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Original Article

Dentistry Section

Evaluation of Surface Roughness and Tensile Strength of Base Metal Alloys Used for Crown and Bridge on Recasting (Recycling)

AMIT AGRAWAL[1], SYED W. HASHMI[2], YOGESH RAO[3], AKANKSHA GARG[4]

ABSTRACT

Background: Dental casting alloys play a prominent role in the restoration of the partial dentition. Casting alloys have to survive long term in the mouth and also have the combination of structure, molecules, wear resistance and biologic compatibility. According to ADA system casting alloys were divided into three groups (wt%); high noble, Noble and predominantly base metal alloys.

Aim: To evaluate the mechanical properties such as tensile strength and surface roughness of the new and recast base metal (nickel-chromium) alloys.

Materials and Methods: Recasting of the base metal alloys derived from sprue and button, to make it reusable has been done. A total of 200 test specimens were fabricated using specially fabricated jig of metal and divided into two groups- 100 specimens of new alloy and 100 specimens of recast alloys, which were tested for tensile strength on universal testing machine and surface roughness on surface roughness tester.

Results: 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.

Conclusion: Within the limitations of the study it is concluded that the tensile strength will not be affected by recasting of nickel-chromium alloy whereas surface roughness increases markedly.

Keywords: Average surface roughness, Casting, Maximum surface roughness, Nickle-chromium alloys

INTRODUCTION

Dental casting alloys play a prominent role in the treatment of the dental diseases. Casting alloys have to survive long term in the mouth and also have the combination of structure, molecules, wear, resistance and biologic compatibility. The compositions and types of casting alloys available to the dental practitioner have changed significantly over the past 25 years. Before the deregulation of the price of gold in the United States in the early 1970's gold-based alloys, with gold comprising over 70 weight percentage (wt%) composition, were virtually the only type of alloy used for fixed prostheses, with or without ceramic veneers [1].

Casting alloys are categorized by several methods. According to ADA system, casting alloys are divided into three groups on the basis of wt% composition [2]:

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.

Predominantly base-metal alloys: The base-metal alloys can be arbitrarily divided into four groups: Ni-Cr-Be, Ni-Cr, Ni-high-Cr, and Co-Cr. In 1930's base metal alloys were introduced to dentistry by RW Eardle and CH Prange [3]. The properties of this alloy satisfy with that of gold alloy with additional advantage of its reduced specific gravity and low cost [4]. Due to this superiority over gold alloy, cobalt-chromium and Ni-Cr alloy and its allies have become immensely popular in the field of restorative dentistry [5].

The popularity of base metal alloys in comparison to other alloys is further enhanced by their resistance to corrosion, reduced weight, and generally more favourable physical properties than those of gold [6].As casting procedures require more metal to be fused than is needed to fill the mould. The surplus, known as a button, is separated from the casting [7]. 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. As an economy measure, excess gold (buttons and sprues) has routinely been recast in combination with new metal to produce clinically acceptable castings.

The aim of the study is to evaluate the mechanical properties such as tensile strength and surface roughness of the new and recast base metal (nickel-chromium) alloys. This study is being carried out to investigate the effect of recasting of base metal alloys on its tensile strength and surface roughness, so as to enable the reuse of button derived from the casting of new alloy and to evaluate and compare the variance in tensile strength and surface roughness between recast alloy with control (new alloy).

MATERIALS AND METHODS

This study was done at the Department of the Prosthodontics in Pacific Dental College, Udaipur in the Dental lab. The study involved testing the surface roughness and tensile strength of the new alloy [Table/Fig-1a] and recast alloy [Table/Fig-1b]. 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 prevent any variability in the results.

[Table/Fig-1a,b]: a) New Alloy & b) Recast Alloy

Materials

Hundred percent New Alloys (Nickel-Chromium- NDN, DFS Germany).

Hundred percent Recast Alloys (Sprue & Button of Casting),

Investment Material (Deguvest),

Inlay wax (Bego Germany),

Sprue former (Wachsdraht, Renfert).

