2].

The structures and kinds of casting alloys available to the dental practitioner have changed enormously during the previous five decades. Casting alloys are categorized by several methods. According to ADA system, casting alloys are divided into three groups on the basis of wt% composition[3].

High-noble alloys:

High-noble dental casting alloys can be divided arbitrarily into those based on gold-platinum (Au-Pt), gold-palladium (Au-Pd), or gold copper-silver (Au-Cu-Ag).

Noble alloys:

Noble alloys are much more compositionally diverse than high-noble alloys because they include gold-based alloys and other elements such as palladium or silver. These alloys have decreased gold

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content and compensate for the reduced gold by increasing copper, silver or palladium.

Predominantly base-metal alloys:

The base-metal alloys can be arbitrarily includes Ni-Cr-Be, Ni-Cr, Ni-high-Cr, and Co-Cr.

However, today's practitioner may select from alloys based on palladium, silver, nickel, cobalt, and titanium, among others[4]. Although uses for pure metals such as gold foil and platinum foil exist in dentistry, the main role for metals in dentistry has been in alloys. Alloys are used for fixed prostheses rather than pure metals because pure metals do not have the appropriate physical properties to function in these types of restorations[5].

In our current economy it is obligatory that dentists and technicians be cost conscious about the materials they use for fixed prosthesis. Therefore, 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[6].

As casting procedures require more metal to be fused than is needed to fill the mold. The surplus, known as a button, is separated from the casting. The button consists of the excess molten metal which is needed to compensate casting shrinkage. The button may be reused to produce an acceptable casting and is a matter of economical consideration[7].

As an economy measure, excess gold (buttons and sprues) has routinely been recast in combination with new metal to produce clinically acceptable castings. Gold alloys may be successfully recycled; whereas limited information is available regarding recasting of base metal alloys. Repeated casting show more stability in noble and nickel-based alloys in comparison with high noble alloys and titanium[8]. Earlier recasting of base metal alloys was not common. Since 1980's studies have reported reuse of cobalt-chromium alloy in the recasting procedure[9].

Due to nobility of the gold alloys, it is possible to recast the materials again and again without losing its required properties, but it's not the same for base metal alloys. There is limited information available in dental literature regarding the recasting of base metal alloys. There are no studies undertaken to check the surface roughness of recast alloys as is evident in the literature. Hence this study was carried out to find out the surface roughness & tensile strength of new alloy and recast alloys.

MATERIALS & METHODS:

This study was carried out in department of Prosthodontics, RKDF dental college and Research center, Bhopal to verify the change in mechanical properties obtained from recasting of base metal alloys. Approval from Institutional Ethical Committee of RKDF Dental College and Research Center was taken before starting the study. The study design was cross sectional in vitro study.

The study involved testing the surface roughness and tensile strength of the new alloy and recast alloy. The study required multiple identical cast alloy specimen. The specimen had to be identical in all respect of dimension and surface finish so as to standardize them and to prevent any variability in the results.

The study included only those specimens in the study with dimension 30x5x7±1 mm. The specimen with Discrepancy of >1mm and with casting defects were excluded from the study.

The study will consist of 120 samples divided into 4 groups equally are given below: a) Group A- Pure Alloys100%; b) Group B-75% New + 25% Old alloy; c) Group C-50% New +50% old alloy and d) Group D-100% Once Recast alloy.

PROCEDURE:

Wax patterns of desired dimension were made from metal mold according to the ADA (American Dental Association) Specification No.38 for testing of alloys used for metal / metal-ceramic restoration. Blue inlay wax was used. For standardization of the specimen Petroleum gel was applied on the glass slab and the metal mold was first positioned onto the glass slab, ensuring that the two surfaces contact each other uniformly. This would show the smooth and even surface of the wax pattern. Then molten wax is poured into mold space gently. Care was taken to avoid entrapment of air bubble. After the wax cooled, the wax pattern was removed carefully. If any distortion in the wax pattern was seen, it was discarded & a new pattern was fabricated. The surface in contact with the glass slab was used for the surface roughness test and hence all the test specimens were standardized. A direct technique of spruing was used.

