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POSSIBILITIES OF IMPROVING THE MECHANICAL PARAMETERS OF THE DENTAL ALLOYS

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Abstract:

In order to obtain metallic restorations with optimal biomechanical properties, it is necessary to transform this structure into a homogeneous solid solution, with fine crystals of equal size.

The optimization of the internal architecture is therefore mandatory for obtaining metallic restorations with high durability over time. The process of optimizing the structures, casting them in to a "cold" mold, is based on the acceleration of the cooling rate, in order to increase the number of crystallization centers, and so getting internal granulations of the smallest size.

For this study we used three different alloys, used for dental fixed restorations: the noble alloy Firmilay (Jelenko), which contains 74.5% gold, palladium 3.5%, silver 11% and copper 10.45%, the alloy based on cobalt-chrome- Brealloy C + B 270 chrome (Bredent), which contains 66% cobalt, chromium 20%, molybdenum 6%, tungsten 6%, silicon 0.9%, carbon 0.02% and manganese 0, 7% and Super Alloy EX-3, a nickel-chromium alloy with nickel in percentage of 59.6%, chromium 23.5%, molybdenum 9.22%, silicon 4.87% and gallium 0.46%. 20 samples were made in each alloy, 10 for the classical casting and 10 for the „cold” mould casting.

The mechanical tests noticed that the samples casted in cold moulds have superior mechanical properties compared to the samples casted by the classical technology.

Key words: dental alloys, melting, casting, cold mould

INTRODUCTION

Metallic dental fixed prostheses are used as therapeutic solution for a various range of clinical situations: inlays, onlays, crowns and bridges. Dental alloys frequently used in practice to realize these appliances are: Chrome- Nickel and Chrome-Cobalt-based alloys [1, 3] The technological flow used to obtain cast frameworks includes several steps: pouring the working casts, the wax pattern carving, the investing and the mold realization, melting and casting the alloy, divesting and finishing.

The chemical behaviour of the alloys influences the oral tissues, the biocompatibility of the metallic prosthetic elements depending on two factors: the chemical composition and the phase structure of the alloy. After melting, casting and welding, at the same sample, changes of the initial structure are noted; When passing from the liquid to the solid phase, crystallization centers appear in to the metal solution: their number generally beeing proportional to the cooling rate. As heat is lost, the amount of solids increases, depositing regularly on the initial crystallization centers and increasing the granulation. The phenomenon continues until the entire amount of material solidifies, resulting in a multitude of granulations, the number of which depends on the initial of crystallization center.

The crystallization of the alloy starts from the center of crystallization, shaped as a tree branch called dendrite. When two or more crystals come into contact, the growth of the branch stops. Finally, the solid solution consists of a plurality of such microcrystals, each crystal being considered from a metallographic point of view a granulation.

In order to obtain restorations with optimal biomechanical properties, it is necessary to transform this structure into a homogeneous solid solution, with fine crystals of equal size. The optimization of the internal architecture is therefore important in order to get metallic restorations with high time durability. In practice, there are a variety of processes for homogenizing the structure of the alloys: heat treatments, changes in the rate of heating of the alloy, changes in the cooling time after casting or the „cold” molding method.

Considering the simplicity of the „cold” molding technology and the possibility of implementing this technique of optimizing the alloy structure in conditions accessible to any dental laboratory, we have proposed in this study a comparative analysis of the mechanical properties of the metal structures cast by the classical technology and by the„ cold” molding method. The process of optimizing the structures, the casting in „cold” moulds, is based on the acceleration of the cooling rate, in order to increase the number of crystallization centers, in order to obtain internal granulations of the smallest size.

MATERIAL AND METHOD:

In our study we used three types of alloys, used for dental fixed restorations: the noble alloy Firmilay (Jelenko), which contains 74.5% gold, palladium 3.5%, silver 11% and copper 10.45%, the alloy based on cobalt-chrome- Brealloy C + B 270 chrome (Bredent), which contains 66% cobalt, chromium 20%, molybdenum 6%, tungsten 6%, silicon 0.9%, carbon 0.02% and manganese 0, 7% and Super Alloy EX-3 and a nickel-chromium alloy with nickel in proportion of 59.6%, chromium 23.5%, molybdenum 9.22%, silicon 4.87% and gallium 0.46%.

