

# Surface Characterization of Some CoCrMo Alloys Used in RPD Technology

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*Aim of study was to compare the processed surfaces of removable partial dentures (RPD) made of different dental alloys of CoCrMo, because processing and finishing of these prostheses is difficult and can cause failures. There were used 4 types of CoCrMo alloys to achieve 50 RPD frameworks. Out of these, 12 were selected with no visible defects, in which the processing was minimum and subsequent adaptation optimal. These were tested in terms of composition, mechanical properties and then analyzed on metallographic microscope, stereomicroscope and Atomic Force Microscope (AFM), both in terms of quality and quantity. Analysis of investigation results showed that among the different CoCrMo alloys obvious differences occur in the processing by cutting - milling with hard cutters both at the reverse metallographic microscope and stereomicroscope. At the qualitative analysis AFM it can be observed that alloy "C" and HERAENIUM CE resemble in milling processing terms, presenting a waved aspect given by the striations parallel to the milling direction. At Wironit alloys and especially Wironit Extrahard it can be observed multiple aciculate bristles (spines) while polishing, which suggests a macroscopic distribution in surface of some tougher (harder) particles. This study allowed highlighting the following conclusions: metal alloys processing is very important for a good functioning of the prosthesis; the alloy Heraenium EC is the most suitable for the finest polishing, which is less used to manufacture RPD; it appears that alloy "C" has a better behaviour during processing than Wironit Extrahard.*

**Keywords:** processing, RPD, analysis

In dental restorative technique the main aim is to use materials with a range of biological, biomechanical and bio security characteristics, as efficient as possible. Replacement solution of noble alloys type AuPt with other cheaper led to appearance on market of the dental alloys from CoCr system, comprising a number of biocompatibility conditions [1-3]. Studies on CoCr alloys started from existence of advanced cutting tools of cobalt alloys resistant to corrosion and oxidation (patented by Elwood Haynes in 1907), named Stella, after the Latin word stella (star), due to the glittering aspect. They were followed by the development of foundry alloys that could be used for: removable partial dentures, and frameworks for ceramic prostheses [3,4]. Then, in the '30s there were made alloys usable for implants (imposed initially by the Austenal laboratories). They comply with ISO 22674 standards in 2006 that define the mechanical properties of alloys usable for framework prosthetics type 4 and 5: (total elongation A: 2% and conventional limit of elasticity: Rp0 de 360-500) and testing modalities as the standards ASTM F 75, ASTM F 799 and ASTM F 562 require [5].

The RPD manufacturing technology implies many working stages. After RPD metallic framework design and casting, during deflasking and surfaces processing, this can be damaged and cracks can appear. Usually, metal alloys processing is made by cutting with hard milling drills, then there is a pre-polishing with gums, followed by final polishing [6,7].

## Experimental part

### Materials and methods

There were selected 12 RPD frameworks out of 50, made by the classic method of casting from 4 types of CoCrMo cast alloys: "C" alloy, WIRONIT Germany and HERAENIUM

CE Germany. Out of 50, there were selected 12 with no apparent defects, in which the processing was minimum and subsequent adaptation optimal. Melting/Casting was achieved with ORCICAST M Hungary high frequency current casting device. After the dentures processing, there were made some observations with help of Inverted Metallurgical Microscope Italy, stereomicroscope Olympus SZX7, equipped with image processing soft Quick-photoMicro 2.2 and Atomic Force Microscope (AFM) on selected areas of about 40x40µm<sup>2</sup>.

Framework processing stages of the RPD are presented in figure 1.

## Results and discussions

Chemical composition of cobalt alloys, determined by spectral analysis and used in our experiments is shown in Table 1. Mechanical properties of the experimental alloys, determined in accordance with standard specifications are given comparatively in table 2.

Analysis of the results in table 1 revealed that the selected alloys for investigation are in accordance with brand prescriptions. Also, the results in table 2, referring to mechanical characteristics values, the selected alloys fall into recommendations regarding brand prescriptions in all the analyzed situations. Microscopic analysis of surfaces processed by milling, as well as the polished surfaces allowed obtaining some information regarding the immediate assessments of the processing quality without being invasive. By macroscopic analysis, we observed that the microscopic aspect of Wironit is similar to that of "C" alloy, in some working stages (sandblasting- fig.2 a, d; polishing- fig.2 c, f). A noticeable difference between microscopic aspects of these 2 alloys appeared in the grinding stage (fig.2 b, e).