A metal casting ring was taken and lined with one strip of asbestos—free cellulose acetate ring liner (BEGO). The ring liner strips were kept 3 mm short on either end of the casting ring.

The sprued wax patterns were then fixed onto the silicone crucible former (UNIDENT) and the wax pattern was then sprayed with surface tension reducing agent (DFS- SILIKON). A carbon-free phosphate-bonded investment (DEGUDENT IMPACT) was used. The necessary amount of investment material was cautiously weighed out. The investment was then thoroughly mixed in a vacuum mixing unit (WHIPMIX) for 30 seconds as suggested by the manufacturer. After 45 minutes the casting ring was placed in cool burnout furnace (HIHEAT- LABO-31 CONFIDENT) for 60 minutes, the highest temperature programmed was 950°C. The ring was allowed to stand for another 10 min. to ensure complete wax burn out. After burnout the casting ring was carefully placed in casting machine and casting was done as per manufactures' instructions

The casting ring was allowed to bench cool to room temperature and then the casting was divested from the refractory. The sprues were detached using high speed cut-off discs and any adherent investment removed by sand blasting.

For standardization of specimens the castings were cleaned with 250 micron alumina particle (BEGO). Each Specimen was sand blasted for 5 min from distance of 50 mm. in the sandblaster.

The samples were first subjected for surface roughness test and later for tensile strength test. This order was followed as the test specimen became distorted once they are subjected for tensile strength test.

***Testing the samples for Surface Roughness**:*

The test samples were subjected to Surface Roughness measuring tester. The samples were mounted on the tester. The diamond point stylus runs back and forth onto the samples and readings of the maximum surface roughness (maximum departure from perfection over a prescribed length) and average roughness (average departure of the surface from perfection over a prescribed sampling length) is displayed on the screen (Figure 1).

The diamond stylus on the surface roughness tester runs across a preset distance and the reading were recorded by a digital meter in terms of Rmax (maximum surface roughness), Ra (average surface roughness),

Testing the samples for Tensile Strength:

The test samples were subjected to a universal testing machine, using a specially fabricated test jig. The samples were supported across two points. Loading was done at a cross-head speed of 0.5 mm/min and the applied load recorded at a chart speed of 20 mm/min. The samples were stretched apart. Loading was continuous until a sudden decrease in the applied load was recorded. This decrease in the load values corresponded to the fracture of the samples. The reading at this particular point was noted down for each test specimen (Figure 2).

SPSS version 22 (statistical package for social sciences) software was used for Statistical analysis. Mean and standard deviation for surface roughness and tensile strength in each group was calculated. One way ANOVA (analysis of variance) followed by Post hoc tukey test was applied for calculating significant differences among 4 groups. P values lower than 0.05 were considered statistically significant in the analysis of the results.

RESULTS:

The mean values and Standard deviation for Maximum Surface Roughness among the four groups was given in (Table 1). The comparison of maximum surface roughness of new alloy showed highly statistically significant difference from recast alloy with F value = 198.43 and p value = 0.001. The Post Hoc Tuckey test shows minimum surface roughness in Group A (Pure alloy) and minimum in Group D (100% Once Recast alloy) with significant difference between groups.

The mean values and Standard deviation for Average Surface Roughness among the four groups was given in (Table 2). The comparison of maximum surface roughness of new alloy showed statistically significant difference from recast alloy with F value = 26.54 and p value = 0.03. The Post Hoc Tuckey test shows minimum surface roughness in Group A (Pure alloy) and minimum in Group D (100% Once Recast alloy) with significant difference between group A with all the alloys.

The comparison of mean values and Standard deviations of Tensile Strength for different groups were shown in (Table 3). The study result found that tensile strength of new alloy showed no statistically significant difference from recast alloy (as p value > 0.05 that is 0.24).

DISCUSSION:

Base metal alloys currently account for a maximum portion of the fixed prosthesis alloy market. The low price of these alloys is the major attraction, although this advantage can be offset by inexperienced handling of the alloys[10]. Two main classes of base metal alloys are the Ni-Cr system and the Co-Cr system. This study was undertaken to evaluate the surface roughness and tensile strength of new alloy and once cast alloy. Aim of the study was to use previously used base metal alloys to produce restorations with minimum cost for the dental laboratories without

Figure 1: (A) New Alloy (B) Recast alloy (C) Mold for fabrication of test specimen (D) Wax Patterns of Specimen.