Equipments

Vacuum Mixing Unit (Whipmix),

Burnout Furnace (Vulcan, DENTSPLY),

Induction Casting Machine (Bego Germany),

Sand Blaster (Santer Labo 16, Confident),

Tensile Strength Testing Machine (CBR Apparatus) and

Surface Roughness Measuring Tester (Mitutoyo).

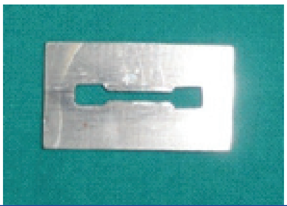
A total of 200 test specimens were fabricated and divided into two groups of 100 specimens each [Table/Fig-2], which were tested for tensile strength and surface roughness as illustrated below:

Groups (No. of samples 200)	Tensile Strength	Surface Roughness
Group 1 (100% NEW ALLOY)	100 Nos.	100 Nos.
Group 2 (100% RECAST ALLOY)	100 Nos.	100 Nos.

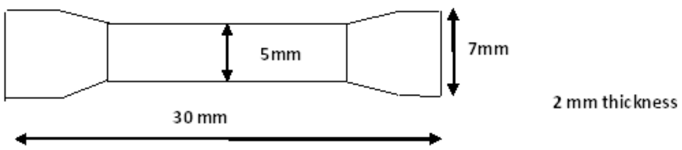
[Table/Fig-2]: Different groups of alloys

DIMENSIONS OF THE TEST SPECIMEN

Wax patterns of desired dimension were made from metal mould [Table/Fig-3], as illustrated in schematic diagram [Table/Fig-4], which is according to the ANSI/ADA Specification No.38 for testing of alloys used for metal/metal-ceramic restoration.



[Table/Fig-3]: Metal mould



[Table/Fig-4]: Dimensions of the metal mould

PREPARATION OF TEST SPECIMENS

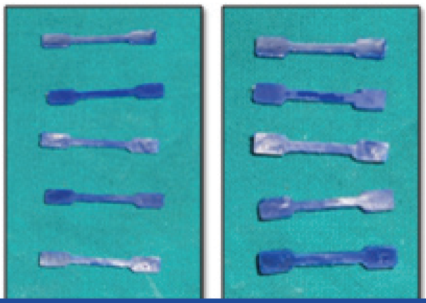
Preparation of Wax Patterns- Then molten wax is poured into mould space gently. Care was taken to avoid entrapment of air bubble. After the wax cooled, the wax pattern [Table/Fig-5] was removed cautiously. If any distortion in the wax pattern was found, it was discarded & a new pattern was fabricated. The surface in contact with the glass slab was used for the surface roughness test and hence all the test specimens were standardized.

A. **Spruing of the Wax patterns-** A direct technique of spruing was used. The wax patterns were sprued with 2mm diameter sprue wax.

B. **Investing and Casting the patterns:** Investing and casting were done using standard procedure (in accordance to manufactures instruction)

Retrieval of casting and surface preparation

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



[Table/Fig-5]: Wax patterns

specimens the castings were cleaned with 250 micron alumina particle. Each specimen was sand blasted for five minute from distance of 50 millimeter in the sandblaster.

For above mentioned two groups, new alloy and buttons derived from previous castings (single) alloys were chosen. The weight of the button and sprue was kept constant simulating the new alloy. The recommended casting procedures were followed for both the groups.

After all the samples [Table/Fig-6a&b] were obtained, they were subjected first 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 Tester [Table/Fig-7]. 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.

Testing the samples for Tensile Strength: The test samples were subjected to a Universal Testing Machine [Table/Fig-8], 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.

[Table/Fig-6a,b]: a) New Alloy sample & b) Recast Alloy sample

[Table/Fig-7]: Surface roughness tester

The samples were stretched apart. Loading was continued 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.

