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Biodegradable magnesium Herbert screw – image quality and artifacts with radiography, CT and MRI

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Abstract

Background: Magnesium alloys have recently been rediscovered as biodegradable implants in musculoskeletal surgery. This study is an ex-vivo trial to evaluate the imaging characteristics of magnesium implants in different imaging modalities as compared to conventional metallic implants.

Methods: A CE-approved magnesium Herbert screw (MAGNEZIX®) and a titanium screw of the same dimensions (3.2x20 mm) were imaged using different modalities: digital radiography (DX), multidetector computed tomography (MDCT), high resolution flat panel CT (FPCT) and magnetic resonance imaging (MRI). The screws were scanned in vitro and after implantation in a fresh chicken tibia in order to simulate surrounding bone and soft tissue. The images were quantitatively evaluated with respect to the overall image quality and the extent and intensity of artifacts.

Results: In all modalities, the artifacts generated by the magnesium screw had a lesser extent and were less severe as compared to the titanium screw (mean difference of artifact size of solo scanned screws in DX: 0.7 mm, MDCT: 6.2 mm, FPCT: 5.9 mm and MRI: 4.73 mm; $p < 0.05$). In MDCT and FPCT multiplanar reformations and 3D reconstructions were superior as compared with the titanium screw and the metal-bone interface after implanting the screws in chicken cadavers was more clearly depicted. While the artifacts of the titanium screw could be effectively reduced using metal-artifact reduction sequences in MRI (WARP, mean reduction of 2.5 mm, $p < 0.05$), there was no significant difference for the magnesium screw.

Conclusions: Magnesium implants generate significantly less artifacts in common imaging modalities (DX, MDCT, FPCT and MRI) as compared with conventional titanium implants and therefore may facilitate post-operative follow-up.

Background

After the discovery of elemental magnesium (Mg) by Sir Humphrey Davy in 1808 Mg-implants were initially used in musculoskeletal surgery in the first half of the twentieth century [1]. In 1900, the Austrian-German physician Erwin Payr proposed possible Mg-implants such as nails, wires, pegs, sheets and plates for internal stabilization of bone fractures [2]. There are several case reports of in vivo magnesium application in patients who had suffered from supracondylar fractures, femoral fractures or pseudarthrosis and who could successfully be treated with Mg-implants [3].

Nevertheless, the rapid degradation of the implants causing a distinct hydrogen gas formation was a common and major complication. The inability to control the rate of degradation in vivo led to the abandonment of magnesium and its replacement by inert and corrosion-resistant materials such as stainless steel for orthopedic implants [3, 4]. However, in the last few years, magnesium based alloys were rediscovered as biodegradable implants and have attracted increasing interest acting as "smart" implants belonging to the "third generation" of orthopedic biomaterials [5, 6]. Magnesium alloys not only possess the ability to degrade but also to stimulate cellular responses at the molecular

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