Figure 2: (A) Casting Machine (B) Cast Specimen of Alloys© Roughness Tester (D) Test of tensile strength.

Table 1: Comparison between new alloy and recast alloy for maximum surface roughness.

Material	N	Mean	Std. Deviation	f	p value
Group A	30	42.53	4.10	198.43	0.00 *
Group B	30	45.57	4.05		
Group C	30	47.62	4.31		
Group D	30	49.45	3.02		

(p<0.01 highly significant*, p 0.01-0.05 significant, p >0.05 not significant)

Table 2: comparison between new alloy and recast alloy for average surface roughness.

Material	N	Mean	Std. Deviation	Mean Diff	f	p value
Group A	30	4.55	0.83	0.93	26.54	0.03 *
Group B	30	4.89	0.85			
Group C	30	5.03	0.85			
Group D	30	5.49	0.88			

(p<0.01 highly significant, p 0.01-0.05 significant*, p >0.05 not significant)

Table 3: comparison between new alloy and recast alloy for tensile strength.

Material	N	Mean	Std. Deviation	f	p value
Group A	30	4488.40	221.64	1.43	0.24 #
Group B	30	4486.93	250.34		
Group C	30	4487.03	274.17		
Group D	30	4484.20	379.68		

(p<0.01 highly significant, p 0.01-0.05 significant, p>0.05 not significant*)

compromising on the properties of the alloys. For evaluation of surface roughness, samples were mounted onto the surface roughness tester. The diamond stylus on the tester runs across a preset distance and the reading were recorded by a digital meter in terms of Rmax and Ra. Later these samples were mounted on UTM for tensile strength test.

The derived results reveal that there was non-significant difference in tensile strength between Groups. Result also shows consistent increase in maximum Surface Roughness and Average Surface Roughness with the increase in number of recasting. Hesby et al.[11] found no significant alteration in physical properties of alloy after 4 times recasting which is in contrast to our study which found significant increase in surface roughness of recast alloys. They also compared tensile strength first through fourth generations and found were no significant differences in tensile strength of different generation recasting alloys.

The similar result was shown by Agrawal A et al.[12] in which surface roughness significantly increases with recasting but there were non significant difference in tensile strength with recasting of alloy.

James J et al.[13] in 2018 conducted a study divided the metals into 5 groups. 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. They found slight variation in mean tensile strength which was statistically insignificant.

However the older studies by Nelson et al[1] in 1986 and Issac & Bhat[14] in 1998 showed significant decrease in Tensile strength on Recasting. Their microstructures showed large amounts of contamination, Porosity, and inclusions, which increased with each casting generation.

Bandela V and Kanaparthi S[15] in their review article had included 44studies. They founded no changes in mechanical properties on recasting of alloy.

Ronald G. Presswood[7] observed the color and the chemical composition of recast alloys & established no notable change in the composition after six melts of the alloys. So alloy was highly castable but Variations of tensile strength and surface roughness within and among groups were present. The direction and the angle of a sprue attachment may be the possible sources of variations in recorded results.

According to Anusavice[2], the classification of causes for defective castings, one of them is surface roughness and irregularities. The outer surface of the casting necessitates additional efforts in polishing and finishing whereas on the tissue surface prevent a proper seating of casting.

Thus it can be hypothesized by this study that causes for the surface roughness is probably related to the compositional change, micro porosity, loss of certain trace elements[7] such as manganese, chromium and molybdenum, the oxide layer formation[1]and incorporation of oxygen and nitrogen[16].

Surface roughness, readily apparent in all castings of study and is an ever present problem. Castings that contain porosity possess a reduced effective cross-sectional area equal to the size of the defect. These essentially weakened areas affect physical characteristics and alter test results.

CONCLUSION:

Tensile strength of new alloy showed statistically non significant difference on comparison with recast alloy used in 25%, 50% and 100%. However, surface roughness increases as the percentage of recast alloy used for preparation of cast. It is minimum for new alloy, then 25% recast alloy, 50% recast alloy and maximum for 100% recast alloy.

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