[Table/Fig-8]: Universal testing machine

STATISTICAL ANALYSIS

SPSS (statistical package for social sciences) software was used for analysis and Student t-test was used to find out the significance.

RESULTS

The study was conducted to use previously used base metal alloys to produce restorations with minimum cost for the dental laboratories without compromising on the properties of the alloys. For evaluation of surface roughness, samples were mounted onto the surface roughness tester and later these samples were mounted on UTM for tensile strength test. 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), Rp (height of highest peak) and Rv (depth of deepest valley), of which Rmax and Ra was taken for the study.

[Table/Fig-9] shows the mean values of the maximum surface roughness, average surface roughness and tensile strength. The results show highly significant difference in the new alloy and recast alloy in terms of the maximum and average surface roughness [Table/Fig-10,11]. Whereas the tensile strength of the new alloy and recast alloy showed no statistically difference in their values [Table/Fig-12].

DISCUSSION

The hypothesis for this study was that recasting of base metal alloys would change the properties of the alloys and, thus, affect the reusability of the alloys.

Previous studies by Hesby et al., [8] on the physical properties found no significant alteration in the physical properties of the alloy after 4 times' recasting. The results were in comparison to that of study done by Maria Peraire et al., [9] in terms of Chemical Composition, Microstructure, Microhardness, and Ion release and results states that the nickel-based alloy demonstrated good stability. Another study done by Jayent Palaskar et al., [10] on the porosity advocated that completely cleaned and deoxidized casted alloy need not be added with new alloy in any proportion, As in the present study new alloys were not added in any proportion for the recast procedure. Whereas, the study by Nelson et al., [1], Issac & Bhat [11] and Al-Hiyasat [12] demonstrated a decidedly degenerative trend in physical properties. Their microstructures showed large amounts of contamination, Porosity, and inclusions, which increased with each casting generation.

		Rmax (µm)	Ra (µm)	Tensile Strength Kg/cm²
New Alloy	Mean	42.257	4.554	4474.200
	S.D.	4.105	0.839	379.690
	N	100	100	100
	Median	40.887	4.657	4660.000
Recast Alloy	Mean	49.514	5.494	4530.100
	S.D.	3.022	0.884	221.645
	N	100	100	100
	Median	49.511	5.334	4594.000

[Table/Fig-9]: Mean values of surface roughness and tensile strength for new and recast alloys

Material	N	Mean	Std. Deviation	Std. Error Mean	Mean Diff	t	p-value
New Alloy	100	42.2574	4.10508	1.29814	7.25620	4.501	0.001*
Recast Alloy	100	49.5136	3.02246	0.95579			

[Table/Fig-10]: Comparison between new alloy and recast alloy for maximum surface roughness
(p<0.01 highly significant*, p 0.01-0.05 significant, p>0.05 not significant)

Material	N	Mean	Std. Deviation	Std. Error Mean	Mean Diff	t	p-value
New Alloy	100	4.5543	0.83871	0.26522	0.9396	2.439	0.025*
Recast Alloy	100	5.4939	0.88371	0.27945			

[Table/Fig-11]: Comparison between new alloy and recast alloy for average surface roughness
(p<0.01 highly significant, p 0.01-0.05 significant*, p>0.05 not significant)

Material	N	Mean	Std. Deviation	Std. Error Mean	Mean Diff	t	p-value
New Alloy	100	4474.2000	379.68958	120.06839	55.900	0.402	0.692*
Recast Alloy	100	4530.1000	221.64459	70.09017			

[Table/Fig-12]: Comparison between new alloy and recast alloy for tensile strength
(p<0.01 highly significant, p 0.01-0.05 significant, p>0.05 not significant*)

As per the literature by Anusavice [6], 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. Surface roughness, readily apparent in all castings in this study, 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.

