"Comparison of Mechanical Properties of Base Metals Dental Casting alloys used for fixed Prosthodontics."

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ABSTRACT:

Study Background: Nowadays number of base metal alloys is commercially available and many more developed on an experimental basis. In view of new developments it is important that different materials are assessed for desirable properties and compared.

Materials and Method: Six set of specimens were made for each alloy (ECODUR^P, MAARC & SUPERCHROME-SC). The specimens were in "as cast" condition. The gauge length of the specimen was kept 15mm and diameter of 3mm was given according to ADA sp.14. A square block 2cm x 2cm in dimension was prepared for testing hardness of the alloy.

Observations & Results: The value of modulus of elasticity of SUPERCHROME-SC was significantly highest of all the three alloys indicating that it was the stiffest of the three alloys, which is a good characteristic for a dental casting alloy. The hardness of SUPERCHROME-SC was incomparably close ($p>0.05$) to the other two commercially available alloys and in the range as per the ADA requirements indicating that the materials was quite hard and was resistant to scratching.

Conclusion: From present study, it can be concluded that the values of tensile strength and yield strength of SUPERCHROME-SC (experimental alloy) are significantly higher than the commercially available and widely used alloy i.e. MAARC.

Keywords: base metal alloys, casting

INTRODUCTION:

The rising cost of precious metals has stimulated interest in the use of base metal alloys for all types of dental castings. These alloys are significantly different from the precious metal alloys in a wide range of properties, such as alloy composition, strength, hardness, specific gravity, melting temperature and casting shrinkage.[1]

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An alloy is defined as a mixture of two or more metals. Base metals are invaluable components of dental casting alloys because of their superior mechanical properties.[2] Properties of the nickel-chromium alloys include greater hardness, greater resistance to sag formation, lower specific gravity, and different porcelain to metal bond strengths.[3] Slightly more than half of these alloys are designed for all-metal crowns, bridges, onlays and inlays, that are described according to ADA specification No.5 as types I to IV.[4] As today, Ni-Cr base metal alloys are the most widely accepted and used base metal alloys for metallic restorations, an in-vitro study was planned to evaluate and compare some clinically relevant mechanical properties of two commercially available Ni-Cr base metal alloys which are imported and marketed in India and one locally manufactured Ni-Cr alloy, which acts as an experimental material.

With this background in consideration present study was planned to evaluate the materials regarding the various mechanical properties like Tensile strength, yield strength, modulus of elasticity, percent elongation and hardness.

MATERIALS AND METHOD:

The Ni-Cr base metal alloys used in this study include two commercially available products and one experimental material which is manufactured locally. The mechanical properties were tested according to the conditions given in ADA specification No.14 and ADA specification No.5 for dental base metal casting alloys.[5]

(1) NIOM ECODUR^{P} (Fig.1) : Made in Germany, Manufacture **:** DFS (Dental Forschung Schleicher GmbH), recognised by CE 0510

(2) MAARC (Fig.2): Ni-Cr Non-precious alloy, German alloy marketed in India by Shiva Products, Mumbai.

(3) SUPERCHROME-SC (Experimental alloy) **(Fig.3)**: Manufacturer **:** White Horse, Square chemicals, Ahmedabad.

Fig.1 : DFS alloy

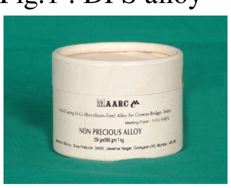

Fig.2 : Maarc alloy

Fig.3 : Superchrome-SC alloy

All the three alloys used were totally beryllium free. The following mechanical properties were tested for the above mentioned three Ni-Cr alloys at the conditions specified by ADA specification No.14 and No.5 : Tensile strength, yield strength, modulus of elasticity, percent elongation and hardness

Sampling : Six set of specimens were made for each alloy. The specimens were in "as cast" condition.

Specimen for tensile test : A wooden die was prepared of the size according to ADA sp.14 which was directly invested and accordingly the samples were casted, finished and prepared. The gauge length of the specimen was kept 15mm and diameter of 3mm was given according to ADA sp.14.

Specimen for testing hardness : A square block 2cm x 2cm in dimension was prepared for testing hardness of the alloy. (Fig.4, Fig.5)

Fig .4 : Wooden die prepared of sample size

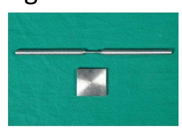

Fig.5 : Casted and finished samples

TEST METHOD

(1) Tensile Strength :

Strain : The change in length, or deformation per unit length, where a material is subjected to a force is defined as strain.[6]

(2) Yield strength :

Yield strength often is a property that represent the stress value at which a small amount (0.1% or 0.2%) of plastic strain has occurred. A value of either 0.1% or 0.2% of the plastic strain is often selected and is referred to as the percent offset.

