Study of bio-tribocorrosion behavior of Ti6Al4V alloys colonized with osteoblastic-like cells for metal hip prosthesis

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Statement of Purpose:

Recently, there is a growing concern on the performance of the metal hip prostheses among the orthopedic community. In Ti6Al4V hip implants, the degradation process occurring at the implant-bone interface were reported as a result of the simultaneous effect of wear and corrosion, while under relative contact movement, in presence of a chemical-biological environment[1]. Retrieval studies have shown that such synergistic effects of wear and corrosion are one of the major factors causing loosening of hip implants and metal ion release to the host body[2]. In these conditions, Barril *et al*[3] found that the osseointegration process would be compromised. On the other hand, the application of mechanical stimuli, as mechanical cyclic strain, was found to promote the proliferation and differentiation of osteoblastic precursor cells in Ti6Al4V alloys[4]. However, the correlation between the bio-tribocorrosion mechanisms and the continuous osseointegration processes is still unknown.

The main objective of this work is to investigate the interplay between bio-tribocorrosion behavior and the process of growth, proliferation and differentiation of osteoblastic cells (bone-forming cells) cultured on Ti-based materials, mimicking in vivo conditions of uncemented femoral stems. Electrochemical and tribological techniques were used to address this phenomenon.

Methods:

Ti6Al4V samples were chemically etched with Kroll´s Reagent (Ra=0.44µm) and then sterilized in alcohol during 1h. The materials were cultured with MG63 osteoblastic-like cells in a complete medium: 87% alpha-MEM supplemented with 10% fetal bovine serum, 1% penicillin, 1% fungizone, 1% ascorbic acid, pH of 7.4, at 37ºC in a humidified atmosphere of 5% CO_2/air. Seeded materials and control groups were characterized through cell viability/proliferation and alkaline phosphatase activity at 1,3,4,6 culturing days. Cell cultures were observed by scanning electron microscopy (SEM) and Confocal Laser Scanning Microscopy (CLSM).

Tribocorrosion tests were performed under a reciprocating sliding configuration at free potential conditions, with sliding duration of 1800 cycles and frequency of 1Hz. The culture medium was used as the electrolyte and an alumina ball (10mm diameter) as the counterbody. A three-electrode electrochemical cell configuration was used with a saturated calomel electrode (SCE) electrode as the reference, a platinum wire as the counter electrode, and the metallic alloy as the working electrode. The normal load applied was 0.05N. All tests were performed at a controlled temperature of 37ºC. The wear scar was observed by scanning electron microscopy (SEM).

Results:

After 6 days of culture, the Ti6Al4V alloys were completely covered with osteoblastic cells. The confocal image of Fig. 1 shows a great number of cells adhered to the surface of the material. This is also confirmed by the increased cell viability/proliferation activity observed in MTT assay (Fig. 2).

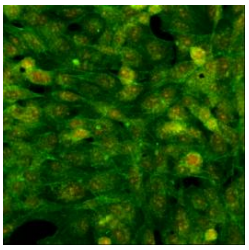

Fig. 1 – CLSM image of colonized Ti6Al4V.

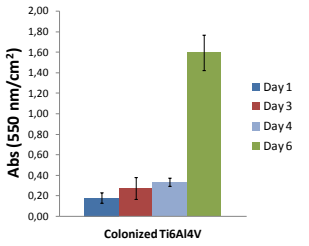

Fig. 2 - MTT assay for each culturing day.

Fig. 3 shows the evolution of potential during the tribocorrosion test. It is observed that when sliding starts the sudden drop in potential indicates a partially destruction of the top layer of the etched material (red curve). For cultured Ti6Al4V (blue curve) this damage is very smooth. When a cell layer is present on top of the material (blue curve) the potential values obtained are higher, indicating a better tribocorrosion resistance of the alloy. In addition, the coefficient of friction (COF) value decreases from 0.52 to 0.15 in cultured material.

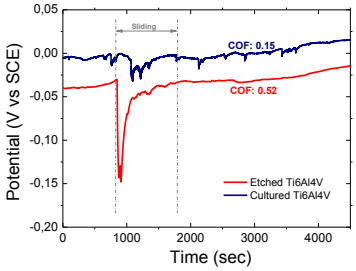

Fig. 3 – Evolution of potential during tribocorrosion test.

Conclusions:

This work has shown that the presence of an osteoblastic cell layer seeded on the implant surface significantly influence the tribocorrosion behavior of Ti6Al4V alloy. Cells adhered on the material surface generate a protective layer, which might increase the wear and corrosion resistance of the alloy. Such results bring valuable insights in understanding how osteoblastic cells influence the degradation process of Ti6Al4V implants in the human body.

References:

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