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A comparative study on biodegradation and mechanical properties of pressureless infiltrated Ti/Ti6Al4V-Mg composites

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Abstract

The mechanical response and biodegradation behavior of pressureless Mg-infiltrated Ti-Mg and Ti6Al4V-Mg composites were investigated by compression and simulated body fluid immersion tests, respectively. Prior porous preforms were surrounded uniformly with magnesium as a result of infiltration and the resultant composites were free of secondary phases and intermetallics. Although the composites' compressive strengths were superior compared to bone, both displayed elastic moduli similar to that of cortical bone and had higher ductility with respect to their starting porous forms. However, Ti-Mg composites were unable to preserve their mechanical stabilities during in-vitro tests such that they fractured in multiple locations within 15 days of immersion. The pressure generated by H_2 due to rapid corrosion of magnesium caused failure of the Ti-Mg composites through sintering necks. On the other hand, the galvanic effect seen in Ti6Al4V-Mg was less severe compared to that of Ti-Mg. The degradation rate of magnesium in Ti6Al4V-Mg was slower, and the composites were observed to be mechanically stable and preserved their integrities over the entire 25-day immersion test. Both composites showed bioinert and biodegradable characteristics during immersion tests and magnesium preferentially corroded leaving porosity behind while Ti/Ti6Al4V remained as a permanent scaffold. The porosity created by degradation of magnesium was refilled by new globular agglomerates. $Mg(OH)_2$ and $CaHPO_4$ phases were encountered during immersion tests while $MgCl_2$ was detected during only the first 5 days. Both composites were classified as bioactive since the precipitation of $CaHPO_4$ phase is known to be precursor of hydroxyapatite formation, an essential requirement for an artificial material to bond to living bone.

Keywords: magnesium composites, titanium, infiltration, mechanical properties, simulated body fluid, biodegradation.

1. Introduction

Increased life expectancy due to recent developments in medicine has increased the need for long lasting biomedical materials used especially in load-bearing joint regions such as knee, hip, elbow and also in dental roots and dental prostheses. Among the candidate biomedical materials, polymers and ceramics cannot be directly used in load bearing parts due to their low mechanical strength and brittle nature, respectively. Accordingly, metallic materials such as titanium and titanium alloys, Co-Cr alloys and stainless steels have become the first choice materials in such applications. On the other hand, metallic materials such as iron, magnesium alloys, tantalum and niobium have also been used; however, their usage is not as common as the aforementioned metallic materials (Niinomi et al., 2012).

In order to serve for longer periods of time in the body without rejection, a metallic implant material should have various attributes like mechanical properties similar to that of bone, high biocompatibility, high corrosion and wear resistance, and satisfactory osseointegration (Geetha et al., 2009). Although bioinert titanium and titanium alloys possess optimum combination of properties and are commonly used as metallic biomaterials, their biological and mechanical biocompatibilities needed to be further improved. The effect of Young's modulus has been studied extensively; the difference between elastic moduli of metallic implants and bone induces a ''stress-shielding'' problem which may finally lead to bone resorption and loosening of the implant (Brunette et al., 2001). Correspondingly, there