VARIATION OF THE MORPHOLOGY OF THE DENTAL ALLOYS STRUCTURE UNDER THE EFFECT OF SELECTED COMMERCIALLY AVAILABLE METHODS OF THERMAL PROCESSING

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Abstract

In the paper the differences in the structure of dental alloys have been presented. The observations of the selected commercial dental alloys (Ni-alloy group) structures have revealed the differences in their morphology - depending on the melting and casting conditions. In the paper the four most commonly alloys used in dental laboratories arts are presented.

Keywords: Dental alloys, Ni-alloys, Co-alloys, casting, remelting

1. INTRODUCTION

The dental materials and prosthetic products in all countries of the European Union are subject to special supervision. Their quality and utility must be confirmed by the fulfillment of a number of standards and conditions laid down in the legislation. However, it is interesting, that very high requirements are placed on the chemical composition of the materials themselves and not on their further processing. In the dentistry market the new materials are constantly with improved composition and ease of use are constantly introduced [1-7]. Keep in mind that each of the processing stages contains many parameters that may adversely affect the properties of the material - not only dental materials but all types of metal materials.

Regardless of the possibilities of new materials and keeping in mind their material costs in prosthetic laboratories well-known and well-tested materials are constantly being used, e.g. despite the possibility of using a composite foundation still the main material for prosthetic structures (total prostheses, crown, bridges and veneers) are Ni, Co, Cr and Mo alloys, and in spite of the disadvantages (allergic actions), the relatively cheapest Ni alloys are most commonly used. The largest disadvantage of nickel-based alloys is that nickel ions as a result of corrosion processes penetrate into surrounding tissues, resulting in systemic allergic reactions, and further contribute to inhibit the natural development and regeneration of cells [8-11].

Commercially used Ni-Cr-Mo alloys (part of Remanium group) are designed for metal-ceramic, metallic-acrylic or metallic-composite dental structures, there are characterized by a dendritic structure. It is known that both the dendrites intermetallic composition and phase in interdendritic spaces is determined by the chemical composition of alloy as well as by melting and casting technologies. And a key role in the Ni-Cr-Mo alloys application (in terms of structure, mechanical properties and corrosion resistance) plays a segregation of major alloying elements (Ni, Cr, Mo). Ni-base alloys exhibit a dendritic γ-fcc metastable matrix and precipitates. In interdendritic spaces are located: $M_{23}C_6$ carbides, an intermetallic σ compound and a lamellar phase formed by interlayed plates of $M_{23}C_6$ [12-15]. Increased molybdenum content in the alloy composition causes the strong segregation, and thus enriches the interdendritic areas in Mo [16]. In most Ni-Cr-Mo alloys, the strong segregation of chromium is not observed, but Cr content is a bit lower in interdendritic spaces [16, 17].

In the dentistry one of the basic techniques for forming metallic prosthetic construction is the technique of metallic materials remelting and casting. Regardless of the specialty of the laboratory and the types of remelting technique the casting is done with the centrifugal force. As evidenced by the author's experience the most common techniques for melting/casting in dental technology include those using flame of oxy-acetylene torch as a heat source in a melting process, induction furnace, Volta's arc and the Autocast equipment - a detailed description of each of these methods has been described in earlier work [17]. Due to the parameters of the melting and casting process, it is expected to change in the morphology of the Ni alloy structure. Due to the cooling rate during the production process, and in the absence of a protective atmosphere of melting/casting technique in interdendritic spaces, two morphologies of precipitation may occur. As like in cobalt alloys in interdendritic spaces precipitation may take the form "blocky type" and a "pearlitic type" as a result of the eutectoid reaction [12-14].

The quality of cast is closely connected many factors also with the experience of a dental technician, during the melting/casting of metallic structures as well as with technical equipment. In the more specialized devices (Autocast method) can be used the protective atmosphere, preventing contamination of alloy with other elements. Processes with vacuum reduces the amount of oxide inclusions in the structure, and these contribute to reduced carbon monoxide partial pressure of the metal, which reduces to a minimum the loss of chromium during the refining (the oxidation of oxygen in the metal bath).

The paper is dedicated for microscopic observation of two kinds of Ni-alloys (commercially used). The literature review and observation allowed to characterize the typical dendritic structure of the casting material and allowed to indicate the difference in the material structure after melting/casting with in flame of oxy-acetylene torch, induction furnace, Volta's arc and Autocast method.

