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The Effect of Various Combinations of New and Recast Ni-Cr Ceramo Metal Alloys On the Mechanical Properties

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Abstract:
Statement of the Problem: *Dental casting alloys have been reused routinely in dental laboratories by combining it with fresh alloys. This combination work of the new and used alloys should not affect the mechanical properties of the dental casting restoration.*
Materials & Methods: *Ni-Cr ceramo-metal dental casting alloys were evaluated in four combinations of 100% fresh alloy, 50% fresh alloy with 50% recast alloy,25% fresh alloy with 75% recast alloy and 100% recast alloy. The mechanical properties tested in this study were modulous of elasticity, yield strength, percentage elongation, and tensile strength.A total of 24 samples were prepared,six samples per group and tested for tension testing to determine the mechanical properties.*
Results: *The mechanical properties decreased from group I to group IV, but the values for group II and group III were within recommended limits for a ceramometal alloy.*
Conclusion:*Within the limitations of the present invitro study, the use of lower percentage combinations though produced statistically significant difference in the alloy's mechanical properties, but was within the required minimum limits except for the 100% recast alloys..*
Keywords: *ceramometalni-cr alloys,modulous of elasticity,percentage elongation, yield strength,recast alloys,*

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I. Introduction

Dental casting alloys play a vital role in restorative and replacement dentistry because of the good physical, economical, and biological properties.[1,2] The ideal casting alloy is gold alloy, not usually preferred for its expensive nature.The base metal alloys cobalt–chromium and nickel alloys meet the requirements with added advantage of low cost and reduced specific gravity.[1,2,3]Most of the laboratories are reusing the alloys left in casting procedures like the sprue and metal remaining in the crucible former with new metal either in part or complete, [1,]The combination of the new and reused metal in casting procedureshould not affect the optimum properties which are necessary for ideal restorations.The aims of this in-vitro study were to analyze the influence of new & recast alloys combinationson the following properties.

1. Modulous of elasticity 2.Yield strength3.Percentage elongation 4.Tensile strength

II. Materials & Methods:

The alloy testedin this study was 4-all Metal white ceramic alloy (IvoclarVivadent) with the following composition Ni-61.4%, Cr-25.7% Mo-11.0%, Si=1.5%, C=<1.0%.The alloy combinations were grouped in four categories based on the percentage of fresh and recast alloys used

Group I: Cast with 100% New Alloy**Group II:** Cast with 50% New and 50% Recast Alloy
Group III: Cast with 25% New and 75% Recast Alloy**Group IV:** Cast with 100% Recast Alloy

2.1 Preparation of Samples.

The samples were prepared as per the requirement of the tests evaluated. A split metal die was constructed in 2 parts enclosing, the mold space to produce the tensile samples in accordance with the ADA specification NO: 38 for metal ceramic systems. Resin patterns were prepared using this metal die.The dimension of the tensile samples as specified by ADA is a cylindrical specimen of 3.0 ± 0.1mm diameter, 15mm gauge length & 6mm minimum end conical section. But the shaft portion was increased to 15mm to align in the testing machine. Dimensions of tensile sample are shown in fig [1]

2.2Spruing, Investing and Casting of Samples

The resin samples were directlyluted to the crucible former vertically as shown in fig [2], that the pattern itself served as the sprue as done in earlier studies anda vent was provided. The patternswere invested using phosphate bonded investment(Flex vest -IvoclarVivadent) in a wet ring liner lined casting ring.The recast alloys used in the present study were once used alloys, and sandblasted.An electronic weighing machine (Fc series) was used to weigh the new & recast alloys required for each group.The amount of alloy required was calculated by multiplying the weight of pattern and density of alloy (8.4gAs specified by the manufacturer)Separate crucibles were used for each group to avoid alloy contamination. After the casting procedure,the casting rings were allowed to cool to room temperature and then divested with 50µ grit aluminium oxide, the surface of the samples were smoothened using tungsten carbide trimmer to remove surface irregularities fig [3].The gauge lengths of tensile samples were marked for future comparison to determine percentage elongation.

