Acta Biomaterialia 8 (2012) 2845–2855

Contents lists available at SciVerse ScienceDirect

Acta Biomaterialia

journal homepage: www.elsevier.com/locate/actabiomat

In vitro corrosion behavior and in vivo biodegradation of biomedical β-$Ca_3(PO_4)_2$/Mg–Zn composites

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A R T I C L E I N F O

Article history:
Received 21 November 2011
Received in revised form 17 March 2012
Accepted 3 April 2012
Available online 11 April 2012

Keywords:
Composite
Corrosion product
Simulated body fluid
Mechanical properties
Cytotoxicity

A B S T R A C T

In this study 5, 10 and 15% β-$Ca_3(PO_4)_2$/Mg–Zn composites were prepared through powder metallurgy methods, and their corrosion behavior and mechanical properties were studied in simulated body fluid (SBF) at 37 °C. The 10% β-$Ca_3(PO_4)_2$/Mg–Zn composite was selected for cytocompatibility assessment and in vivo biodegradation testing. The results identified the α-Mg, MgZn and β-$Ca_3(PO_4)_2$ phases in these sintered composites. The density and elastic modulus of the β-$Ca_3(PO_4)_2$/Mg–6% Zn composite match those of natural bone, and the strength is approximately double that of natural bone. The 10% β-$Ca_3(PO_4)_2$/Mg–6% Zn composites exhibit good corrosion resistance, as determined by a 30 day immersion test and electrochemical measurements in SBF at 37 °C. The 10% β-$Ca_3(PO_4)_2$/Mg–6% Zn composite is safe for cellular applications, with a cytotoxicity grade of ~0–1 against L929 cells in in vitro testing. The β-$Ca_3(PO_4)_2$/Mg–6% Zn composite also exhibits good biocompatibility with the tissue and the important visceral organs the heart, kidney and liver of experimental rabbits. The composite has a suitable degradation rate and improves the concrescence of a pre-broken bone. The corrosion products, such as $Mg(OH)_2$ and $Ca_5(PO_4)_6(OH)_2$, can improve the biocompatibility of the β-$Ca_3(PO_4)_2$/Mg–Zn composite.

1. Introduction

Biomedical metals and alloys are widely used for joint and bone implants because of their good physical properties, such as strength, toughness, ductility and corrosion resistance [1]. The typical biomedical metals and alloys used for implants include stainless steels and Ti-based, Co-based, Ni-based and Ta-based alloys [2]. These materials can be fabricated into plates, screws and pins to repair serious bone fractures or to assist in the healing process, but a second surgical intervention must be performed to remove the metallic implants from the body after the bones or tissues have healed, or they will remain there permanently [3,4]. The need for additional surgery increases the patient suffering. In contrast, biodegradable materials dissolve after the healing process is complete, and no additional surgery is required to remove these implants [5]. These materials also eliminate the complications associated with the long-term presence of implants in the body. Polymers such as polyglycolic acid, polylactic acid and polydioxanone were the first materials used in biodegradable implants. However, these materials are limited by their poor mechanical properties and radiolucency [1]. Metals and alloys have desirable mechanical properties because of their relatively high strength, but studies have shown that conventional surgical alloys produce corrosion products that are harmful to the human body [2,3]. On the other hand, magnesium and its corrosion products have excellent biocompatibility, and thus Mg has garnered significant attention as a biomaterial for temporary medical implants [6].

Magnesium and its alloys are light weight metal materials with mechanical properties similar to those of natural bone [3]. The elastic modulus of Mg-based implants matches with that of cortical bone tissue, so it can avoid the stress shielding effect induced by a serious mismatch between the modulus of natural bone and other metal implants [7]. Mg-based implants corrode when in contact with body fluid, with the degradation occurring via corrosion in the electrolytic physiological environment [8,9]. This finding implies that Mg alloys have the potential to serve as biodegradable implants because they form non-toxic corrosion products with an appropriate pH level in the high chloride environment of physiological systems. Hence, it is important to study the in vitro corrosion behavior and in vivo biocompatibility of Mg-based implants.

Many previous investigations have studied the properties of different Mg alloys as candidates for biodegradable materials in the orthopedic field [10,11]. The properties, biological performance and challenges of magnesium and its alloys as orthopedic biomaterials have also been summarized in review articles [8,12]. In vitro

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1742-7061/$ - see front matter
http://dx.doi.org/10.1016/j.actbio.2012.04.009