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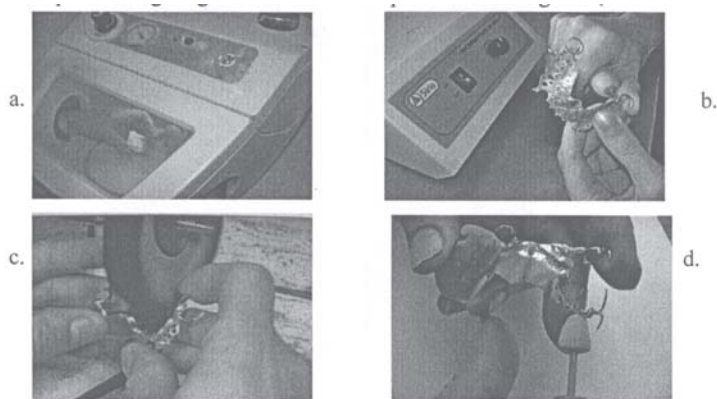


Fig. 1. Different RPD manufacturing stages:  
a.sandblasting; b. grinding, c.surface finishing  
with cotton mop wheel and polishing agent;  
d. rubber polishing

**Table 1**  
CHEMICAL COMPOSITION OF COMMERCIAL DENTAL ALLOYS INVESTIGATED IN THE PRESENT STUDY

Alloy Co-Cr-Mo	Chemical composition / technical prescriptions, %gr						
	C	Si	Mn	Mo	Cr	Mg	Co
Alloy "C"	0.35/ 0,4	1.22/ 0.35	0.5/ 0.4	6.8/5	37.56/29	0/0	54.11/65
Heraenium CE	0.33/ 0,3	0.98/1.0	1.29/ 0.6	9.20/6.6	33.50/27.8	0/0	55.04/63.5
Wironit	0.37/ 0,4	1.69/1.0	1.73/ 0.4	9.39/5	34.15/28.6	0/0	53.04/64
Wironit extrahard	0.36/ 0,4	1.53/1.0	2.23/ 0.4	6.66/5	35.25/30	0.50	53.37/65

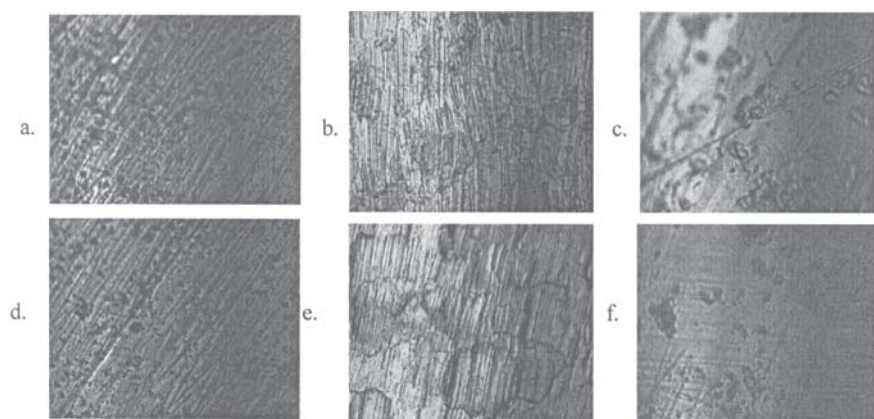


Fig. 2. Microscopic aspects of manufacturing stages at Inverted Metallurgical Microscope:  
a. Wironit sandblasting aspect; b. Wironit grinding aspect; c. Wironit polishing aspect;  
d. "C" alloy sandblasting aspect; e. "C" alloy grinding aspect; f. "C" alloy polishing aspect

**Table 2**  
MECHANICAL CHARACTERISTICS VALUES OF COMMERCIAL DENTAL ALLOYS INVESTIGATED IN THE PRESENT STUDY

Alloy	Obtained mechanical proprieties /Recommended mechanical proprieties		
	Young's elasticity modulus <b>E [MPa]</b>	ultimate tensile strength, <b>R<sub>m</sub> [MPa]</b>	Total Elongation, A [%]
Alloy "C"	236580	751.41	1.47
Heraenium CE	223450	835.66	2.16
Wironit	202520	741.66	1.94
Wironit Extrahard	235870	857.89	2.33

Evaluation at the Olympus stereomicroscope reveals similar aspects to the ones obtained at the metallographic microscope for the four experimental cobalt alloys investigated.

The macrostructural aspects of the four experimental alloys are shown comparatively in figure 3. Note the fact that, after sandblasting, some obvious gashes (crevices) occur in the metal, generally spherical (fig. 3a, e, i, m). They disappear after further processing though. In case of grinding, the metallic material surface becomes covered by some rough parallel treads, as evidenced by the images in figure 3 (b, f, j, n). After milling, the rubbed surface begins to be covered by areas with small bumps, all

oriented parallel to the direction of milling force (fig. 3, c, g, k, a). After polishing (fig. 3, d, h, l, p), all the bumps disappear, the surface having a glossy bright characteristic. In this case, there are highlighted only some possible non-metallic inclusions existing on surface.