2.3. Evaluation & Testing of Samples

The completed tensile specimens were tested on a Universal testing machine (Shimadzu AG-IS; UTM Autograph) using a cross head speed of 1.0 mm/min under 500kg load up to the fracture point of the specimens. The specimen was mounted by its ends into the holding grips of the testing apparatus as illustrated in fig[4].The tensile testing machine is designed to elongate the specimen at a constant rate continuously until the fracture of the specimen.The specimen was deformed to fracture, with a gradually increasing tensile load that is applied uniaxially along the long axis of the specimen. The deformation is confined to the narrow center portion, which has a uniform cross section along its length.From the resultant stress-strain curve of each sample fig[5], values of Modulus of elasticity, Yield strength (at 0.2% offset), and tensile strength were obtained. For determining percentage elongation the fracture parts were repositioned as accurate as possibleand the gauge distance between the two marks made earlier was re-measured.The percentage elongation was calculated by dividing the difference between the two measurementswith the original length and multiplying with 100 fig[6].

III. Results.

The values of the tested properties were statistically analyzed using,One-way ANOVA, Duncan's Multiple range test.In the present study, the within group variance and between the group variance were studied. As the P value for all the properties evaluated was less than 0.001, there is a significant difference between the groups with regard to various percentage of alloy combination.Table 1 to Table 4 represents the mean value of the all the groups for each property, with the statistical analysis using Duncan multiple range test calculated at 0.05% significance, which is represented as alphabets in superscript. Different alphabets denote that values are significant at 5% level.The mean values of modulus of elasticity for the group I, II, III, &IV were 188.26GPa, 169.75GPa, 156.3 GPa, and 127.28GPa respectively.The mean values of yield strength in MPa for group I, II, III, &IV were 313.83MPa, 290.41MPa, 254.98MPa, and 190.1MPa respectively.The mean values of tensile strength of the group I, II, III, &IV were 680.25 MPa, 663MPa, 638.78MPa, and 601.27MPa respectively. The mean values of group I, II, III, &IV were 14.85%, 11.2%, 8.53%, and 6.51% respectively

IV. Discussion

Dental casting alloys continue to be used as one of the principle materials for prosthodontic treatment because of their excellent physical & mechanical properties to survive long term in the mouth as a dental prosthesis. [16,17,18,19,20,21,22] With the increased cost of base metal alloy, the practice of combining new with already cast alloy evolved in routine casting procedure. [1,6,23,24].Recommendations for combining recast alloys with new alloy vary from adding no new metal- to some new metal-to 50% new metal. [5,12,18,19,25,26]The problem with using recast alloys primarily involves oxidation of alloy constituents. Elements like Ti, Ta, Cr, Ni, C, Fe, Nb, and Si are subjected to increased oxidation upon melting. The decline in the concentration of one or more alloying elements on subsequent remelting may result in alteration in mechanical properties, corrosion resistance and ceramometal bonding.[5,25,28,29]

The clinical success of porcelain fused to metal restoration depends upon the physical properties of both ceramic and metal substructure. The properties used to characterize a dental casting alloy are Castability, Modulus of Elasticity, Yield Strength, Hardness, Tensile Strength and Percentage Elongation in the order of their importance .[1,29]Modulus of elasticity is essential for a long span metal ceramic fixed prosthesis to reduce the amount of bending deflection under functional loading, as excessive flexure can cause fracture of brittle porcelain.Asgar& Peyton [12] pointed out that yield strength of an alloy is important since it represents the value at which permanent deformation takes place in the structure. The tensile strength has minimal importance when ceramic alloys are considered, because the corresponding permanent strain does not occur under clinical condition. However Wataha[34] stated that a tensile strength of atleast 300 MPa is necessary to avoid the fracture of alloys in high risk areas such as connectors between pontics of a multiple FPD. [22]

A total of 24 tensile samples, six samples per group were prepared in accordance with ADA specification No: 38 [25, 34, and 35,36,37,38] to evaluate the mechanical properties namely, MOE, yield strength, tensile strength & percentageelongation. The samples were then subjected to tensile loading in a Universal Testing machine (Shimadzu, Autograph, Japan). Modulus of Elasticity, Yield Strength (at 0.2 % offset) & Tensile strength were obtained from the resultant stress – strain curve. Percentage of Elongation was calculated by realigning the fractured segments.

