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MECHANICAL CHARACTERISTICS FOR COBALT - CHROMIUM AND NICKEL - CHROMIUM CAST ALLOYS RECOVERY

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Abstract: Since cobalt-chromium or nickel-chromium casting alloys became available for cast removable partial-denture restorations, their popularity have continued to increase. It was estimated that more than 80% of all partial-denture appliances were cast from some type of these of base-metal alloy.

According ANSI/ADA the specification of these dental restorative materials has to indicate the comply satisfactorily with requirements on toxicity, hypersensitivity, and corrosion of elemental composition, and the required minimum values for elongation, yield strength, and elastic modulus.

The paper presents experimental considerations (experimental diagrams and values) concerning the possibility to recovery the cobalt-chromium and nickel-chromium alloys after the first casting.

Key words: mechanical characteristics, Co-Cr and Ni-Cr cast alloys, recovery

1. INTRODUCTION

Base-metal alloys are widely used in dentistry for appliances and instruments.

Stainless steel alloys are used principally for orthodontic wires, in making endodontic instruments, and preformed crowns.

Titanium alloys are used in cast and wrought forms for crowns, bridges, implants, orthodontic wires, and endodontic files.

Introduced in dentistry practice to replace gold alloys, cast Co-Cr alloys are used for making partial denture frameworks, cast Ni-Cr alloys are used in crowns and bridges making, and in some cases may be used for dental porcelain structure. Cast Co-Cr alloys and Ni-Cr are used in porcelain-fused-to-metal restorations.

Dental applications of cast and wrought base-metal alloys principally are classified [1]:

- wrought stainless steel alloys (endodontic instruments; orthodontic wires and brackets; preformed crowns);
- wrought Ti and Ti alloys (implants; crowns; bridges);
- cast Ti alloys (crowns; bridges; partial dentures; implants);
- cast Co-Cr alloys (partial-denture framework; porcelain-metal restorations);
- cast Ni-Cr alloys (partial-denture framework; crowns and bridges; porcelain-metal restorations).

To be used as substitutes for gold alloys in dental appliances these metal alloys have to be characterized by some minimal properties: the alloy's chemical elements should not produce harmful toxicology or allergic effects in the patient or the operator; the chemical properties of the appliance should provide resistance to corrosion and physical changes when in the oral fluids; the physical and mechanical properties (thermal conductivity, melting temperature, coefficient of thermal expansion, and strength) should all be satisfactory, meeting minimum values and being variable for various appliances; the technical expertise needed for fabrication and use should be feasible for the average dentist and skilled technician; the metals, alloys, and companion materials for fabrication should be plentiful, relatively inexpensive, and readily available, even in periods of emergency.

This list of requirements for the ideal substitute for dental gold alloys calls attention to the fact that a combination of chemical, physical, mechanical, and biological qualities is involved in the evaluation of each alloy; properties depend on material, compositional, and processing factors [1,5].

The study for cast and wrought base-metal alloys, including Co-Cr-Ni, Ni-Cr-iron, commercially pure titanium, Ni-Ti, and Ti-Mo, stainless steel alloys has to be based on the synergistic relationship between processing, composition, structure, and properties of the materials [1,5].

2. SPECIFIC PROPERTIES FOR Co-Cr AND Ni-Cr CASTING ALLOYS

According to ANSI/ADA the weight of Cr should be no less than 20%, and the total weight of Cr, Co and Ni should be no less than 85%. In principle, Cr, Co and Ni, must together account for 82 to 92 wt%.

Alloys with other compositions may also be accepted in respect with the requirements on toxicity, hypersensitivity, and corrosion. Elemental composition to the nearest 0,5% must be marked on the package, along with the presence and percentage of hazardous elements and recommendations for processing the materials.[1]

Cr is responsible in special for the corrosion resistance of these alloys. The Cr content of an alloy, higher than 30%, determine more difficult to alloy casting.

In general, Co and Ni, up to a certain percentage, are interchangeable elements. Co increases the strength and hardness of the alloy more than does Ni. One of the most effective ways of increasing the hardness of Co-based alloys is by increasing their carbon content.