Then followed an isometric representation of surface topography for CoCrMo alloys tested both qualitatively and quantitatively after milling and after polishing through the Atomic Force Microscope (AFM) (fig. 4). For this, there were selected areas of 40x40µm<sup>2</sup>.

The qualitative information focused on representation of heterogeneity distribution after processing, while the

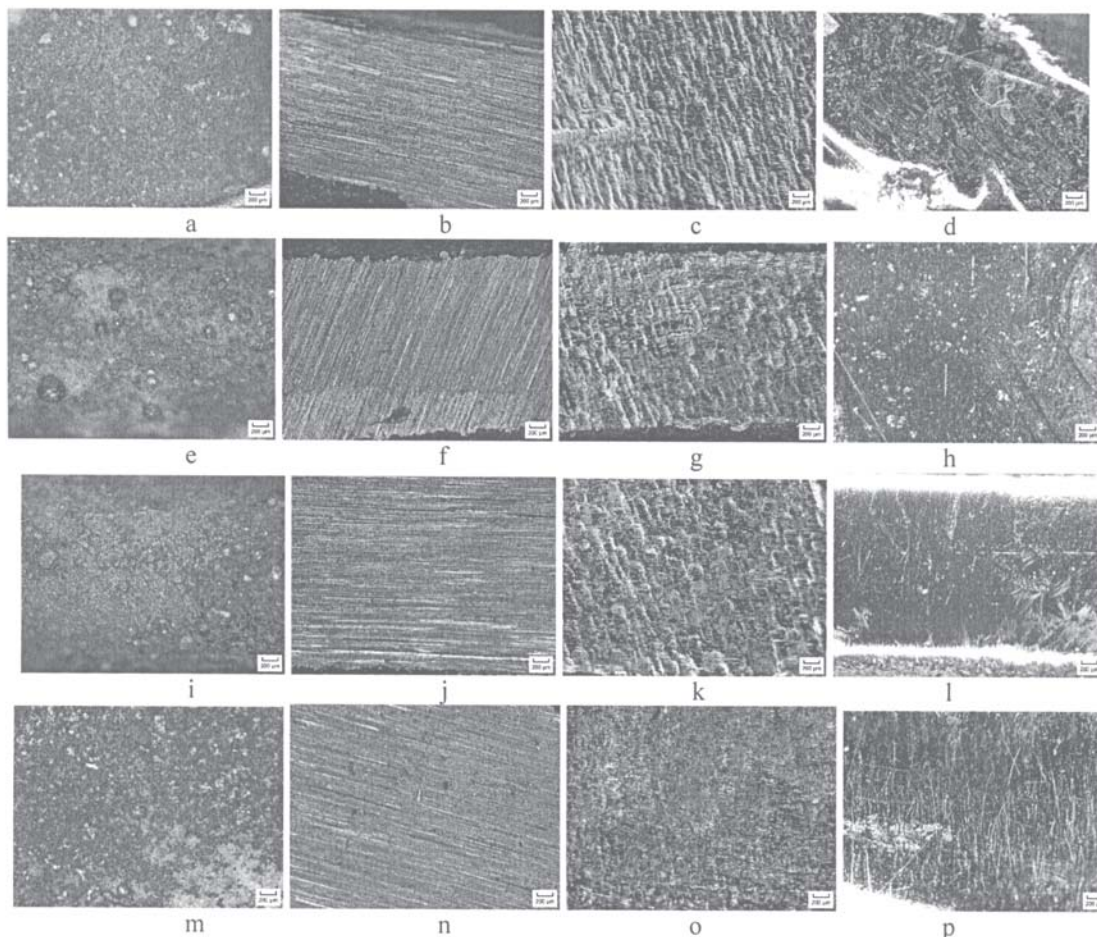


Fig.3- Macrostructural aspects of experimental cobalt alloys: alloy "C" (a,b,c,d ), alloy Heraenium CE (e,f,g,h), alloy Wironit (i,j,k,l), alloy Wironit Extrahard (m,n,o,p), after various transformations of surfaces: sandblasting (a, e, i, m), grinding (b, f, j, n), milling (c, g, k, o), polishing (d, h, l, p)

quantitative information on measurements of surface roughness. Isometric representation by AFM of surface topography for CoCrMo alloys is shown in figure 4.

