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Degradation of mechanical properties of magnesium alloy

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Abstract. In this study, biodegradation behaviour of WE43 magnesium alloy have been studied and compared during exposure to three different media commonly used to simulate the conditions of human body environment. Magnesium alloys emerged as a new class of bioresorbable implant materials. Their applications reduce certain risks associated with conventional permanent implants. Biodegradation behaviour of the WE43 magnesium alloy was observed under Dulbecco Modified Eagle Medium (DMEM, Sigma Aldrich) supplemented with 5 % fetal bovine serum and gentamicin antibiotic as standard. The samples were stored in the medium at 37° C and in a 5 % CO_2 atmosphere. The second type of medium was Hank's Salt Balanced Solution (HBSS, Sigma Aldrich), which simulates the inorganic composition of blood plasma. HBSS was tempered at 37° C. The last solution was an acidic solution of HCl + NaCl (pH2) with pH ~ 2 (0.01M HCl and 0.14M NaCl) tempered at 37° C. The acidic type of solution was used to simulate a local acidic environment associated with osteoclast activity during bone remodelling. Changes in the mechanical properties of the samples during exposure to simulated body conditions were observed.

Introduction

Magnesium alloys emerged as a new class of bioresorbable implant materials [1-3]. Their applications reduce certain risks associated with conventional permanent implants [1]. The need of reliable *in vitro* models to predict degradation in human body is increasing. In this study, biodegradation behaviour of WE43 magnesium alloy have been studied and compared during exposure to three different media commonly used to simulate the conditions of human body environment. Changes in the mechanical properties and surface area of the samples during exposure to simulated body conditions were observed.

Materials, methods and results

Biodegradation behaviour of the WE43 magnesium alloy was observed under three different simulated body conditions. The first was Dulbecco Modified Eagle Medium (DMEM, Sigma Aldrich) supplemented with 5 % fetal bovine serum and gentamicin antibiotic as standard. The samples were stored in the medium at 37° C and in a 5 % CO_2 atmosphere. The second type of medium was Hank's Salt Balanced Solution (HBSS, Sigma Aldrich), which simulates the inorganic composition of blood plasma. HBSS was tempered at 37° C. Both solutions are

physiologically neutral or slightly alkaline. The last solution was an acidic solution of HCl + NaCl (pH2) with pH ~ 2 (0.01M HCl and 0.14M NaCl) tempered at 37° C. The acidic type of solution was used to simulate a local acidic environment associated with osteoclast activity during bone remodelling. Samples (n = 5) in dimensions of 6 mm in diameter and 9 mm in length were exposed to the medium for one and two weeks (see Fig. 1). The solutions were completely replaced every 24 hours. The pH of the solutions was checked throughout the experiment.