(3) Modulus of elasticity :

The slope of the straight line region (elastic range) of the stress-strain diagram is a measure of the relative rigidity or stiffness of a material. Young's modulus is tested according to specification ANSI/ASTM E111-61.[7]

(4) Percent elongation :

The two portions of the specimen are fitted together and the elongation between the marks shall be recorded to the nearest 0.1%.

Elongation = **(lf – lo) /lo** X 100

where, lf = length at fracture

lo = Original length of the specimen

(5) Hardness :

BHN test is done according to method specified in ANSI/ASTM E10 standard.[8] The Brinell hardness number is converted into Vickers hardness number using approximate hardness conversion number table for nickel alloys given by standard ANSI/ASTM E140-77 as ADA sp.5 demands mean value for Vickers hardness number.[9] The method used is according to ANSI /ASTM E92-72 standard.[10] In this study Brinell's hardness number was determined on Amsler hardness testing machine at a load of 3000 kg which is applied for 10 sec with the indenter ball having a diameter of 10 mm, on the specimens. (Fig.6)

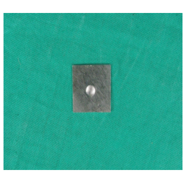

Fig.6 : Hardness calculated by indentation on cast block

DATA AND RESULTS :

Six specimens each of a single alloy were used to perform all the mechanical tests. The tensile properties which included tensile strength, yield strength (0.1% offset) and modulus of elasticity for each alloy were calculated using the stress-strain curves obtained from the universal testing machine.

The curve of a single specimen for each alloy is given below (Fig.7,8,9).

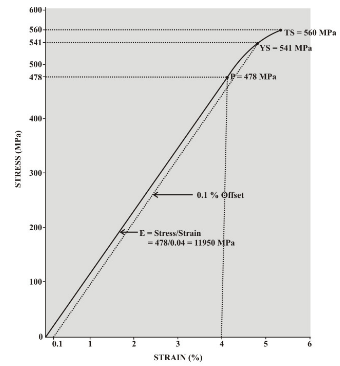

Fig.7 : Stress-strain curve for specimen casted from ECODUR[P](DFS) base metal alloy subjected to tension.

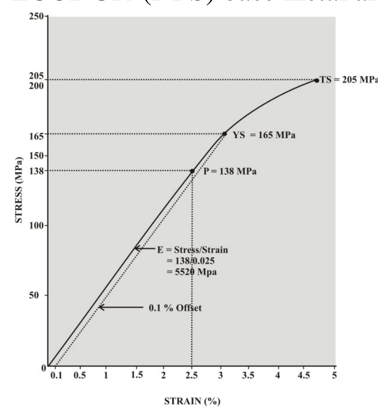

Fig.8 : Stress-strain curve for specimen casted from MAARC base metal alloy subjected to tension.

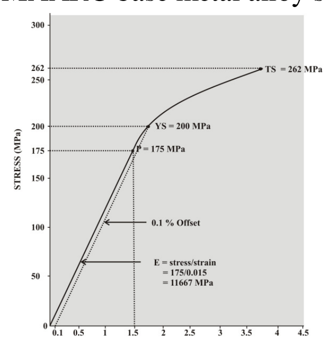

Fig.9 : Stress-strain curve for specimen casted from SUPERCHROME-SC base metal alloy(experimental alloy) subjected to tension.

Table 1: Shows the mean values for tensile strength and standard deviation for each base metal alloy i.e. ECODUR[P](DFS), MAARC and SUPERCHROME-SC (experimental alloy)

TENSILE STRENGTH (MPa)			
Specimen No.	ECODUR[P] (DFS)	MAARC	SUPERCHROME-SC (experimental alloy)
1	481	198	262
2	333	198	255
3	576	212	276
4	580	205	467
5	590	210	453
6	560	200	460
Mean	520	204	362
Standard Deviation	99.73	6.15	107.48

Table 2 : Shows the mean values for yield strength (0.1% offset) and standard deviation for each alloy.