On each left-hand images there are represented the milled surfaces, and the polished surfaces on right. If in the milled samples images are noticed that waved aspect, given by the striations parallel with the milling direction, on the polished surfaces one can see a relatively flat surface.

Along the striations, uneven spherical formations can be seen with an average diameter of 1-3  $\mu\text{m}$ . It can be seen that polishing does not provide a perfectly flat surface and that here and there (on some areas) appear protuberances, which suggests a macroscopic distribution in surface area of some harder particles.

The rugosity is expressed by the average arithmetic deviation of rugosity  $R_a$ , which represents the average value of the successive points' heights of the profile. Results of rugosity measurements are shown in figure 5. The analysis of rugosity values allowed obtaining the following observations:

- for all alloys, the rugosity values after milling are much higher than those after grinding, having a ratio of about (4÷5):1,

- depending on alloy, it can be established a hierarchy regarding the behavior at rugosity: alloy "C" has the lowest values of rugosity for both states, followed by Heraenium alloy, Wironit alloy and Wironit Extrahard (which has the highest rugosity values for both analyzed states milled/grinded).

Alloys type CoCr have been imposed since the '30s in performing fixed and removable dentures. This is because

their optimal mechanical properties, similar to those of platinized gold, and even sometimes better such as: modulus of elasticity two times higher than those of the noble alloys, less density than the latter ones, their rigidity at relatively small sizes, a lighter weight of the prosthetic work, a good fusibility, good resistance to corrosion [8-10]. Besides the positive aspects, the processing difficulties are well-known, especially by splinting with drills, caused by this type of alloy hardness. Knowing all these, we can intercede in the future either to correct the material composition or the performing technology of dentures [11-13].

At a RPD is required both external and internal polishing of the metallic framework [2,7]. A special consideration should be paid to adaptation and finishing of metal components, since the transition from a retentive framework to a non-retentive one is fast bringing serious problems in supporting of RPD. Above all these, the existing material defects visible or hidden must be considered too, which can cause the failure to achieve a good prosthetic work.

Therefore, nowadays the emphasis falls mainly on the structural analysis [7,10,13], on the non-invasive assessments such as the finite element method for predicting or detecting optimization variants and failure elimination in dental technology and dentistry [14,15].

After the major problem of rugosity is related to the casting system and to the imposed requirements, but also to the composition. An increased rugosity leads to a longer and more difficult processing [6-8, 11].