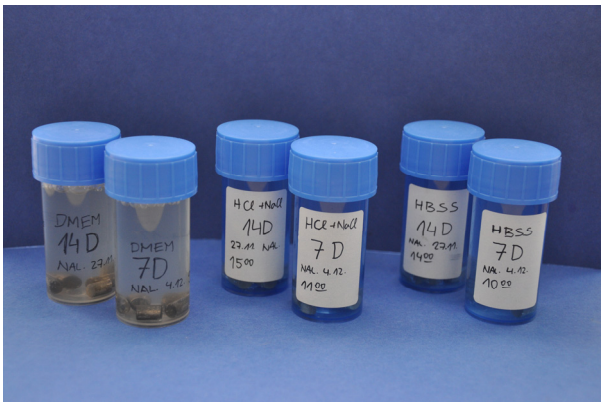

Fig. 1: Cylindrical specimens placed in boxes

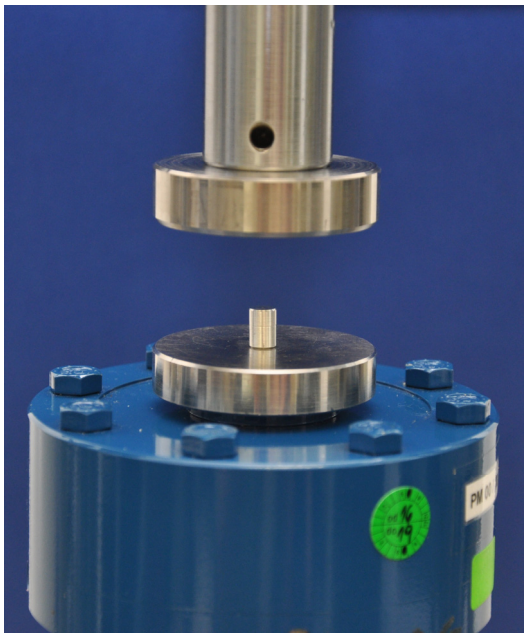

Fig. 2: Testing system MTS 858 Mini Bionix

The effect of sample exposure to media was observed by mechanical compression tests (see Fig. 2). Furthermore, the sample surface was scanned on a scanning electron microscope (SEM) and optical microscope. The results of mechanical tests are illustrated in Fig. 3.

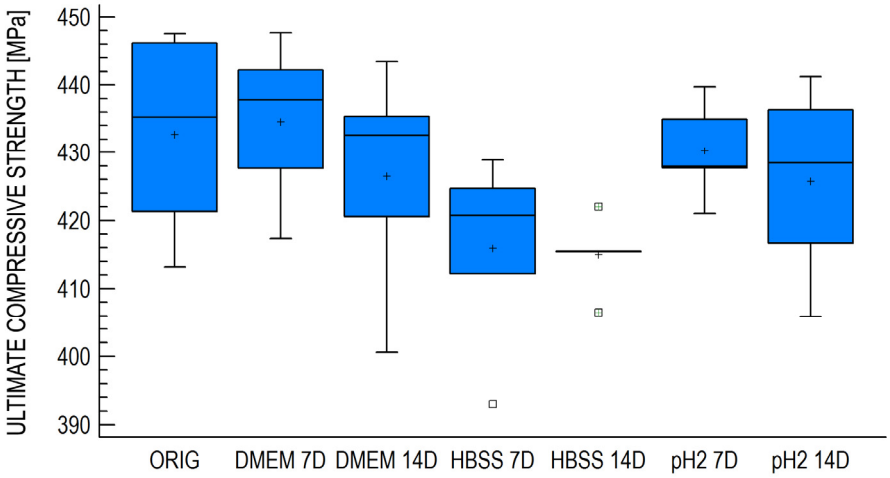

Fig. 3: Compressive strength of magnesium alloys before (ORIG) and seven days (7D) and fourteen days (14D) after exposure to Dulbecco Modified Eagle Medium (DMEM), Hank's Salt Balanced Solution (HBSS) and acidic solution of HCl + NaCl (pH2). There are no statistically significant differences between the samples in the multiple comparison of all groups (Games-Howell test, 0.05)

The results show that the short-term exposure used in all ingested media has no statistically significant effect on the observed mechanical properties ($p = 0.05$). However, the results obtained may also be affected by the sample sizes used. The image analyses showed that the short-term exposure was seen mainly on the surface of the samples, while the reduction of the mechanical properties of the cylindrical samples with a diameter of 6 mm and a height of 9 mm has no effect.

Conclusions

The aim of the biodegradation study was to assess the potential changes in the mechanical properties of cylindrical samples made from magnesium alloy WE43. The need of reliable *in vitro* models to predict degradation in human body is increasing. At present time, there is practically no general consensus on which medium would best and comprehensively simulate events occurring under *in vivo* conditions. Thus, three types of media commonly used to simulate the body environment were selected for the purpose of the study. Two weeks after the exposure, only local surface degradation was observed while no statistically significant effect on mechanical properties was determined. For the short-term degradation-induced loss of mechanical integrity, specimens with smaller dimensions should be used, e.g. specimens with comparable size to that of implants such as cardiovascular stents and orthopaedic wires [1]. The differences among the three kinds of simulated body conditions were not observed within two weeks period.

Acknowledgements

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