Acta Biomaterialia 8 (2012) 3852–3864

Contents lists available at SciVerse ScienceDirect

Acta Biomaterialia

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

Characterization of MgNd2 alloy for potential applications in bioresorbable implantable devices

J.-M. Seitz [a,*], R. Eifler [a], J. Stahl [b], M. Kietzmann [b], Fr.-W. Bach [a]

[a] Institute of Materials Science, Leibniz Universität Hannover, An der Universität 2, 30823 Hannover, Germany
[b] Department of Pharmacology, Toxicology and Pharmacy, Stiftung Tierärztliche Hochschule Hannover, Bünteweg 17, 30559 Hannover, Germany

ARTICLE INFO

Article history:
Received 20 December 2011
Received in revised form 25 April 2012
Accepted 4 May 2012
Available online 5 June 2012

Keywords:
Magnesium
Neodymium
Implant material
Stent materials
Suture materials

ABSTRACT

The aim of this study is to investigate and demonstrate the mechanical and corrosive characteristics of the neodymium-containing magnesium alloy MgNd2 (Nd2), which can be used as a resorbable implant material, especially in the field of stenting applications. To determine the mechanical characteristics of Nd2, tensile and compression tests were initially carried out in the hot extruded state. Here a unique elongation ratio (∼30%) of the alloy could be observed. Subsequent T5 and T6 heat treatments were arranged to reveal their effect on the alloy's strengths and elongation values. The general degradation behaviour of Nd2 in a 0.9% NaCl solution was investigated by means of polarization curves and hydrogen evolution. In addition to this, by using various in vivo parameters, a corrosion environment was established to determine the alloy's degradation in vitro. Here, the mass loss per day in (MgF_2 and Bioglass)-coated and uncoated states and the corresponding maximum forces resulting from subsequent three-point bending tests revealed slow and steady corrosion behaviour. The cell viability and proliferation tests carried out on L-929 and MSC-P5 cells also showed good results. The mechanical and corrosive characteristics determined, as well as the in vitro test results obtained within the scope of this study, led to the development and successful in vivo testing of an MgF_2-coated Nd2 mucosa stent which was introduced as an appropriate resorbable application.

1. Introduction

Various biomedical research projects are currently focusing on magnesium alloys as degradable biomaterials for use in stents, sutures and orthopaedic applications [1–3]. By means of degradable and resorbable materials, surgical procedures aimed at removing temporary implants may be eliminated. Moreover, negative long-term consequences, such as an adverse biological response caused by non-degradable implants following wear or fatigue on the device, could be avoided by the use of such resorbable implants [4].

Currently, magnesium is of special interest due to the benefits of it having appropriate mechanical properties, biocompatibility and the ability to be absorbed by the body [5,6].

Regarding their mechanical properties, current implant materials, like biodegradable polymers, are limited in application due to their low yield strength and elastic modulus, while common permanent implants, such as titanium and steel, exhibit high yield strength and a high elastic modulus, which can lead to negative stress shielding effects [6–8]. However, magnesium offers mechanical properties similar to those of bone, such that it fits perfectly into the niche between the mechanical characteristics of polymers and permanent metallic implants, thus making it an ideal material for orthopaedic implants [6–9]. Stents made of magnesium are currently one of the most promising applications. Studies have proven that absorbable magnesium stents can be expanded at high pressures in coronary arteries, providing good mechanical scaffolding [10,11]. These magnesium stents may negate some of the complications of current permanent metallic stents, such as stent thrombosis and the need for prolonged dual anti-platelet therapy [12]. However, early recoil is identified as a main contributor for restenosis at 4 months in human arteries [11]. Multiple numerical modelling approaches to describe the corrosion of metallic biomaterial having a complex stenting geometry and the impacts of mechanical loadings were recently introduced to validate designs in terms of durability and scaffolding ability over time [13–15]. Grogan et al. [13] developed a computational corrosion model for absorbable magnesium stents. The corrosion experiments have shown widespread localized attack on alloy AZ31, resulting in a significant reduction in foil mechanical integrity while showing relatively little loss of mass [13]. The experimental results validated the numerical model. However, besides pitting corrosion mechanisms, fatigue corrosion mechanisms play an important role in the resistance of a stent device subject to a pulsatile flow and should be considered in future research efforts [14]. An optimized three-dimensional design that resulted from a numerical model, for

* Corresponding author. Tel.: +49 511 762 3908; fax: +49 511 762 5245.
E-mail address: seitz@iw.uni-hannover.de (J.-M. Seitz).

1742-7061/$ - see front matter
http://dx.doi.org/10.1016/j.actbio.2012.05.024