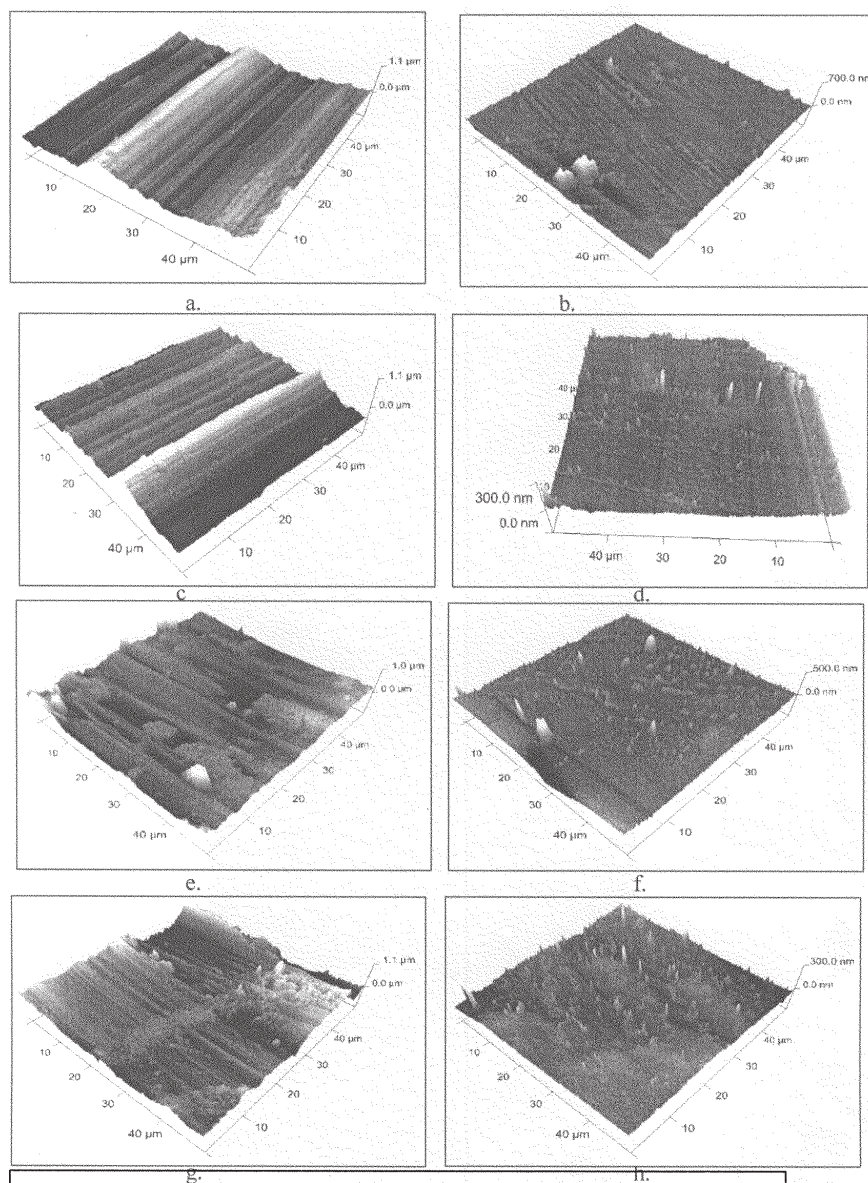


Fig. 4. Isometric representation through AFM of the surface topography for CoCrMo alloys: a. Alloy "C"; b. Heraenium CE; c. Wironit; d. Wironit Extrahard

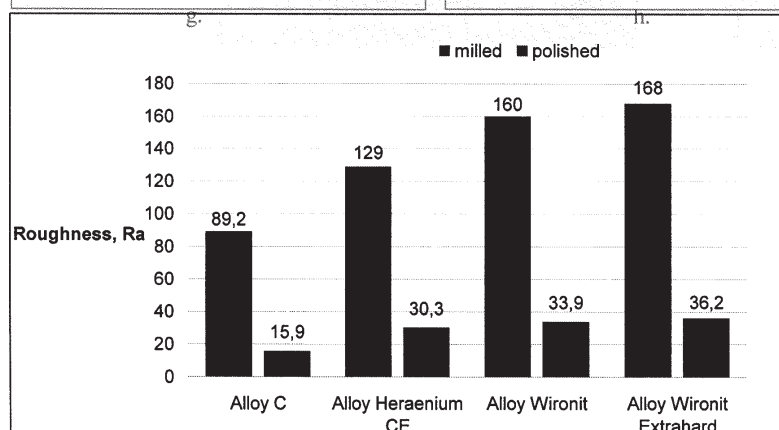


Fig. 5. The standard deviation values of surface roughness after milling and polishing the experimental alloys of cobalt

Structural analysis includes the applied mechanics domains too, materials science and applied mathematics to calculate a structure of deformations, internal forces, stresses, support reactions, acceleration, and stability [8,9]. Structural analysis is thus a key part of structures design. The results of such analysis typically include the support areas, stress and displacement. There are three approaches of analysis: mechanical – materials resistance, approaching the elasticity aspects and using the finite element method.

Each method has its limitations due to simplification of reality. For that matter, the known or usable data are very important to have as few errors as possible. Analyzes

obtained in these investigations are consistent with research literature, also having a novelty by obtaining some comparative data, as well as by joining the macrostructural results with those from AFM microscope [9].

## Conclusions

Comparative investigations of some cobalt alloys used in current practice of dental offices, respectively alloy "C", Heraenium CE alloy, "Wironit" alloy and "Wironit Extrahard" alloy allowed formulating the following conclusions:

- the comparative macrostructural aspects highlighted at stereomicroscope are similar for the four experimental alloys:

- after sandblasting, some obvious gashes (crevices) occur in the metal, generally spherical, which disappear after further processing though,

- after grinding, the metallic material surface becomes covered by some rough parallel treads,

- after milling, the rubbed surface begins to be covered by areas with small bumps, all oriented parallel to the direction of applied milling force,

- after polishing, all the bumps disappear, the surface having a glossy bright characteristic, emphasizing only some possible non-metallic inclusions existing on surface.

Isometric aspects of the investigated alloys are similar: in case of the milled surfaces there can be noticed a waved look, given by the parallel striations with the milling direction, and on the polished surfaces we can observe a relatively flat surface.

Polishing does not provide a perfectly flat surface, on some areas appear protuberances, suggesting a macroscopic distribution in surface of some harder particles.

For all alloys, the rugosity values after milling are much higher than those after grinding, having a ratio of about  $(4 \div 5):1$ .

Depending on alloy, it can be established a hierarchy regarding the behavior at rugosity: alloy "C" has the lowest values of rugosity for both states, followed by Heraenium alloy, Wironit alloy and Wironit Extrahard (which has the highest rugosity values for both analyzed states milled/grinded).

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