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Bioinspired TiO_2/chitosan/HA coatings on Ti surfaces: biomedical improvement by intermediate hierarchical films

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Abstract

The most common reasons for hard-tissue implant failure are structural loosening and prosthetic infections. Hence, in this study, to overcome the first problem, different bioinspired coatings, including dual acid-etched, anodic TiO_2 nanotubes array, anodic hierarchical titanium oxide (HO), micro- and nanostructured hydroxyapatite (HA) layers, and HA/chitosan (HA/CS) nanocomposite, were applied to the titanium alloy surfaces. X-ray diffraction and FTIR analysis demonstrated that the *in situ* HA/CS nanocomposite formed successfully. The MTT assay showed that all samples had excellent cell viability, with cell proliferation rates ranging from 120% to 150% after 10 days. The HO coating demonstrated superhydrophilicity ($\theta \approx 0^\circ$) and increased the wettability of the metallic Ti surface by more than 120%. The friction coefficient of all fabricated surfaces was within the range of natural bone's mechanical behavior. The intermediate HO layer increased the adhesion strength of the HA/CS coating by more than 60%. The HO layer caused the mechanical stability of HA/CS during the 1000 m of friction test. The microhardness of HA/CS (22.5 HV) and micro-HA (25.5 HV) coatings was comparable to that of human bone.
A mechanism for improved adhesion strength of HA/CS coatings by intermediate oxide layer was proposed.

1. Introduction

Titanium (Ti) and its alloys are forefront materials for biomedical applications because of their decent biocompatibility, excellent mechanical properties, and corrosion resistance [1–5]. These characteristics make titanium a promising candidate for orthopedic implants. However, the interactions of metallic titanium surface with the living tissue during the initial stages of implantation should be considered [6–8]. Inadequate bioactivity of titanium, which is followed by accumulation of fibrous tissue on the implant's surface, could result in isolation of implant from its adjacent living tissue and consequent patient suffering of precocious loosing. Accordingly, Ti implants need surface modification for improving their biological responses and subsequent osseointegration [9, 10].

Many surface treatment methods, including chemical, physical, mechanical, and biological modifications, have been studied to improve Ti surface bioactivity and osteoconductivity [11, 12]. The purpose of most modification approaches is to alter the surface chemistry and morphology, which are influential factors in the biological performance of the implant [13, 14]. Among various proposed modification treatments, simple, rapid, and low-cost procedures such as anodic oxidation (anodization) and sol–gel could be noteworthy processes to enhance surface properties. Anodization is an electrochemical