A change in the carbon content of approximately 0,2% changes the properties to such an extent that the alloy would no longer be usable in dentistry. For example, if the carbon content is increased by 0,2% over the desired amount, the alloy becomes too hard and brittle and should not be used for making any dental appliances. Conversely, a reduction of 0,2% in the carbon content would reduce the alloy's yield and ultimate tensile strengths to such low values that, once again, the alloy would not be usable in dentistry.[1, 6]

The presence of 3% to 6% molybdenum contributes to the strength of the alloys. The addition of as little as 1% to 2% beryllium to nickel-based alloys lowers the fusion range by about 100° C. Corrosion resistance is also compromised, as corrosion occurs preferentially in the Ni-Be eutectic phase. [1, 6]

Typical mechanical properties of the partial denture alloys are represented by tensile strength, yield strength, and elongation. The yield strength gives an indication for permanent deformation of alloys intended for removable partial denture restorations. The ultimate tensile strength of cast base-metal alloys is less influenced by variations in specimen preparation and test conditions than are some other properties, such as elongation. The percent elongation of an alloy is important as an indication of the relative brittleness or ductility a restoration will exhibit. There are many occasions, therefore, when elongation is an important property for comparison of alloys for removable partial-denture appliances.

3. MATERIAL. METHOD

To determine the mechanical characteristics for recoverable cobalt-chromium and nickel-chromium cast alloys the experimental research were performed using a mechanical testing machine Lloyd Instruments LRX Plus (precision class 1) with specialized Nexygen soft, that is used for interdisciplinary research concerning a large variety of materials (metal; plastic; horticultural; dental) in Unconventional Technologies and Equipment for Agro-Food Industry Laboratory within Faculty of Horticulture in Craiova. [2, 3]

The study presented in this paper concerns in two free of beryllium alloys:

- Co-Cr alloy, Wirobond C type [4]: 63,3%Co; 24,8%Cr; 5,3%W; 5,1%Mo; rest Si, Fe, Ce;
- Ni-Cr alloy, V alloy type [5]: 72%Ni; 20%Cr; max 6%Fe; 1,5%Si; 0,5%Mn ; max 4%Mo.

The mechanical characteristics recommended by the technical norms (specified in quality certificate) for each of these alloys are presented in Table 1.

Table 1: Mechanical characteristics recommended for Co-Cr alloy and Ni-Cr alloy

Alloy type	Tensile strength, R_m [MPa]	Yield strength 0,2% offset, $R_{p0.2}$ [MPa]	Elongation, (A_5) [%]
Co-Cr alloy, Wirobond C type	min. 720	min. 480	min. 6
Ni-Cr alloy, V alloy type	min. 450	min. 300	min. 4,5

To determine the real specific mechanical characteristics, the dental row material (figure 1) for both alloy type were plastic cold deformed.

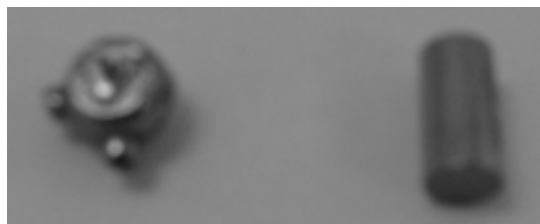


Figure 1: Dental row materials (Ni-Cr alloy, V alloy type; Co-Cr alloy, Wirobond C type)

In case of re-casting must be used only identical alloys. To re-cast Co-Cr alloy, the specific norm recommends to add at least 50 % of new material [4], and to re-cast Ni-Cr alloy, the specific norm recommends to add at least 20 % of new material [5]. For cast or re-cast, the old material must be blasted using only clean ceramic crucibles. To determine the real mechanical characteristics of the cast alloy type, after the first cast, and after re-cast (second cast) the longest sprue pins were cutted from the sprue base (figure 2).



a) Co-Cr alloy
b) Ni-Cr alloy
Figure 2: Dental alloy sprue base and sprue pins, after cast or re-cast process

4. RESULTS

To determine the mechanical characteristics of Co-Cr alloy and Ni-Cr alloy, after the first cast and after the second cast (re-cast), 6 sprue pins ($\varnothing 2,5$) of each alloy were tested.

The mechanical characteristics of Co-Cr alloy in three specific process stages are presented in table 2.

The test graphic for Co-Cr alloy sprue pins after the first cast stage, is presented in figure 3.