Ronald G Presswood [7] observed the colour and chemical composition of the recast alloys & established no notable change in composition after six melts of the alloys. So, the alloy was highly castable. But variations of tensile strength and surface roughness within and among group were present. The direction and angle of sprue attachment to a wax pattern has a direct effect on turbulence in molten metal and ultimately on physical characteristics. The point of attachment between the sprue and the wax pattern must be properly flared, rounded, and contoured. Sharp angles at the sprue-wax pattern junction disrupt the flow of metal into the mould, contributing to porosity and altered physical properties. Considering the number of castings in this study, subtle differences in spruing represented a possible source of the variations in recorded results. Thus it can be hypothesized by this study that causes for the surface roughness is probably related to the compositional change [7], micro porosity [1], loss of certain trace elements [7] such as manganese, chromium and molybdenum, the oxide layer formation [1,11] and incorporation of oxygen and nitrogen [9].

For gold-based alloys, a small grain size has been shown to improve tensile strength and elongation [13]. For base-metal alloys, small, dispersed secondary phases (each with a small grain structure) are critical to the strength of the alloys. In other base-metal alloys, the grains are large and may approach 1 mm in diameter [4]. These large grains, which do not have anisotropic properties, may be a clinical liability if they occur in critical areas such as the connectors between units of a multiple-unit fixed restoration. In the present study there was much variation in values of the tensile strength. As with phase structure, grain structure is not visible to the naked eye. A tensile strength above 300 MPa is necessary to avoid fracture of alloys in high-risk areas such as between pontic of a multiple-unit fixed restoration [14].

Repeated casting show more stability in noble and nickel based alloys in comparison with high noble and titanium alloys [15]. MA Ameer et al., [16] studied the corrosion behaviour of dental alloys in artificial saliva using chemical and electrochemical technique. Ruohong et al., [17] found that bond strength of porcelain-high noble was significantly greater on third casting. Whereas Azam S Madani [18] concluded that the bond strength of porcelain-base metal alloys decreases significantly upon recasting. Nagam R Reddy [19] found that Hi Nickel CB shows maximum elemental release and cytotoxic effect in pure and re-casted forms, followed by cermet and wiron 99.

There is scope for further studies in terms of multiple recast alloys, new alloy can be added in varying proportion, other physical properties, compositional analysis and elemental release, bond strength of the recast alloy to the ceramic, time, material and equipment should be evaluated and calculated for economical consideration.

CONCLUSION

A clinician requires the benefit of data to predict the reusability of the button derived from the previous casting. The possible cause for the difference in the data could be related to the compositional change, micro porosity, loss of certain trace elements such as manganese, chromium and molybdenum, the oxide layer formation and incorporation of oxygen and nitrogen.

It was always interesting to study these alloys and develop an understanding of their chemical and physical characteristics. Since 1980's, investigators have made attempts to recast the alloy up to many generations. There are, however, many universally accepted tests for tensile strength and roughness. Based on the results obtained, the study concludes that the tensile strength of new alloy showed no statistically significant difference from recast alloy. New alloy had statistically significant Maximum surface roughness and Average surface roughness difference as compared to recast alloy.

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1.Dr Ponanna A.A

Department of Prosthodontics, Pacific Dental College, Udaipur (RAJ), India.

2.Dr Ravi Kumar CM.

Department of Prosthodontics, Pacific Dental College, Udaipur (RAJ), India.

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PARTICULARS OF CONTRIBUTORS:

1. Senior Lecturer, Department of Prosthodontics, New Horizon Dental College and Hospital, Bilaspur (CG), India.
2. Reader, Department of Prosthodontics, New Horizon Dental College and Hospital, Bilaspur (CG), India.
3. Senior Lecturer, Department of Prosthodontics, Maharana pratap Dental College and Hospital, Gwalior (MP), India.
4. Post Graduate, Department of Periodontics, Pacific Dental College, Udaipur (RAJ), India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Amit Agrawal,
Senior Lecturer, Department of Prosthodontics, New Horizon Dental College and Hospital,
Bilaspur (CG)-495001, India.
E-mail: wassup.dr.amit@gmail.com

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