Morphological Analysis (SEM) of the Surface of a Non-Noble Dental Alloy SubJECTED TO Electrocorrosion

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Abstract. Corrosion consists in the degradation of a material under the chemical or electrochemical action of the environment where it is placed. The investigations carried out aimed to show the structural modifications produced in Co-Cr-Mo alloy, Robur 400 (Eisenbacher Dental – Waren ED GmbH, Germany) subjected to electrocorrosion in Fusayama-Mayer artificial saliva. The specimens prepared by mechanical polishing were analysed structurally by using a scanning electron microscope. During the tests run we could notice a general corrosion of the surfaces of the specimens made from Robur alloy. Through 2D and 3D microscopy and qualitative determinations of the luminous variation we could notice the effects of electrocorrosion tests on the surface of the metal material.

1. Introduction
In the 1970s, as the price of gold was going up significantly, a cheaper alternative, namely the cobalt-chrome alloys, was introduced in the market of dental materials. Thanks to the modern technology of vesting and polishing, cobalt-chrome-based dental alloys are widely used today in dental prosthetics to make skeletonized removable partial dentures. These alloys also have indications for the making of fixed restorations [1].

Co-Cr-based alloys represent an advantageous alternative as compared to the Ni-Cr-based alloys due to their biocompatibility and the lack of allergic reactions that the latter may develop. At the same time, Co-Cr-based alloys have an increased hardness as they are very resistant to corrosion due to chrome which forms a protective oxide coating on the alloy surface [2,3,4,5].

Since metal biomaterials are subjected to an intense corrosive attack after they have been introduced in the environment of the human body, the resistance to corrosion represents an important quality of them.

2. Goal
The goal of this study consists in determining the structural modifications taking place in Co-Cr-Mo alloy, Robur 400 (Eisenbacher Dental – Waren ED GmbH, Germany) used in the metal components of the skeletonized removable dentures following electrocorrosion in Fusayama-Mayer artificial saliva.
3. Materials and method

The semi products from non-noble dental alloy under study were purchased from the manufacturing companies and they have values of the chemical composition, physical and mechanical properties in accordance with the product’s technical sheet.

As for the chemical composition, we may notice that the material exhibits the features of a complex alloy as it has a high number of alloying elements (table 1).

| Alloy trade name | Chemical composition, [ % ] | Technical norm |
|------------------|-----------------------------|----------------|
| Robur 400        | Co  -29.10 Ni  5.85 Cr 5.85 Mo 0.72 Ti 0.48 Nb 0.57 Al 0.52 W 0.52 Si 0.52 Mn 0.52 | DIN EN ISO 22674:2007 |

For the experimental researches we made specimens from the alloy mentioned above in the shape of cylinders that were mounted in Teflon holders (figure 1).

![Figure 1. Robur alloy.](image)

The specimens prepared this way were analysed structurally. For this we used an electron scanning microspore. Then they were subjected to electrocorrosion tests in Fusayama-Mayer artificial saliva (table 2). To identify the structural modifications taking place in the alloy following the corrosion process, we repeated the microscopy tests.

| Artificial saliva Compounds | NaCl g/l | KCl g/l | NaHCO₃ g/L | Urea g/L | CaCl₂ g/L | NaH₂PO₄ H₂O g/L | Na₂S g/L |
|----------------------------|----------|---------|------------|---------|-----------|------------------|---------|
| Fusayama                   | 0.4      | 0.4     | 0.69       | 1       | 0.65      | 0.69             | 0.05    |

The pH of the solution was measured by a multi-parameter analyser of CONSORT 831C type, and the pH value of Fusayama Mayer saliva was 7.

4. Results and discussions

Robur experimental alloy was polished before the corrosion resistance test by means of metallographic paper having granulation between 200 and 2000. The surface of the material is given in figure 2.

We may notice a poor highlighting of the microstructure, figure 2 a), and we mention that no chemical attack was performed on the surface of the metal alloy.
In figure 2 b) we present the 3D state of the alloy surface after polishing with a slight difference, below 3-4 µm, between the dendritic phase, which is a level higher and is characteristic to the alloy, and the rest of the metal matrix. The difference occurred due to the different response the two phases had to the mechanical polishing stress.

![SEM microscopies of Robur alloy before the electrocorrosion test a) 2D, b) 3D and c) variation of luminous intensity on surface.](image)

**Figure 2.** SEM microscopies of Robur alloy before the electrocorrosion test a) 2D, b) 3D and c) variation of luminous intensity on surface.

In figure 2 c) we present a variation of the luminous intensity on the surface of the metal material given by the difference of composing phases of the alloy and obtained by microscopy based on VegaTescan analysis software and the registered spectrum of secondary electrons. We may notice small variations of the luminous intensity on the surface ranging between 50 and 70 ADU (adimensional units).

After having run the electrocorrosion test in the experimental conditions specified above, the surface of the corroded material is presented in fig.3. We may notice a serious and generalized corrosion of the material, figure 3 a), with the formation of cracked films of material, figure 3 b). The dendritic compounds remained stable, figure 3 b), and the cracked pellicular corrosion product formed only on the rest of the metal matrix. The cracking of the pellicular coating is general and the coating is relatively stable when rinsed under water.
Figure 3. Images of Robur alloy surface after the corrosion test, a) 2D – 500x, 
b) 2D – 5000x, c) 3D and d) variation of the luminous intensity.

The state of the surface after the formation of the corrosion compounds is presented also through 3D micrography in figure 3 c), where we may see a layer 2-3 µm thick and its tendency of exfoliation from the surface of the basic metal material. From the variation of the luminous intensity in figure 3 d), also confirmed by the 3D image of the surface, we may notice that the layer formed on the surface of the metal matrix is smaller than the remained dendritic phases highlighted while preparing the specimen by polishing. In this case, variation was about 200 ADU (adimensional units).

5. Conclusions
We analysed a Co-Cr-Mo-based dental alloy with applications in the field of dental prosthetics, before and after an electrocorrosion test run in electrolytic solution of Fusayama artificial saliva.

The specimens from the selected alloy prepared by mechanical polishing are characterized by two chemically different phases, one being the metal matrix, and the other of dendritic type.

After the running of tests, we noticed a general corrosion of the surface of the metal material, Robur alloy presenting a stable layer on the surface with numerous fissures and exfoliations mainly made of oxides.

Through 2D and 3D microscopy and qualitative determinations of the luminous variation, we could see the effects of the electrocorrosion tests on the surface of the metal material.

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