2. EXPERIMENTAL

The materials used in this study were the casting alloys: Remanium G and Remanium CSe with a chemical composition presented in **Table 1**. The Remanium G alloy was dedicated to acrylic or composite veneering whilst Remanium CSe alloy was dedicated to ceramic veneering. The metallic material has been melted and then casted using - **Table 2**:

(1) in flame of oxy-acetylene torch,

(2) induction furnace,

(3) Volta's arc,

(4) in the Autocast device.

In all these methods the casting mold was filled with molten metal by centrifugal force. Castings were shaped in discs with a diameter of ø = 10 mm i height *h* = 5 mm (although the casts representing substructure of the crown have slightly different dimensions, in this work the standard shape of the samples were used, to standardize the examination).

Table 1 The chemical composition of commercial Ni-alloys (wt.%)

Commercial Ni-alloy	*Chemical composition* - subscript are percentages mass
Remanium G	$Ni_{66}Cr_{27}Mo_5Si_2$ with low content of Mn and B
Remanium CSe	$Ni_{61}Cr_{26}Mo_{11}Si_{1,5}$ with a low contents of Fe, Co, Al and Ce

Table 2 The samples indicators and characterization of melting/casting technologies

Identification of technology	*Selected method of melting/casting*
(1)	oxy-acetylene torch (ceramic crucible, non-controlled atmosphere)
(2)	the induction furnace (ceramic crucible, non-controlled atmosphere)
(3)	the Volts arc (ceramic crucible, non-controlled atmosphere, 220V)
(4)	the Autocast methods (copper crucible, protective argon atmosphere)

3. RULTS AND DISCUSSION

The dental alloys Remanium G and Remanium CSe have been investigated using an optical microscope AxioImager. Before observation samples surface has been digested in a reagent Mi28Ni at 60 - 90 °C. The optical micrographs exhibited grain boundaries. For better observation the structures have been observed with different magnifications (**Figures 1 to 4**).

