Enhancement of cell ingrowth on bioactive titanium surface by low-temperature plasma treatment

K.L. Ou[1], Y.N. Lin[2], S.Y. Lee[3], C.T. Lin[3]

[1]Graduate Institute of Oral Sciences, College of Oral Medicine Taipei Medical University, Taiwan, ROC.
[2]Institute and Department of Mechanical Engineering, National Chiao-Tung University, Hsinchu 300, Taiwan, ROC.
[3]Graduate Institute of Oral Rehabilitation Sciences, College of Oral Medicine, Taipei Medical University, Taiwan, ROC.

E-mail: klou.mse87g@nctu.edu.tw

Abstract

Biocompatibility is the prime requisite for implant material and is determined by the bulk properties and especially the surfaces of implant which directly contacting the host tissue. Even though the relationships and reactions between the surface of implant and tissue and their long-term integrity and clinical efficacy are still not well understood, the first biological reaction known to occur after implantation of a biomaterial is the adsorption of tissue fluid proteins onto its surface and these tightly bound proteins strongly influence the subsequent interactions of cells with the surface. In order to optimize the integration of implants, it is desirable to control interfacial reactions such that nonspecific adsorption of proteins is minimized and beneficial molecules are selectively adsorbed onto biomaterials prior to their implantation. In this regard, our goal is to develop a glow-discharge method to functionalize titanium surfaces by the covalent immobilization of bioactive organic molecules. Titanium plate first was cleaned by glow discharge using argon plasma to eliminate surface contaminants and to produce a consistent and reproducible titanium oxide surface layer. Then an intermediary allylamine deposition was covalently linked to the oxide layer by glow discharge, followed by the covalent binding of albumin to the free terminal NH_2 groups using glutaraldehyde as a coupling agent. Surface morphologies were observed by SEM and AFM. Analyses of surface composition were performed by SEM-EDS, XPS, and surface coverage by bound albumin was evaluated by FEG-SEM visualization of colloidal gold immunolabeling. Based on the results, the effectiveness of titanium plates with Ar and allylamine plasma treatment to produce a biocompatible layer between the plate and bone tissue and implants was investigated. Functional groups were found to form on the surface of the titanium plate after allylamine plasma treatment (as shown in Fig. 1). Oxygen and nitrogen bonding states were observed for Ar and allylamine plasma-treated titanium plates. Cell activity of plasma-treated titanium plates was better than those of untreated titanium plates. Surface smoothing was observed. An amino group layer was induced on the surface of the titanium plate with reactions and bombardment of nitrogen radicals and ions. The biocompatibility performance of the titanium plate was obviously improved after plasma treatment. The osteoblast-like cell MC3T3-E1/albumin/allylamine/TiO_2/Ti contact systems retain high activity after stressing at room temperature for 48 h (as shown in Fig. 2). The cell growth rate of the sample plasma-treated titanium plate was higher than that of the sample untreated titanium plate. Albumin was detected by immunogold labeling in which the distribution and density of the labeling were visualized by SEM. The binding density of immunolabeling for albumin is about 175 gold particles/μm^2. It suggests that the surface coverage of albumin is in excess of what expected for inducing biological activity. The surface modification of implants with appropriate bioactive molecules can be used to advantageously influence the initial stages of biomaterial implantation by activating and/or controlling the early biological events at the implant/host interface. Surface cleaning and chemical modification by plasma treatments are believed to improve tissue healing.

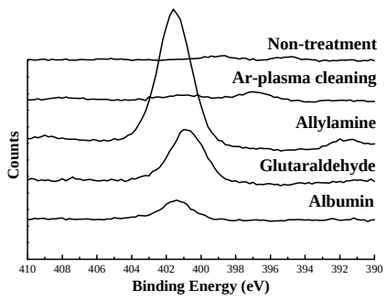

Fig. 1 XPS spectra obtained from allylamine plasma-polymerized titanium plate (a) N1s spectrum,

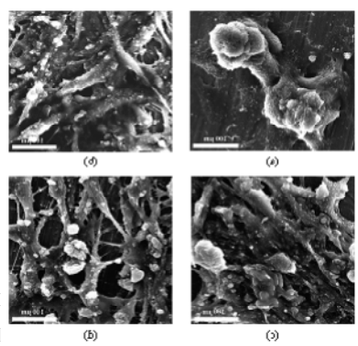

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Fig. 2 SEM micrographs demonstrating cellular morphology after various hours of culture. (a) 1 h, (b) 8 h, (c) 24 h and (d) 48 h.

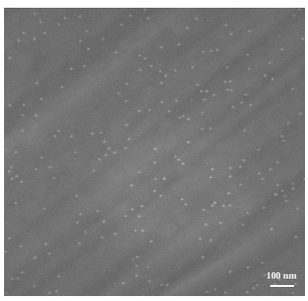

Fig. 3 SEM image of albumin conjugated to plasma-polymerized titanium plate.