Table 2: Mechanical characteristics for Co-Cr alloy

Specific process stages	Maximum force, F_{max} [N]	Tensile strength, R_m [MPa]	Yield strength 0,2% offset, $R_{p0,2}$ [MPa]	Elongation, (A_5) [%]
Initial (commercial)	4013,4	819,1	589,7	7,5
After the first cast	3902,5	796,4	557,2	6,7
After the second cast (re-cast)	3591,5	732,9	498,4	7,7

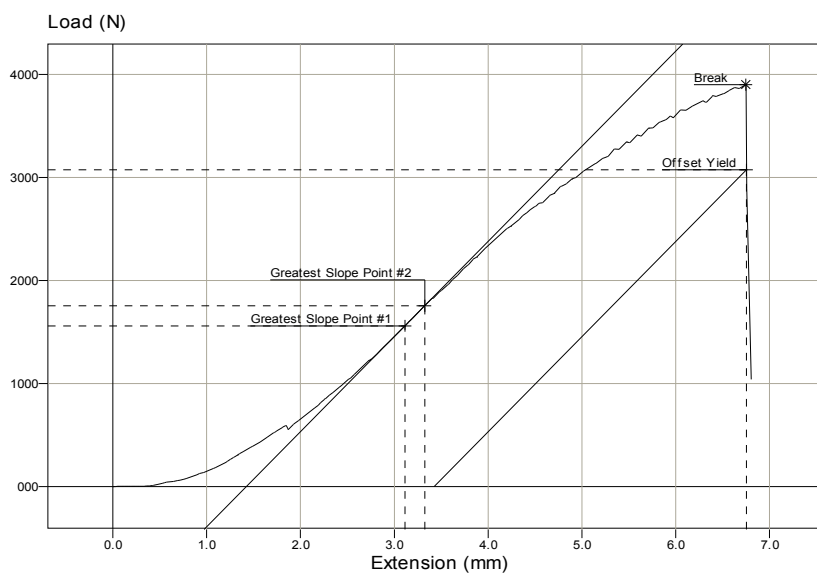


Figure 3: Test graphic for Co-Cr alloy sprue pins after the first cast stage

The mechanical characteristics of Ni-Cr alloy in three specific process stages are presented in table 3. The test graphic for Ni-Cr alloy sprue pins after the second cast (re-cast) stage, is presented in figure 4.

Table 3: Mechanical characteristics for Ni-Cr alloy

Specific process stages	Maximum force, F_{max} [N]	Tensile strength, R_m [MPa]	Yield strength 0,2% offset, $R_{p0.2}$ [MPa]	Elongation, (A_5) [%]
Initial (commercial)	2711,1	553,3	398,4	5,7
After the first cast	2640,3	538,8	377,2	5,4
After the second cast (re-cast)	2257,7	446,8	298,8	4,6

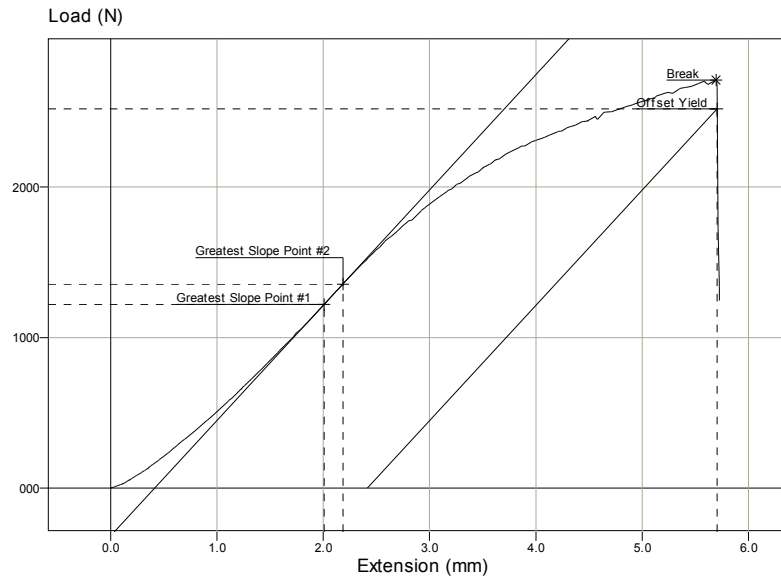


Figure 4: Test graphic for Ni-Cr alloy sprue pins after the second cast (re-cast) stage

5. CONCLUSION

According to mechanical characteristics experimental obtained for cobalt-chromium and nickel-chromium cast alloys, the recovery is possible up to the second cast (re-cast).

After the third cast (re-re-cast) the real mechanical characteristics are less those recommended for minimum values by the alloy technical norms.

Due to the recommended high temperature in dental casting process, and the impurities that can not be totally blasted, the decrease of percentage in alloyed elements can occurred, and supplementary microstructure and chemical laboratory research are necessary to be performed to evaluate the recoverable properties of cobalt-chromium and nickel-chromium cast alloys.

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