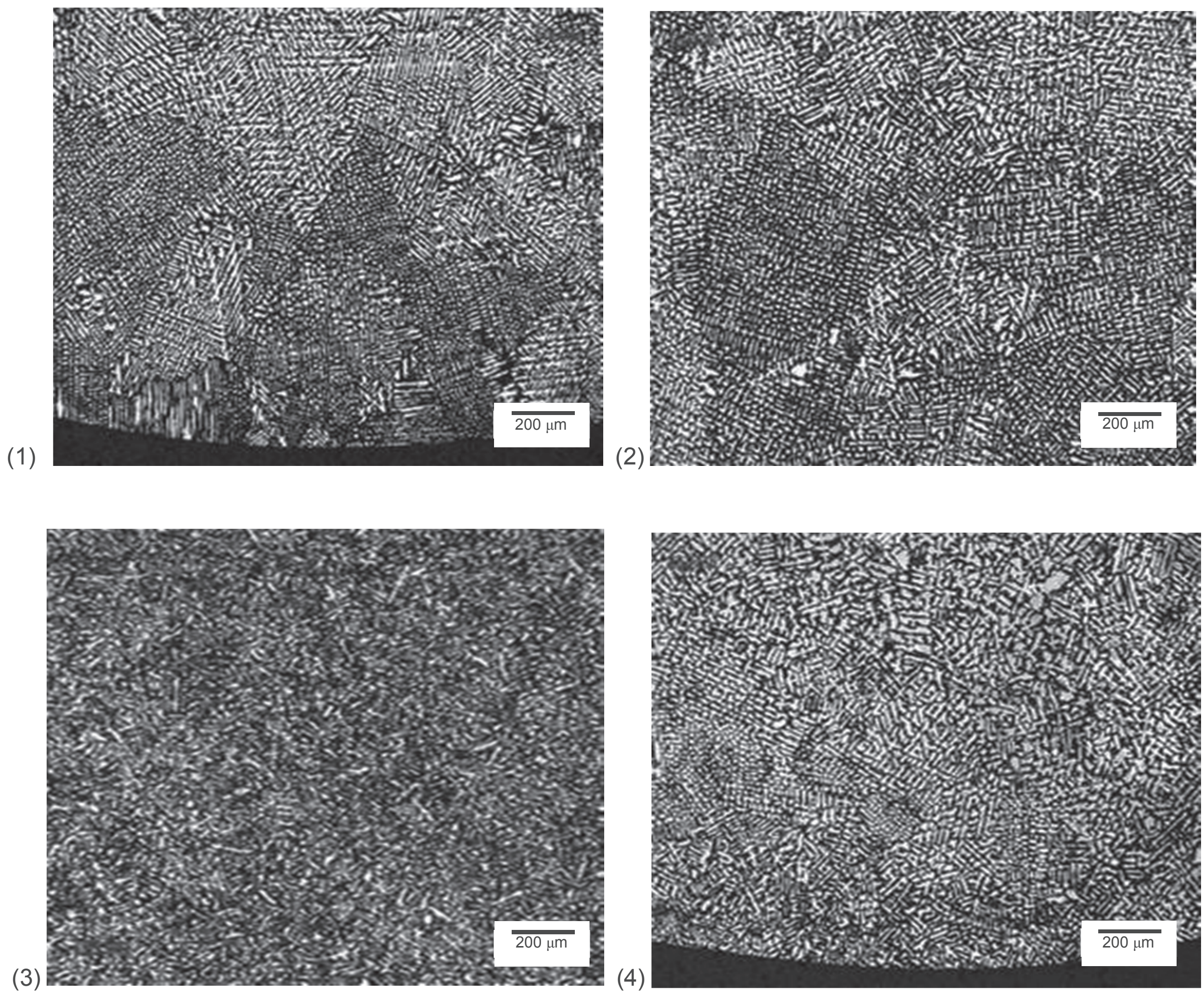

Figure 1 The microstructure images of dental alloys Remanium G ($Ni_{66}Cr_{27}Mo_5Si_2$ with low content of Mn and B) melted and then casted using (1) in flame of oxy-acetylene torch, (2) induction furnace, (3) Volta's arc, (4) in the Autocast device

Observations at small magnifications made it possible to estimate the size of the grains, it is niticeable that their sizes are comparable in four tested samples: melted and then casted using (1) in flame of oxy-acetylene torch, (2) induction furnace, (3) Volta's arc, (4) in the Autocast device, in the structure of Remanium G as well as Remanium Cse alloys.