From each alloy 20 samples were made, 10 for classical casting and 10 for „cold” mould casting.

The wax patterns were made of blue inlay wax, 2 mm thickness, with the following dimensions: 75 mm length, 12.5 mm width (the extremities) and 4 mm in thickness (the central area), for tensile tests and rectangular wax patters, with a 10 cm length and 3 cm width, designed for the hardness studies. The samples were prepared for investing, by applying the sprues with a length of 8 mm and a diameter of 5 mm, for casting by the classical method and with a length of 5 mm for casting in "cold" moulds.

The samples were invested with investing materials, specific for each type of alloy and in order to obtain the mould, the wax specimens were subjected to preheating and heating procedures.

For classical casting, the mold was heated to a temperature equal to the melting temperature of the alloy, and for cold molding the heating was done at a temperature 300-400 ° C lower than the alloy casting temperature (Table I).

Alloy	**Melting temperature (ºC)**
Firmilay	1040
Brealloy C+B 270	1450
Super Alloy EX-3	1180

Table I : Alloy categories

The melting and casting steps were done with the Ducatron Quatro (Dentotal) device; after cooling the framework was removed from the investment, the spues were removed with separating discs, finished and polished (fig, 1).

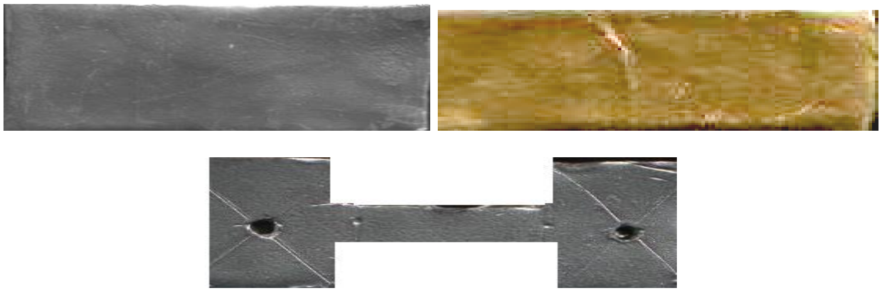

Fig.1 The metallic samples after finishing and polishing

Hardness testing

On the very first step we tested the hardness of the cast samples obtained by the classical casting and after the casting in „cold" moulds. Hardness is an extremely important parameter used in to the comparison of the restoration materials. It can be defined as the resistance to the superficial printing or to penetration; the hardness is, therefore, a resistance measure to plastic deformation and it will be expressed as the force related to the area unit of the print. Hardness indicates the resistance of a material to cracking and to abrasion during mechanical stresses

There are many methods used to determine the hardness. We chosed the Vickers method. This is a static technique of determining the pressure resistance exerted by a diamond pyramid, with the peak angle of 136^{0}. The Vickers hardness was calculated according to the formula:

$$HV = \frac{F}{S} \cdot \frac{2F \sin \frac{136^0}{2}}{d^2}$$

where F is the stressing force, S is the area of the surface left by the penetrator on the specimen and d is the diagonal of the pyramid base. In order to test the Vickers hardness we used the standard Vickers microhardness device

Tensile tests

On the tensile tests, we analyzed the yield stress and the tensile strength. Tensile tests were carried out at room temperature according to the ISO 527-1: 2000 standard, using a computer-controlled testing machine (Instron 3382) equipped with a dynamic clip-on strain gauge extensometer (Instron 2620-601) for direct strain measurement. The rectangular specimens were placed and fixed between the grips of the testing machine (fig.2). The tensile load was applied at a crosshead speed of 1 mm/min. tensile yield (tensile stress at yield) and tensile strength (maximum tensile stress during the test) were determined.

