SURFACE MODIFICATION OF Ti- BASED MATERIALS FOR BIOMEDICAL APPLICATION

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INTRODUCTION

Titanium metal and its alloys are the most extensively used materials for fabricating long-term implants in the biomedical sector. Despite the material choice, implants in general suffer from the drawback of susceptibility to bacteria-induced inflammation, which causes loosening of the implants and other complications [1]. Antibiotic treatment of the inflammations is increasingly becoming ineffective due to development of drug resistant bacterial strains. Currently, there are implants decorated with silver and versions dip-coated with antibiotics on the market [2], but their toxicity and effectiveness to prevent bacterial biofilm formation are questionable due to overuse.

METHODE

An alternative to antibiotics is the creation of a defined nano-topography on the surface of the implant materials, which inhibits adherence of bacterial cells to them. One of the methods used for surface nano-structuring of Ti- based materials is anodization in fluoride containing electrolytes, resulting in formation of nanotubes [3]. It has been shown that nanotubes of 100 nm diameter promote osseointegration and antibacterial efficiency even without the use of pharmaceuticals [4]. In order to enhance the antibacterial properties, the nanotubes can be loaded with antibacterial agents like Ag, Cu, Se [5] and zinc selenide [6]. Se in particular exhibits osteogenic and antimicrobial activity, while suppressing inflammations. Studies with Se nanoparticles produced from precipitation indicate decrease in the function of adhesion-mediating proteins, inducing the production of damaging reactive oxygen species and inhibition of the proliferation of macrophages [5]. Se compounds like copper selenide [7] and silver selenide are attractive for implant surface modification due to low solubility, making it suited for low long-term release of antibacterial agents.

The biocompatibility and bioactivity of the implant material can be improved by an additional coating of hydroxyapatite (HAp), which promotes bone formation and growth [8]. Crystalline HAp provides mechanical stability, but has been shown to degrade slowly in simulated body fluid leading to insufficient bone ingrowth [9]. Amorphous HAp has a slightly higher solubility, which promotes faster initial bone fixation due to resorption and bioactivity [10].

RESULTS

Surface modifications of Ti and Ti6Al4V alloys were carried out to confer antibacterial properties and improved biocompatibility to it. The materials were first subjected to anodization to nanopattern the surface. The anodization parameters (voltage and time), the electrolyte composition and acidity were varied in order to grow uniform phosphate-doped nanotube-shaped structures with a diameter of 100. Subsequently, Se and Se alloys (Ag_2Se and Cu_2Se) were uniformly incorporated into the titania nanotubes by pulse electrodeposition for enhancement of antibacterial properties. The electrochemical response of modified Ti-based substrates and the electrodeposition process of Se and Se alloys were studied by cyclic voltammetry. Se-doped hydroxyapatite top coats were then deposited by precipitation on the nano-structured surface which acts as template and provides anchorage for HAp crystals. It was found that addition of Se to the electrolyte influences the HAp nucleation and highly facilitates its deposition and adhesion. The formation of fine globular crystal bundles on top of the HAp needles approximates a two- phase coating, expected to provide high resorption, bioactivity as well as mechanical stability. Preliminary medical in-vitro experiments show significantly better anti biofilm results for samples with Se related coatings compared to silver coated. The electrochemically and chemically treated surfaces were characterized by EDX, FE-SEM, FIB, RAMAN spectroscopy and XRD.

OUTLOOK

Current efforts focus on fabrication of nano-containers filled with potential antibacterial agents for medical testing. The fundamental theory of the nanotube formation is not yet fully understood and more insight might be obtained by planned measurements with optical waveguide spectroscopy, which will be utilized to monitor the layer formation and uniformity of nanotube loading. Medical in-vitro testing of samples for determining antibacterial properties are ongoing and future in-vivo experiments are being considered.

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