Degradation Study of Magnesium Alloys for Development of Resorbable Bone Fixation Products

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INTRODUCTION

- Removal of bone fixation products is one of the most frequently performed surgeries in the western world[1] with over 180,000 conducted in Germany alone in 2010[2]
- Creation of degradable fixation products would eliminate the need for these second surgeries
- Magnesium alloys have been considered previously for degradable implants due to their bio resorbable properties under physiological conditions and non-toxic corrosion products
- Corrosion of magnesium alloys is dependant on a number of factors from alloying composition to degradation solution

Figure 1 50 Year-old woman with distal radius immobilised by 4 K-wires[3]

AIM: TO STUDY THE DEGRADATION OF VARIOUS MAGNESIUM ALLOYS IN SIMULATED BODY FLUIDS FOR THE CREATION OF DEGRADABLE BONE FIXATION PRODUCTS

MATERIALS AND METHODS

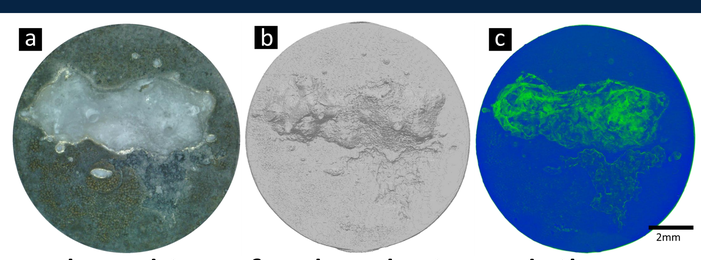

Figure 2 AZ31 coupon in SBF for 1 Day a) image b) µCT reconstruction c) µCT coloured density map with blue representing magnesium and green corrosion products

- AZ31 (Mg 96/Al 3/Zn 1) coupons of 10 mm Ø x 1 mm were subjected to 25ml solutions of DI water, phosphate buffered saline solution (PBS) and simulated body fluid (SBF) for 1, 3 and 7 days. Samples were placed into fresh solutions daily
- Samples solutions were characterised by Atomic Absorption Spectroscopy to determine daily Mg ion release
- Alloy discs were characterised using optical microscopy, µCT, x-ray photoelectron spectroscopy and gravimetric analysis

RESULTS AND DISCUSSION

- AZ31 coupons degraded in all solutions with corrosion products visible on the surface of coupons in PBS and SBF solutions, Figure 3
- Coupons degrading in PBS exhibited a greater magnesium ion release than coupons degrading in DI water, Figure 4
- Coupons degrading in SBF exhibited a greater loss in magnesium volume and a greater increase in coupon surface area than coupons in DI water and PBS at 7 days, Figure 5

The results of this study show that AZ31 alloys degrade at higher rates in solutions of PBS and SBF. This is due to the passivating layer $Mg(OH)_2$ which is created when magnesium reacts with water being readily attacked by ions of many types. Solutions with a higher ionic content also have a greater galvanic potential, increasing the amount of corrosion occurring.

Planned future work involves studying the degradation of Mg alloys of varying elemental composition and investigating inorganic CaP barrier layers to control a tailored degradation rate.

