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Behaviour of a CoCrMo Implant Alloys in Ringer´s Type Solutions Studied by Electrochemical and Surface Analysis Techniques

J. C. Mirza Rosca*, A. Santana López** and D. Mareci***

*Dept. of Mechanical Engineering, University of Las Palmas de Gran Canaria, Tafira, 35017, Spain
**Dept of Processing Engineering, University of Las Palmas de Gran Canaria, Tafira, 35017, Spain
***Chemical Engineering Faculty, Technical University ¨Gh. Asachi¨, 300050, Iasi, Romania

Metallic materials play an essential role in assisting with the repair or replacement of bone tissue that has become diseased or damaged. Metals are more suitable for load-bearing applications compared with ceramics or polymeric materials because they combine high mechanical strength and fracture toughness. However, the main limitation of these metallic materials is the release of the toxic metallic ions that can lead to various adverse tissue reactions and/or hypersensitivity reactions. The most important components of these alloys are: nickel, cobalt, chromium, cooper, iron and titanium. The most commonly used base metal alloys in dentistry are Ni-Cr and Co-Cr alloys. One of the main applications of Co-Cr alloys is in dental skeletal structures and orthopedic implants such as screws, pins and plates. When metal alloys are used as implants, a comprehensive knowledge of their effect on the surrounding tissues is required. For example, the oxidation of Co-Cr-Mo may produce soluble Co and Cr species, which can be released to the neighbouring tissues. Depending on the nature and concentration of such chemical species, several adverse reactions may take place, including cytotoxicity, allergic and carcinogenic effects, irritant reactions1 and local symptoms in gingival when used as dental implants.

In this paper the electrochemical behaviour and corrosion resistance *in vitro* of a two Co-Cr-Mo alloys: Vitallium (63.8%Co 28.5%Cr 6%Mo, Bego-Germany) and VeraPDI (63.5%Co 27%Cr 5.5%Mo 2%Fe 1%Ni, Aalba Dent, USA) was studied. The corrosion medium was an Ringer´s type solution having the composition: NaCl – 6.8 g/L, KCl – 0.4 g/L, $CaCl_2$ – 0.2 g/L, $MgSO_4 7H_2O$ – 0.2 g/L, $Na_2HPO_4H_2O$ – 0.14 g/L, $NaHCO_3$ – 1 g/L, glucose – 1 g/L and pH = 6.8. The corrosion behaviour was studied by potentiodynamic polarization and electrochemical impedance spectroscopy (EIS). The microstructure and surface condition after corrosion measurements was evaluated by Optical Microscopy.

It can be see in Figure 1 that Vitallium and VeraPDI cast alloys surface showed a dendritic microstructure, a rippled structure between the matrix and particle phases. Plots in a semi-logarithmic version between -600 mV and +1200 mV SCE of the Vitallium alloy maintained 1 min, 1 hour and 24 hours in Ringer´s type solution are displayed in Figure 2. Figure 3 shows in linear representation the part of the polarisation curve for VeraPDI alloy maintained 1 min, 1 hour and 24 hours in Ringer´s type solution, in the scale of anodic currents comprising between 0 and 500 $\mu A/cm^2$. This helps to visualise the breakdown potential (E_{bd}). The experimental impedance data for VeraPDI, at open circuit potential (E_{OC}), with the alloy at different intervals of electrode immersion are presented as Bode plots in Figure 4 and the equivalent circuit (EC) used to fit the experimental data is presented in Figure 5.

The good corrosion resistance of the CoCrMo alloys in Ringer´s type solution is due to the highly protective passive (oxide) film that is the key factor for its compatibility. All the alloys translated directly into a stable passive region, without exhibiting the traditional active-passive transition. Very low corrosion current densities were obtained for all the samples tested in Ringer´s type solution showing that they are passive in this electrolyte. For all the samples the corrosion currents decrease (polarisation resistance increase) with increasing immersion time probably because of the surface passivation. The EIS results show that CoCrMo alloys exhibits passivity at open circuit potential.