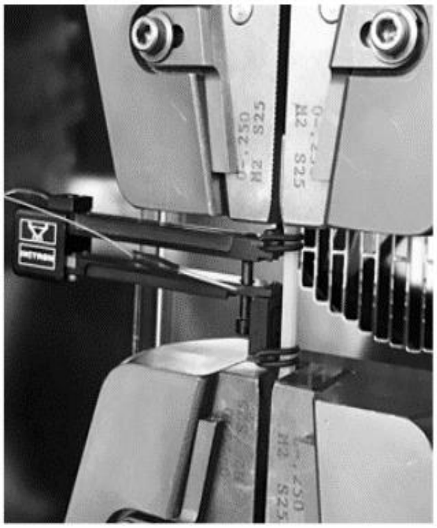

Fig.2 The testing machine

The yield stress is the stress corresponding to the yield point on which the material begins to deform plastically. The yield strength is often used to determine the maximum allowable load in a mechanical component, since it represents the upper limit to forces that can be applied without producing permanent deformation. The higher yield stress limit values, the more fragile the structures will be.

Tensile strength is the maximum load that a material can support without fracture. The elongation of the material can be conventionally divided into two phases: the increase in length of the sample, before the limit of proportionality, which is not permanent and is proportional to the applied force and elongation from the limit of proportionality to the fracture, which is a permanent deformation. The permanent deformation was determined after the end of the test by measuring the dimensional increase between two fixed points of the sample. The elongation (ε) is calculated according to the formula: $\varepsilon = (\Delta L/L) \times 100$, where ΔL is the change in length and L the initial length.

This parameter is very important regardless of the nature of the material and the stress, becasuse each stress is accompanied by strain and elongation.

If the value of the elongation is smaller it means that the deformation of the structure will be lower; so for the metal prosthetic devices, alloys with low values of tensile strengh will be preferred.

RESULTS AND DISCUSSIONS

The values of Vickers micro-hardness, which we noticed in table II, in order to perform a comparative analysis of the data.

Alloy	**Vickers hardness after classical casting**	**Vickers hardness after„cold” mould casting**
Firmilay	182	196
Brealloy C+B 270	270	284
Super Alloy EX-3	335	355

Table II: Hardness values

Hardness tests demonstrate an increasing of this value, in case of cold cast samples, for all types of alloys.

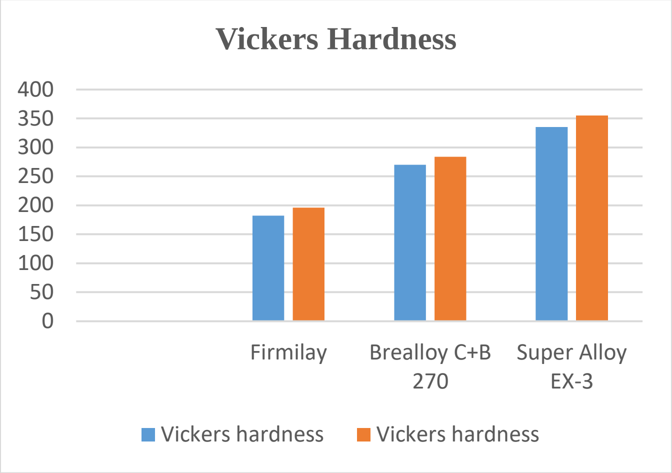

Fig.3 Comparative values of Vickers hardness

Analyzing the yield stress we obtained the following values (TableIII):

Alloy	Yield stress after classical casting (Mpa)	Yield stress after „cold” mould casting (Mpa)
Firmilay	276	254
Brealloy C+B 270	390	310
Super Alloy EX-3	507	497

Table III Yiels stress values

Gold-based alloys have the lowest yield stress value and Ni-Cr type have the highest value, so a higher fragility also. Cold casting reduced the elasticity limit for all three types of alloys, more significantly for Cr-Co-based alloys (fig.4).

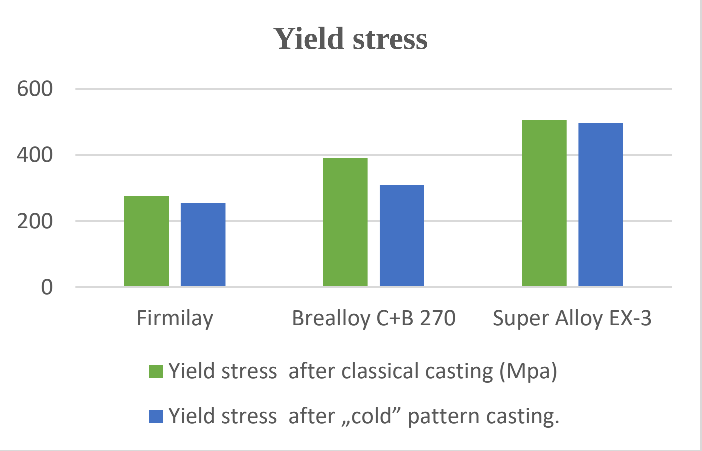

Fig.4 Comparative values of yield stress

The values of the tensile strengh for the three types of alloys were analyzed comparatively, for the both casting methods and we obtained the following data (Table IV):

