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Preliminary Cell Culture Study of Medical Grade β Titanium Alloys for Next Generation Orthopaedic Applications

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ABSTRACT

The word “osseointegration” was originally termed by Professor Bränenmark in the late 1950s. The integration of titanium and bone was observed after the interfacial remodelling between bone and implant[1]. Ideal osseointegration can be achieved if the biomaterial surface offers[2] good and tight initial adhesion[2], supports cell attachment and viability and[3] elicits a positive influence upon differentiation[2]. In this study samples were heat-treated between 400°C and 700°C, and the microstructure was characterised using optical microscopy and X-ray diffraction (XRD) techniques. Results showed that recrystallisation occurred at ~700°C. A preliminary cell viability study was also conducted on the control samples. Results indicated that the samples were biocompatible as evidenced by the elongated fibroblasts attached to the surface.

Introduction

The metallic materials used in orthopaedic devices must possess an elastic moduli in the same range with human bone (7-30GPa)[3] to avoid a shielding effect which will result in bone loss in the long term. Beta titanium (β Ti) has an elastic modulus of 55GPa, making it an excellent choice of material to reduce stress shielding and aseptic loosening.

Heat treatment (HT) is a simple and fast process to enhance the material’s surface and mechanical properties. In this study, it serves as the preliminary work to understand the material preparation process and microstructure analysis.

The purpose of this study was to heat treat β Ti at various temperatures and study the effect on microstructure and phase composition. Control samples were used for cell culture.

Results and Discussion

Microstructure

The samples consisted of equiaxed grains that vary in both shape and size throughout individual samples. The samples after HT at 400°C and 700°C had an average grain size of 0.6 mm and 0.78 mm, respectively. The slight increase in grain size indicated recrystallisation has occurred which is also proven through the XRD results.

XRD Analysis

The β Ti phase in the XRD spectra showed the presence of [110], [200] and [220] diffraction lines. Additional Titanium oxide (Ti6O) peaks were present in the 700°C heated treat sample at ~ 41 and 54 2θ position.

Cell Culture Viability Study

The degree of cell response varies from one type of cell to another. Generally, osteoblasts prefer rough surfaces while fibroblasts prefer smooth surfaces[4].

DAPI highlighted the cell cytoplasm rather than just the nucleus. Slightly elongated cells can be seen in Figure 4, suggesting the cells were alive and non-spherical prior to staining. Optical microscopy highlighted the presence of debris, as a result the protocol will be revised to eliminate this from future studies.

Conclusions

The optical micrograph and XRD results showed that recrystallisation has occurred proving that the HT has an effect on the microstructure. The cell culture test using fibroblasts showed that the untreated samples were biocompatible.

Future Work

Larger study culturing heat treated samples. Laser is one of the widely-used methods to modify the surface properties of metal, because it is clean, fast, and highly repeatable process. The effect of laser on the responses of different cells will be explored and compared with the HT samples.

References: