Osteosynthesis of partial rib osteotomy in a miniature pig model using human standard-sized magnesium plate/screw systems: Effect of cyclic deformation on implant integrity and bone healing

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Magnesium alloys are candidates for resorbable material in bone fixation. However, the degradation and performance of osteosynthesis plate/screw systems in vivo, under cyclic deformation, is unknown. We evaluated the outcomes of human standard-sized magnesium plate/screw systems with or without plasma-electrolytic surface modifications in a miniature pig rib model. Of a total of 14 minipigs, six were implanted with coated magnesium WE43 six-hole plates/screws, six received magnesium uncoated plates/screws, and two received titanium osteosynthesis systems.

The performance of the plate/screw fixation system on partially osteotomized 7th ribs was compared with that on intact 9th ribs. Radiological examinations were performed in vivo at 1, 4 and 8 weeks and after euthanasia at 12 and 24 weeks. After euthanasia the bone blocks were analyzed by computed tomography (CT), microfocus computed tomography (micro-CT), histology and histomorphometry. Follow-up post-surgery showed no trouble with wound healing. In vivo radiological examinations showed higher amounts of gas formation above the uncoated magnesium plates fixed on the partially osteotomized and intact ribs. CT scans showed no broken plates or implant displacement. The micro-CT examination demonstrated better surrounding bone properties around the coated than the uncoated magnesium implants 12 weeks after surgery. No negative influence of magnesium degradation on bone healing was observed with histological examinations. Plastic deformation during surgery and cyclic deformation did not affect the integrity of the used magnesium plates. This study showed promising results for the further development of coated magnesium plate/screw systems for bone fixation.

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1. Introduction

Bone fractures are highly prevalent and are a great burden on healthcare and the economy. In the United States, annual fracture incidences are estimated to be 6.3 million (Stevens et al., 2008). In the European Union, there were 3.5 million cases of osteoporosis-related fractures in 2010, with estimated financial costs of €37 billion (Hernlund et al., 2013). These expenditures are projected to grow by 25% in the next 10 years (Hernlund et al., 2013). With rising clinical and financial burdens, the development of more efficacious and cost-effective fracture therapy remains a key topic of research.

To promote skeletal healing, fracture therapy often involves the use of load-bearing fixation appliances. Commonly, these appliances are made from non-resorbable metals such as titanium (Staiger et al., 2006). However, these metallic materials have been found to cause long-term clinical issues such as impediment of normal skeletal growth in pediatric patients (Yaremchuk et al., 1994), infection, and pain (Orringer et al., 1998). Arising from these problems, the non-degradable devices may have to be...