Influence of the Presence of Biofilms on the Biotribocorrosion of Titanium

H.V. Cruz[1], M. Henriques[2], J-P. Celis[3], L.A. Rocha[1,4]

[1]CT2M – Centre for Mechanical and Materials Technologies, [2]Institute for Biotechnology and Bioengineering, University of Minho, Braga, Portugal, [3]MTM - Department of Metallurgy and Materials Engineering, Katholieke Universiteit Leuven, Belgium, [4]DEM – Department of Mechanical Engineering, University of Minho, Guimarães, Portugal.

Statement of Purpose: Even though titanium (Ti) has the ability to develop a highly stable passive oxide layer (TiO_2) that provides an excellent corrosion resistance; it's not inert to corrosive attack. Under *in vivo* conditions, such as in orthopedic and dental implants, a tribological contact may be formed in association with a chemical aggressive environment. Consequently, wear debris and corrosion products or ions can lead to inflammatory reactions, such as osteolysis (bone resorption), provoking peri-prosthetic bone loss and subsequent loosening of the implant/prosthesis [1]. The microbial effect on the corrosion of metallic biomaterials remains unknown. Chang *et al*. [2] reported an increase on the corrosion behaviour of dental metallic materials in the presence of *Streptococcus mutans* and its growth byproducts. Moreover, brushing can lead to the production of wear debris, which together with the attachment of microbes can disturb the passivity of the metal oxide. In addition, the organic acids produced by bacteria may reduce the pH, favoring the corrosion and tribocorrosion of implants.

The aim of this work was to study the influence of mixed biofilms on the biotribocorrosion behaviour of commercially pure (cp) Ti for dental implants, and the consequent effect of fluoride.

Methods: Cp-Ti grade 2 samples (10 x 10 x 1 mm) (Goodfellow Cambridge Ltd., Cambridge, UK) were polished in order to create a mirror-like surface with $R_a \approx$ 0.04 µm. Prior to cell culture experiments, all the samples were ultrasonically cleaned with acetone and propyl alcohol, and sterilized in a steam autoclaving at 121 °C for 20 min. Mixed biofilms of *Candida albicans* and *Streptococcus mutans* were formed on the cp-Ti surfaces in a tryptic soy broth containing mucin, peptone, yeast extract and sucrose, at 37 °C. After 8 days, biofilm biomass was analysed by crystal violet staining method. Electrochemical Impedance Spectroscopy (EIS) was used to investigate the corrosion behaviour of polished cp-Ti samples covered with biofilms in artificial saliva (AS) in the absence or presence of 227 ppm of fluoride (227F). Before the EIS measurements, open-circuit potential (OCP) was registered for 5 min until the potential was stabilized. EIS experiments were performed at 37 ºC after 30 min, 4 h and 8 h of immersion. Wear tests were performed on samples with and without biofilms, immersed in AS or 227F solutions, using a reciprocating ball-on-plate tribometer. The sliding tests were performed against an alumina ball (5 mm) at a normal load of 100 mN, a sliding frequency of 1 Hz, and a linear displacement amplitude of 500 µm. Scanning Electron Microscopy (SEM) was also used to observe the wear tracks after tribological tests.

Results: Different biomass values were obtained amongst the cp-Ti samples with biofilms, as identified by the crystal violet method. EIS experiments revealed an increase on the corrosion resistance of cp-Ti samples covered with biofilms. In addition, these specimens also presented lower values of coefficient of friction (COF), as can be seen in Figure 1 (biofilmAS and biofilm227F). Concerning the effect of the fluoride on the cp-Ti corrosion resistance, no significant differences were found. However, in the presence of fluoride, a slightly COF decrease was verified on samples without biofilms (control227F), and a transition regimen was observed for those covered by biofilms, as pictured in Figure 1. These results were confirmed by SEM. Cp-Ti specimens immersed in AS showed a slight improvement on corrosion resistance after 8 h of immersion, unlike those immersed in 227F.

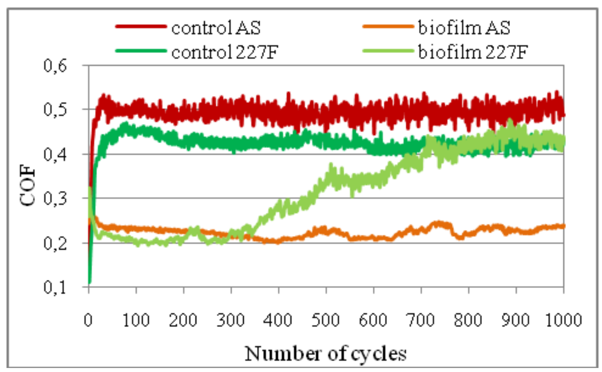

Figure 1. Coefficient of friction (COF) of polished cp-Ti samples with or without biofilms, in artificial saliva (AS) and artificial saliva with 227 ppm of fluoride (227F).

Conclusions: It can be highlighted that biofilm formation on implants can significantly affect the biotribocorrosive behaviour of cp-Ti, reducing the release of wear debris and improving its resistance to corrosion. Thus, microorganisms can actually be beneficial to metal implants and prevent its degradation. On the other hand, the presence of fluoride mainly influenced the tribological behaviour of samples with biofilms, facilitating its passive film destruction.

References:

[1] (Sinnet-Jones PE, Wear. 2005;259;898–909)

[2] (Chang JC, Biomed Mater Eng 2003;13:281-95)