Alloy	Tensile strengh after classical casting (Mpa)	Tensile strengh after „cold” pattern casting (Mpa)
Firmilay	310	290
Brealloy C+B 270	476	450
Super Alloy EX-3	699	670

Table IV **Tensile strengh values**

After the „cold” mould casting method it was observed the decreasing of the tensile strength values, which means a lower risk of deformation for the prosthetic devices made by this technology (fig.5).

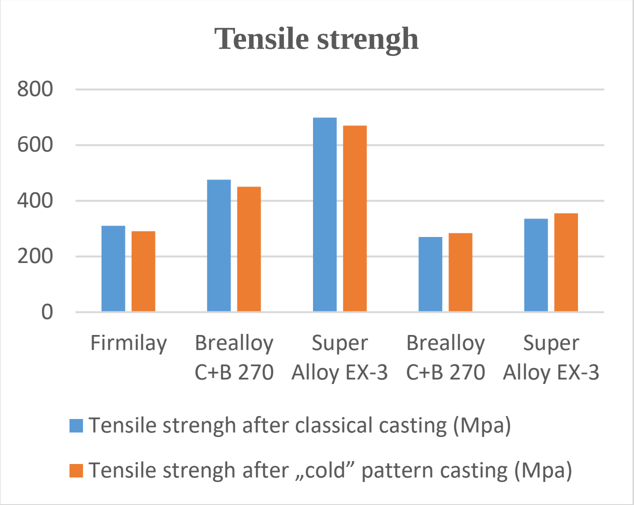

Fig.5 Comparative values of tensile strengh

A homogeneous structure of the alloy offers it a higher level of biocompatibility in the oral cavity; this organized internal architecture is conferred by the small crystalline granulations, evenly distributed in the solid solution. During the cooling process, crystallization centers appear in to the solid solution; the number of these centers depending on several factors: the composition of the alloy, the crystallization rate and the cooling rate being the most important. As the temperature decreases, the amount of solid alloy increases, depositing regularly on the initial crystallization centers, and increasing the size of the granulations. The process continues until the entire amount of alloy solidifies, resulting a multitude of granulations. When the mold is at the same temperature as the molten alloy and the cooling is slow, large grain tends to form. Optimization of the structure of the alloys by casting in "cold" moulds, is based on the acceleration of the cooling rate, in order to increase the number of crystallization centers, to obtain internal grains of the smallest size. The explanation is related to the increasing of the cooling rate, the formation of crystallization centers that is faster than the crystallization, thus obtaining smaller granulations. Smaller the grain size is, a higher quality of mechanical properties will be noticed.

Research shows that in addition to the optimization of the mechanical properties, the samples cast by this method also increase the corrosion resistance of the alloy.

CONCLUSIONS

Studies show that a homogeneous alloy structure, with small crystalline granulations, evenly distributed in the solid solution, will be more chemically stable, thus increasing the biocompatibility of the metal element. During the technological steps of melting and casting, the structure of the alloys changes, becoming less homogeneous, so it is necessary to apply some processes of structure re-homogenization, which will improve the mechanical and biological properties of the alloy.

We focused our research on the possibilities of improving the internal architecture of the alloys, in order to optimize prosthetic devices clinical performances. We also wanted to demonstrate the influence of the casting technology on the alloys structure, and on the mechanical and biological behavior of the dental alloys.

The modification of some technological parameters influences the microstructure and the behavior of the prosthetic constructions.

As a result of the mechanical tests, we noticed that the samples casted in cold moulds have superior mechanical properties in comparison to the samples casted by the classical technology.

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