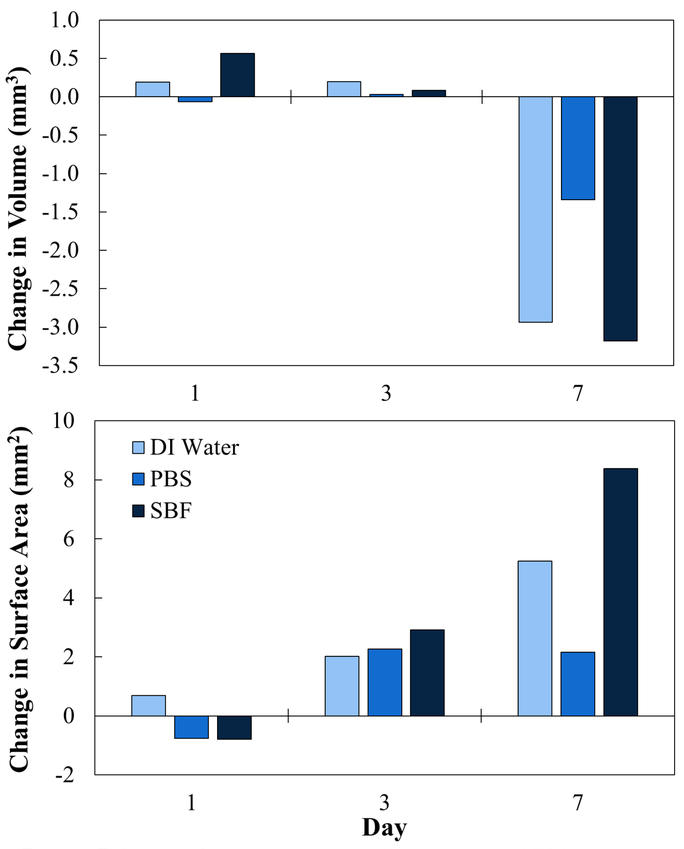

Figure 5 Change in volume and surface area of AZ31 coupons in DI water, PBS and SBF at 1, 3 and 7 days

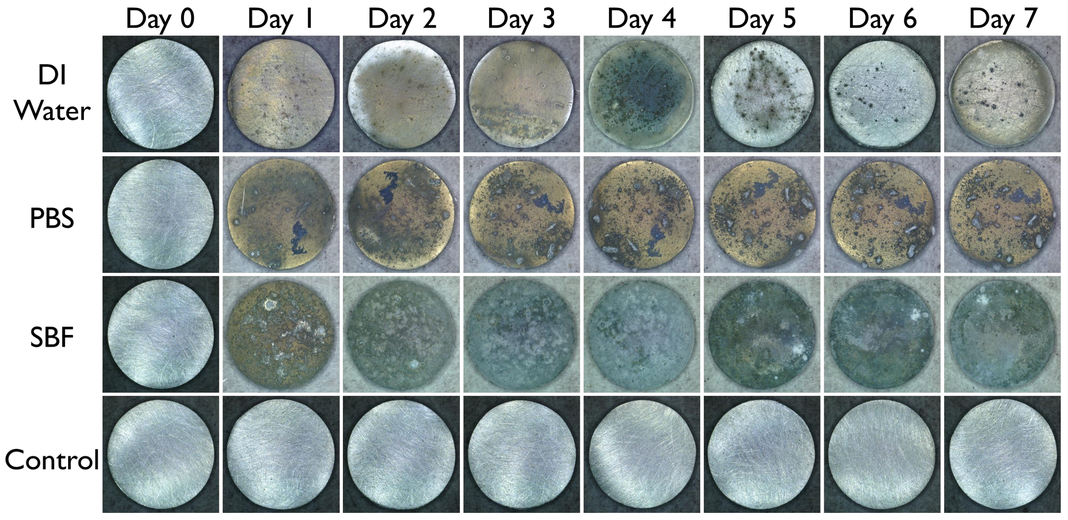

Figure 3 Optical microscopy of AZ31 coupons in DI water, PBS and SBF as the degradation study progressed

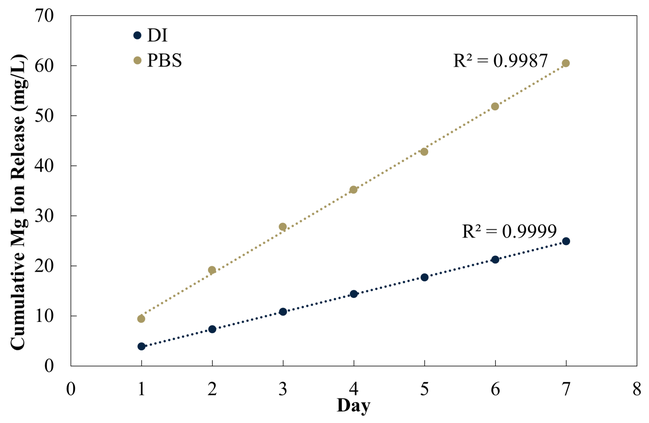

Figure 4 Mg ion release from AZ31 coupons in solutions of DI water and PBS

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[1] Reith, G. et al. BMC Surg. 15, 96 (2015)
[2] Harrison, R. et al. Prog. Nat. Sci. Mater. Int. 24, 539–546 (2014)
[3] TB. Hunter, Gallery of Fracture Fixation Devices http://medapparatus.com/Gallery/Gallery_FractureFixation_Page2.html