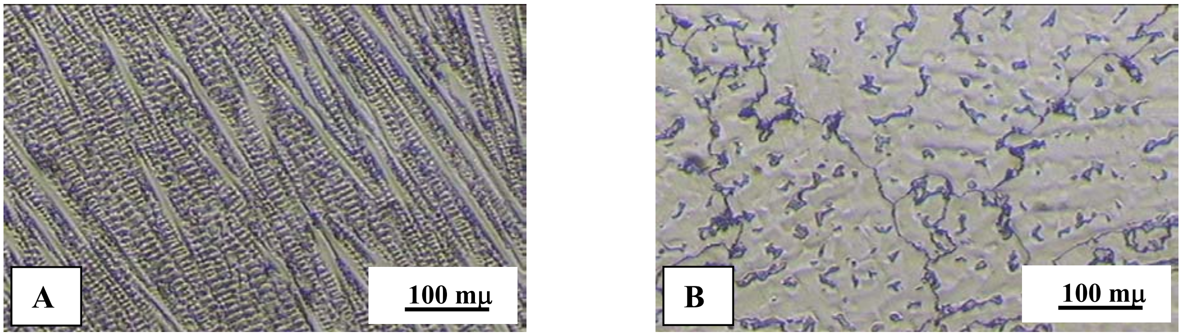

Figure 1. Microstructure of CoCrMo alloys: (A) Vitallium, (B) VeraPDI

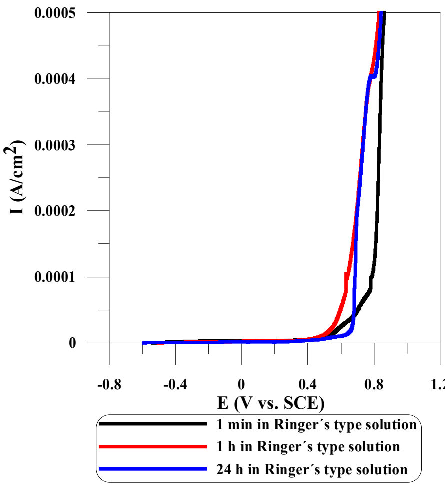

Figure 2

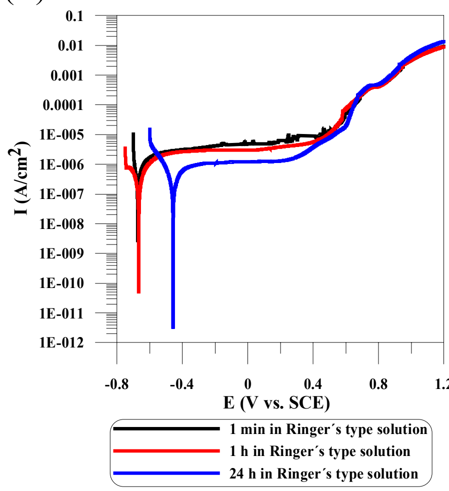

Figure 3

Figure 2. Potentiodynamic polarisation curves of Vitallium alloy tested, on semi-logarithmic axes.
Figure 3. Potentiodynamic polarisation curves presented on linear axes in order to reveal the breakdown potential for VeraPDI alloy.

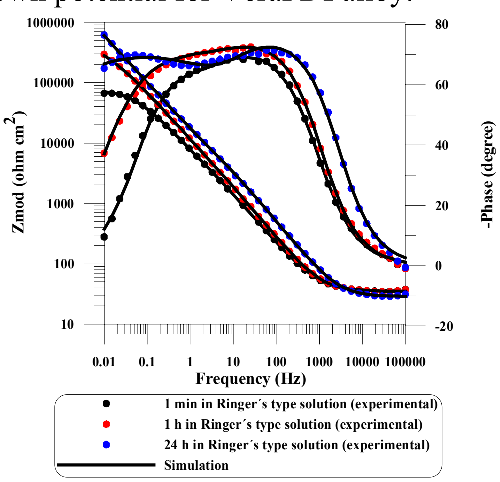

Figure 4

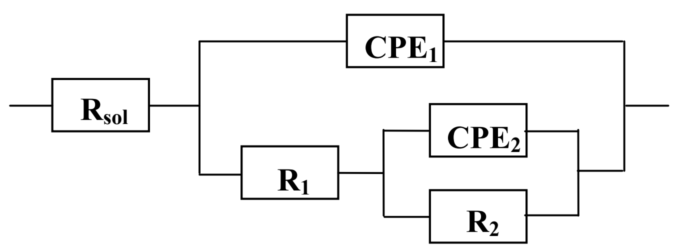

Figure 5

Figure 4. The impedance spectra of VeraPDI alloy in Ringer´s type solution measured at E_{OC}
Figure 5. The Equivalent circuit (EC) used in the generation of simulated data.