The values of modulous of elasticity& yield strength of group II, group III were significantly less than the group I (100% new alloy), but the were within the minimum requirement for a ceramometal alloy (255 MPa, 150GPa respectively) suggesting that these alloy combinations can be used clinically. But the yield strength and modulous of elasticityof group IV (100% recast alloy) was well below the required minimum limits suggesting that use of 100% recast alloys alone for fabrication of dental restoration will influence the alloy's clinical performance. Issac L, Bhat S [39](1998) evaluated the effect of reusing Ni-Cr alloy on its ultimate tensile strength, yield strength & modulus of elasticity. Results showed degenerative changes in the properties evaluated when complete recast alloy was used.The values of tensile strength & percentage elongation of group II (50% new & 50% recast alloy), group III (25% new & 75% recast alloy), group IV (100% recast alloy) were significantly less than group I (100% new alloy). But the tensile strength & percentage elongation of groups II, III, were above the minimum limits for a ceramometal alloy (400 MPa and 8% respectively) suggesting that new & recast alloy combination have clinically negligible effect on these properties. The percentage elongation of group IV was below the minimum requirement. But the tensile strength of group IV was within the recommended limits. This was consistent with the results of earlier studies[18,22,26]

In this study, the use of lower percentage combinations (50% new & 50% old, 25% new & 75 % old) though produced statistically significant difference in the alloy's properties, were within the required minimum limits for a ceramometal alloy. Use of higher percentage of recast alloy (> 75%) had a definite effect on the alloy's castability, MOE, yield strength, percentage elongation and microstructure. Hence from this invitro study it can be inferred that combination of new and recast alloy will influence the mechanical properties, ought to be considered cautiously for fabrication of a successful fixed prosthesis.

V. Conclusion

Within the limitations of the present invitro study, the following observations were made;

1. The values of modulus of elasticity,yield strength,tensile strength & percentage elongation decreased from group I to group IV.
2. Themechanical properties of group II & group III were within recommended limits for a ceramometal alloy.
3. The group IV satisfies the minimum requirement for tensile strength but not the other properties.

From the results of this in-vitro study, a porcelain fused metal coping of up to 50% recast alloy appears to be an adequate safety margin. But use of recast alloys up to 75% can be considered provided alloy contamination by excessive melting or inadequate cleaning are reduced and proper investing and casting steps are carried out to minimize casting defects. Further investigation regarding the corrosion resistance, cytotoxicity of this alloy should be evaluated for better.

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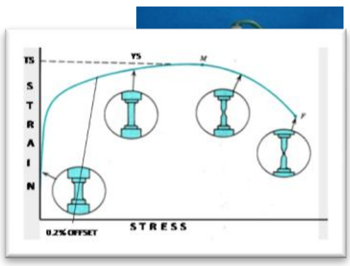
FIGURES

Fig 1 –Sample Dimension Fig 2- Sprued Sample Fig 3- Cast Samples



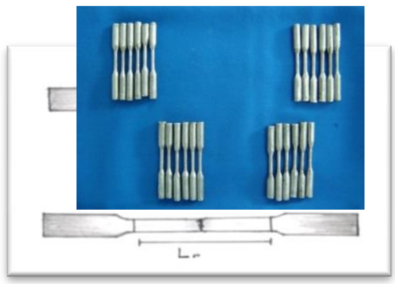


Fig 4 Sample in Testing Machine Fig 5Stress-Strain Curve Fig 6Percentage Elongation Calculation

TABLES

Table 1 Modulus of Elasticity(Duncan Multiple Range test – in superscript)**Table 2 Yield Strength**

Statistical Result of Modulus of Elasticity				
S.NO	GROUPS	MEAN	SD	P VALUE
1	I	188.26^{d}	3.70	**<0.001****
2	II	169.75^{c}	4.90	
3	III	156.30^{b}	3.70	
4	IV	127.28^{a}	4.98	

Statistical Result of Yield Strength				
S.NO	GROUPS	MEAN	SD	P VALUE
1	I	313.83^{d}	13.88	**<0.001****
2	II	290.42^{c}	5.45	
3	III	254.98^{b}	7.41	
4	IV	190.10^{a}	6.50	

Table 3 Tensile Strength (Duncan Multiple Range test – in superscript)

Statistical Result of Tensile Strength				
S.NO	GROUPS	MEAN	SD	P VALUE
1	I	680.25^{d}	5.92	< **0.001****
2	II	663.00^{c}	5.83	
3	III	638.78^{b}	6.92	
4	IV	601.27^{a}	13.75	

Table 4Percentage Elongation

Statistical Result of Percentage Elongation				
S.NO	GROUPS	MEAN	SD	P VALUE
1	I	14.85^{d}	0.92	< **0.001****
2	II	11.20^{c}	1.49	
3	III	8.53^{b}	0.64	
4	IV	6.52^{a}	0.48	

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