YIELD STRENGTH (MPa)			
Specimen No.	ECODUR[P] (DFS)	MAARC	SUPERCHROME- SC (experimental alloy)
1	475	186	200
2	330	176	220
3	560	190	202
4	571	165	445
5	571	202	440
6	541	187	442
Mean	508	184	325
Standard Deviation	94.34	12.63	128.91

Table 3: Shows the mean values for modulus of elasticity and standard deviation for each alloy

MODULUS OF ELASTICITY (MPa)			
Specimen No.	ECODUR[P] (DFS)	MAARC	SUPERCHROME- SC (experimental alloy)
1	8696	4400	11667
2	7000	4118	11538
3	10239	7200	11928
4	10060	5520	12800
5	10638	4175	11714
6	11950	4706	12667
Mean	9764	5020	12052
Standard Deviation	1711	1184	544

Table4 A: Shows the mean values for modulus of elasticity and standard deviation for each alloy

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Mean	9764	5020	12052
Standard Deviation	1711	1184	544

Table 4 B : Shows the mean values for percent elongation and standard deviation for each alloy

PERCENT ELONGATION (%)			
Specimen No.	**ECODUR^P (DFS)**	**MAARC**	**SUPERCHROME- SC (experimental alloy)**
1	6	4.7	4
2	5.3	5.3	3.3
3	6	3.3	4
4	6	4.7	4
5	6	5.3	4
6	5.3	4.7	4
Mean	5.8	4.7	3.9
Standard Deviation	0.29	0.73	0.28

Table 5 : Shows the mean values for Vickers hardness number and standard deviation for each alloy

Hardness (kg/mm2)									
SP. No.	ECODUR[P] (DFS)			MAARC			SUPERCHROME-SC (EXPERIMENTAL ALLOY)		
	d	BHN	VHN	d	BHN	VHN	d	BHN	VHN
1	4.83	153	155	4.78	157	159	4.56	174	177
2	4.87	151	153	4.51	178	181	4.54	175	178
3	3.98	231	237	4.4	185	189	4.56	174	177
4	4.12	215	220	4.25	201	205	4.97	144	145
5	4.2	205	209	4.56	174	177	4.54	175	178
6	4.0	227	234	4.4	185	189	4.56	174	177
Mean for VHN	201			183			172		
Standard Deviation For VHN	38.02			15.31			13.23		

Where, d = diameter of indentation on the specimen (mm)
BHN = Brinell hardness number (kg/mm2)
VHN = Vickers hardness number(kg/mm2)

STATISTICAL ANALYSIS: One-way ANOVA (Analysis of Variance) test was carried out to compare results of tensile strength, yield strength, modulus of elasticity, percent elongation and Vickers hardness number for all the three alloys and then interalloy comparison between the alloys for a particular property was done using Tukey–HSD test. From the ANOVA test it was found that the alloys differ significantly with respect to tensile strength, yield strength, modulus of elasticity and percent elongation of each alloy ($p<0.001$). The alloys do not differ significantly with respect to Vickers hardness number ($p>0.001$). From the results of Tukey-HSD test in which interalloy comparison is done between all alloys for a particular property it was found that ECODUR[P](DFS) has significant higher values ($p<0.05$) for tensile strength and yield strength followed by SUPERCHROME-SC (experimental alloy) and lastly MAARC, SUPERCHROME-SC has significant higher value ($p<0.05$) for modulus of elasticity, followed by ECODUR[P](DFS) and lastly MAARC, ECODUR[P](DFS) has significant higher value ($p<0.05$) for percent elongation, followed by MAARC and lastly SUPERCHROME-SC (experimental alloy). For the property of Vickers hardness number the three alloys can't be significantly compared ($p>0.05$).

DISCUSSION:

Eugene F. Huget, Jesus M. Vlica and Richard M. Wall in conducted a study in which compositions, microstructures, mechanical properties and heat treatment characteristics of two ceramic base-metal alloys were studied.[11]

Strength and rigidity of the nickel-chromium alloys suggest their potential usefulness in fixed prosthodontic procedures. Hesby Kobes, Garver and Pelleu undertook a study to evaluate hardness, tensile strength and percentage of elongation of a non-precious metal alloy used repeatedly for fixed partial denture casting. These properties were compared between single melt alloy castings and second, third, and fourth generation melt alloy castings. There were no significant differences observed in the properties among any of the four generations of casting. This finding indicates that the metal can be reused for atleast four generations.[12]

Goodhead, D.T., R.J. Bery, et al presented a review of the various types of alloys currently available in the western world, as well as of the biological, techniques and clinical aspects of their use in dentistry. Special attention was paid to the possible risks of various types of pathological reactions associated with alternative alloys containing nickel, beryllium or cadmium.[13] So it is necessary to assess different materials and compare them for desirable properties. So this in-vitro study was planned to compare important mechanical properties of three Ni-Cr base metal alloys. All the three Ni-Cr alloys used in this study were totally beryllium free. Exposure to beryllium vapor or particles is associated with a number of diseases from contact dermatitis, to chronic granulomatous lung disease, known as chronic beryllium disease (CBD).[14,15] So due to beryllium induced toxicity it is now advised by OSHA (Occupational Safety and Health Administration) to use beryllium free alloys.

