Interactions between MC3T3-E1 cells and textured Ti6Al4V surfaces

W. O. Soboyejo,1,2 B. Nemetski,1,2 S. Allameh,1,2 N. Marcantonio,3 C. Mercer,1,2 J. Ricci4
1Princeton Materials Institute, Princeton University, Princeton, New Jersey 08544
2The Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey 08544
3Division of Engineering, Brown University, Providence, Rhode Island 02912
4Department of Prosthodontics, University of Medicine and Dentistry of New Jersey, Newark, New Jersey 07103

Received 20 July 2001; revised 8 November 2001; accepted 11 January 2002

Abstract: This paper presents the results of an experimental study of the interactions between MC3T3-E1 (mouse calvarian) cells and textured Ti6Al4V surfaces, including surfaces produced by laser microgrooving; blasting with alumina particles; and polishing. The multiscale interactions between MC3T3-E1 cells and these textured surfaces are studied using a combination of optical scanning transmission electron microscopy and atomic force microscopy. The potential cytotoxic effects of microchemistry on cell–surface interactions also are considered in studies of cell spreading and orientation over 9-day periods. These studies show that cells on microgrooved Ti6Al4V geometries that are 8 or 12 μm deep undergo contact guidance and limited cell spreading. Similar contact guidance is observed on the surfaces of diamond-polished surfaces on which nanoscale grooves are formed due to the scratching that occurs during polishing. In contrast, random cell orientations are observed on alumina-blasted Ti6Al4V surfaces. The possible effects of surface topography are discussed for scar-tissue formation and improved cell–surface integration. © 2002 Wiley Periodicals, Inc. J Biomed Mater Res 62: 56–72, 2002

Key words: cell–surface interactions; MC3T3-E1 cells; Ti6Al4V; surface textures; laser microgrooves

INTRODUCTION

In recent years, the Ti6Al4V alloy has been used extensively in biomedical applications such as hip replacements1,2 and dental implants3,4 due largely to its attractive combinations of mechanical properties,1,2 corrosion resistance,7 and biocompatibility.1–4 In most applications, the integration of Ti6Al4V with bone cells is the key to a successful integration of the implant.1 For example, in the case of Ti6Al4V hip implants, the interface between bone cement and Ti6Al4V can be degraded by the osteolysis that occurs as a result of interactions with polyethylene particles that are liberated due to contact between the polyethylene cap and Co-Cr/Co-Cr-Mo or ceramic (ZrO2 or Al2O3) heads that are used in modern hip implants.5,6 Since the subsequent detachment/delamination of the stem from the femur may result in patient discomfort and the need for implant retrieval/replacement within 10–15 years,1–4 there is a need to explore various means of improving the integration of bone cells with Ti6Al4V surfaces.

One method used to improve bone cell–Ti6Al4V integration involves the use of roughened surfaces produced by blasting surfaces with alumina or silica particles.3,7 Such roughened surfaces appear to promote cell–surface attachment while limiting the extent of cell spreading. However, blasted surfaces also have complex microchemistries, and they may contain higher levels of cytotoxic elements such as Al or V.7 Blasted surfaces also may give rise to random cell orientations that may give rise to scar tissue formation.8

The other approach that is being explored for the design of improved cell–surface integration involves the use of microgrooved Ti6Al4V geometries.3,4,9–13 Such microgroove geometries can be produced by laser texturing3,4 or by microfabrication processes.9–11 In the case of Ti6Al4V, laser microgrooves with dimensions (depths) between ~1–16 μm have been produced. Such grooves have been shown to result in improved adhesion/integration in animal (dog) implant studies.4 They also have been shown to reduce the extent of scar tissue formation, due possibly to the alignment of cells via contact guidance.8 However, al-