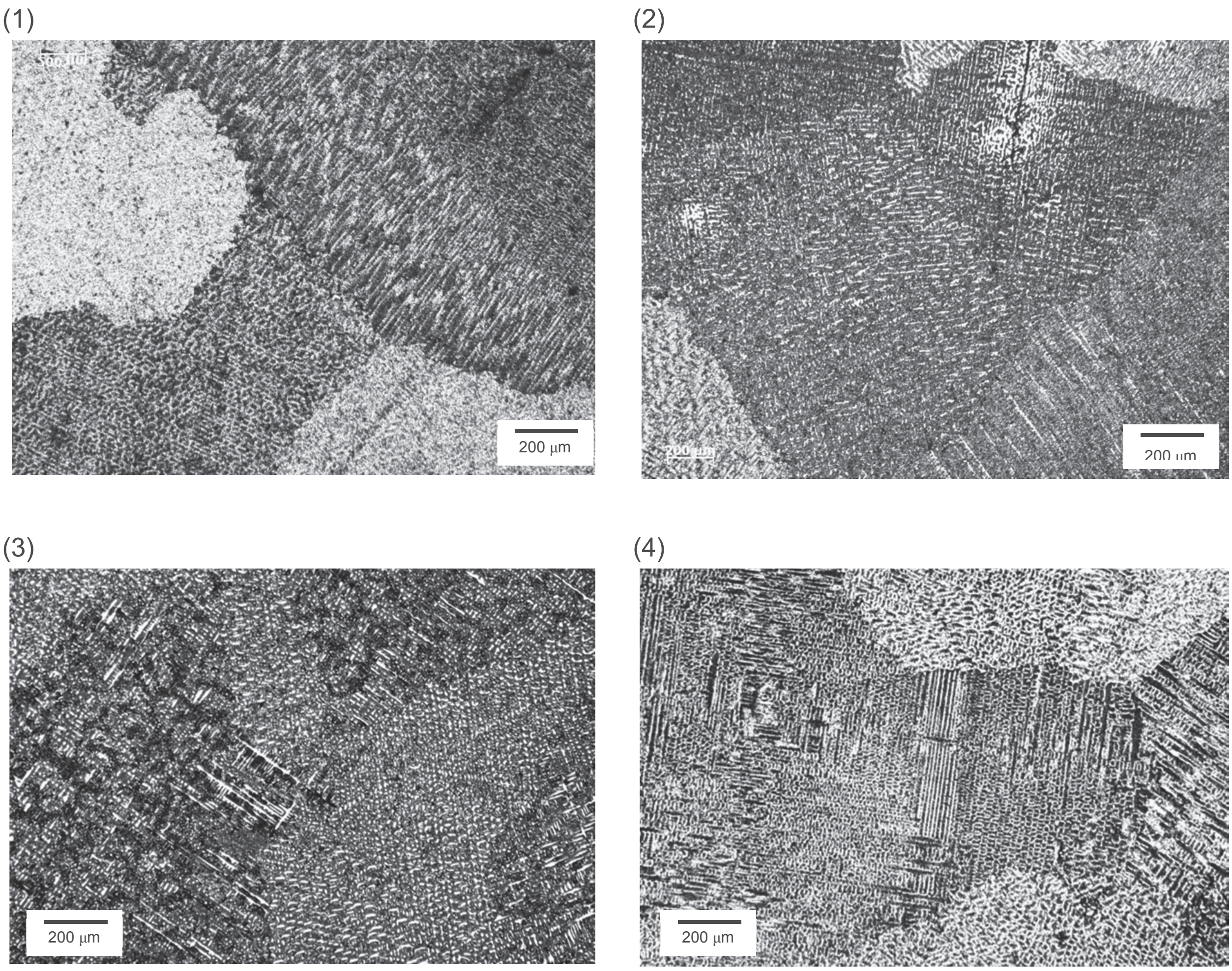

Figure 2 The microstructure images of dental alloys Remanium CSe ($Ni_{61}Cr_{26}Mo_{11}Si_{1,5}$ with a low contents of Fe, Co, Al and Ce) melted and then casted using (1) in flame of oxy-acetylene torch, (2) induction furnace, (3) Volta's arc, (4) in the Autocast device

As it is known from the literature, the dendritic structure is composed mainly of intermetallic γ phase enriched in nickel [18] the content of molybdenum is accountable for the strong segregation - the interdendritic areas are enrich in Mo. In many cases there are observed the interdendritic structures probably formation of the eutectic. In interdendritic spaces precipitation may take the form "blocky type" and a "pearlitic type" as a result of the eutectoid reaction [12-14]. The formation of the eutectic in the case of low rate of cooling and that is a mixture of γ phase (austenite, phase enriched in Ni with stoichiometrical formula $MoNi_3$) and phase P (chemical composition of phases is close to stoichiometry of $Cr_{18}Mo_{42}Ni_{40}$, phase range varies accordingly 31-35 % mass. Ni, 50-58% mass. Mo, 9-18% mass. Cr) [18, 19] - **Figures 3, 4**.

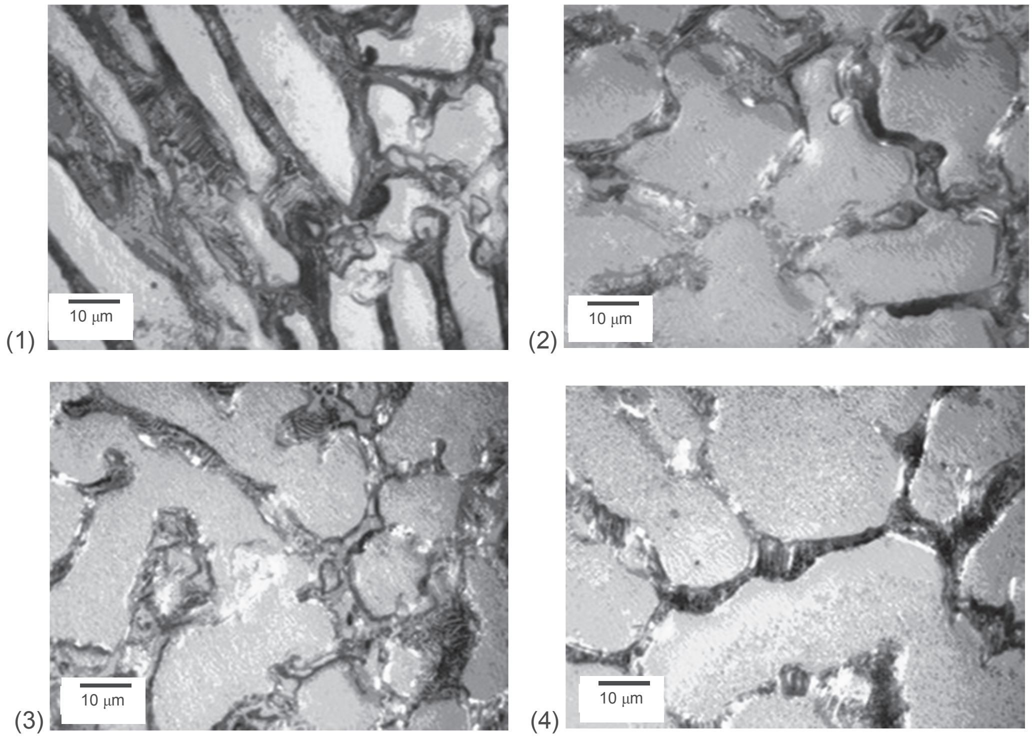

Figure 3 The microstructure images of dental alloys Remanium G ($Ni_{66}Cr_{27}Mo_5Si_2$ with low content of Mn and B) melted and then casted using (1) in flame of oxy-acetylene torch, (2) induction furnace, (3) Volta's arc, (4) in the Autocast device