Tensile Strength : In our present study, according to results obtained for tensile strength from Table.1 & Tukey-HSD statistical analysis of interalloy comparison for tensile strength ECODUR^{P}(DFS) alloy has significant ($p<0.05$) high tensile strength (520 MPa) followed by SUPERCHROME-SC (experimental alloy) (362 MPa) and lastly MAARC alloy (204 MPa).

Yield strength: Proportional limit and yield strength indicate the stress at which material no longer functions as an elastic solid. These two properties are particularly important because a restoration can be classified as a clinical failure when a significant amount of permanent deformation takes place even though the material does not fracture. In our present study, according to results obtained for yield strength (0.1% offset) from Table.2 & Tukey-HSD statistical analysis of interalloy comparison for yield strength ECODUR^{P}(DFS) has significant ($p<0.05$) high yield strength (508 MPa), followed by SUPERCHROME-SC (experimental alloy) (325 MPa) and lastly MAARC alloy (184 MPa).

Modulus of elasticity: Stiffness is important in the selection of alloys, since large deflections under stress are not desired. In our present study, according to results obtained for a modulus of elasticity from Table.3 & Tukey–HSD statistical analysis of interalloy comparison for modulus of elasticity SUPERCHROME-SC (experimental alloy) has significant ($p<0.05$) high modulus of elasticity (12052 MPa), followed by ECODUR^{P} (9764 MPa) and lastly MAARC alloy (5020 MPa).

Percent elongation: The percentage of elongation is an important property as it is measure of ductility of the material. In our present study, according to results obtained for percent elongation from Table.4 & Tukey-HSD statistical analysis of interalloy comparison for percent elongation ECODUR^{P}(DFS) has significant ($p<0.05$) high percent elongation (5.8%), followed by MAARC (4.7%) and lastly SUPERCHROME-SC (experimental alloy) (3.4%).

Hardness : In our present study, according to results obtained for Vickers hardness number from Table.5 ECODUR^{P}(DFS) has the highest VHN value (201), followed by MAARC (183) and lastly SUPERCHROME- SC (experimental alloy) (172).

According to Tukey-HSD statistical analysis of interalloy comparison for Vickers hardness it was found that the Vickers hardness of three alloys was very close to each other and hence can't be significantly compared ($p>0.05$). ADA Sp.14 has given a range for the following properties under which these properties of base metal alloys should ideally fall.

Yield strength (MPa) (0.1% offset) minimum 500, Modulus of elasticity (MPa) minimum 1,72,000,

Percentage elongation minimum 1.5.

According to results obtained it was found that all the three alloys satisfy the percent elongation range according to ADA sp.14, while non of the alloys satisfy the modulus of elasticity range, only ECODUR^{P} (DFS) alloy falls within the yield strength range as per ADA sp.14. According to ADA sp.5 the mean value of six specimens for Vickers hardness should be within 10% of the value specified by the manufacturer.

The two commercially available alloys used in this study i.e. ECODUR^{P}(DFS) and MAARC, both do not satisfy the ADA requirements completely and are not certified by ADA, but were still used clinically all over giving good results. Very few Ni-Cr alloys are there which were ADA certified and at present they are very costly plus not freely available in the Indian market. It has been surveyed that all the commercially available Ni-Cr alloys in Indian market (either imported or locally manufactured) with good mechanical properties are not certified by ADA but are still used clinically with good results. None of the alloy satisfy the ADA criteria completely still ECODUR^{P}(DFS) and MAARC are widely used with good results for fixed prosthodontics.

It can be said that the mechanical properties of SUPERCHROME-SC are quite satisfactory with some properties satisfying the ADA requirements and some properties even superior than the other two commercially available alloys i.e. ECODUR^{P}(DFS) and MAARC. Though SUPERCHROME-SC is not used clinically and it is experimental alloy in our study, it has multiple advantages that it is easily available, comparatively cheaper than the other commercially available alloys, beryllium free and has superior modulus of elasticity, tensile strength, yield strength than some commercially available alloys.

SUMMARY AND CONCLUSIONS:

From our present study ,we may conclude that SUPERCHROME-SC experimental alloy's tensile strength and yield strength are significantly higher than the commercially available alloy MAARC which indicates that the alloy has high strength and good ability to resist forces without fracture or deformation.

RECOMMENDATIONS:

Clinical application of this experimental alloy can be possibly carried out on the basis of mechanical properties requirements but further studies should be carried and other important properties like biocompatibility of the alloy, its tarnish and corrosion resistance etc. should be assessed before the alloy is used clinically.

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