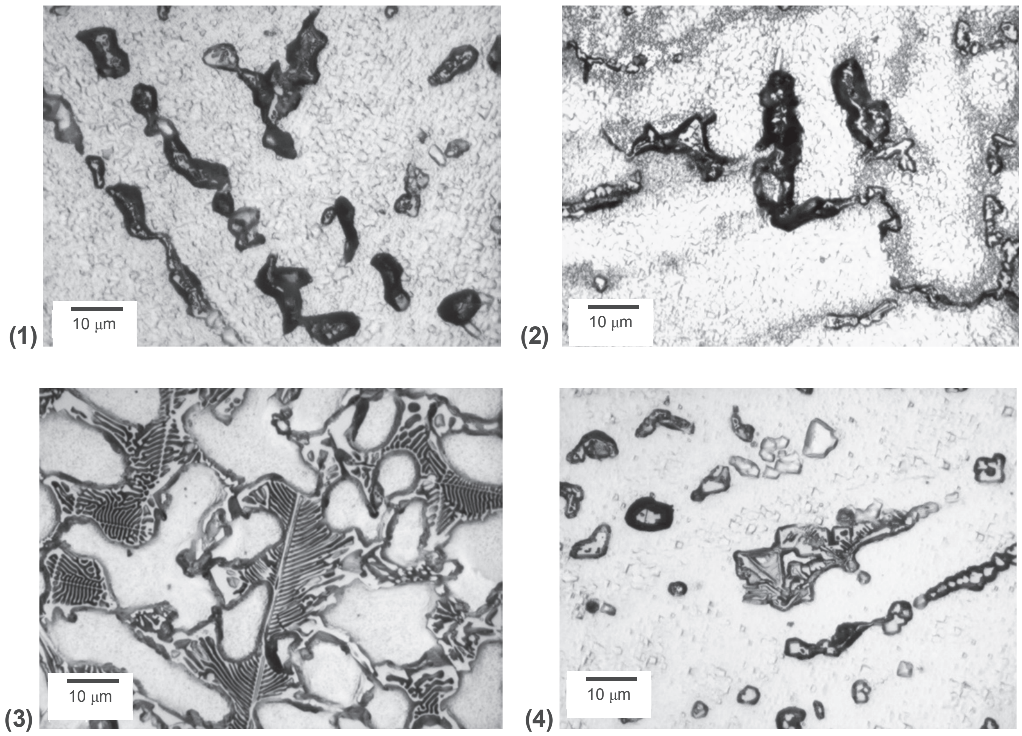

Figure 4 The microstructure images of dental alloys Remanium CSe ($Ni_{61}Cr_{26}Mo_{11}Si_{1,5}$ with a low contents of Fe, Co, Al and Ce) melted and then casted using (1) in flame of oxy-acetylene torch, (2) induction furnace, (3) Volta's arc, (4) in the Autocast device

Due to the higher content of nickel in the Remanium G ($Ni_{66}Cr_{27}Mo_5Si_2$) alloy, it has been observed that regardless of the type of processing method, the austenitic phase occupies a much larger share of the material volume and the interdendritic spaces are definitely smaller. On the other hand, for the Remanium G as well as for Remanium CSe alloy it has been noticed that the interdendritic spaces are filled by the eutectic mixture (in the Ni-Cr-Mo alloys it is usually a mixture of phases γ + P). And a typical example of eutectic mixture can be seen in **Figure 4c.**

4. CONCLUSION

Based on the results presented in this paper (as well as from previous work of the author) conclusions have been drawn. The type of technique for remelting/casting of Ni alloys ($Ni_{61}Cr_{26}Mo_{11}Si_{1,5}$ and $Ni_{66}Cr_{27}Mo_5Si_2$) has a significant effect on the material structure. The obtained images of the Remanium G alloy and of the Remanium CSe alloy microstructure revealed two or more phases. Observing the dendritic structure of alloys melted/casted with four techniques, it must be noted that the dendrites lines and grains system was compatible with the direction of heat rejection. There was the elements segregation, although the separation was most similar to a regular, their distribution was irregular over the entire observed area. There were differences in the morphology of the basic alloy phases. The main differences were primarily the share of the main phase (size of dendrite axes) and morphology of precipitates in interdendritic spaces. Samples prepared with Volta arc were characterized by greater amounts of impurities and the presence in the interdendritic spaces precipitation in the form of "blocky type" and a "pearlitic type".

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