Development of Nanostructured Coatings for Controlling the Biodegradation of Magnesium Implants

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Summary: Results of nanostructured-hydroxyapatite (nHA) coating on magnesium substrate suggest the nanocoatings positively mediated magnesium degradation.

Magnesium (Mg) alloys, a novel class of degradable, metallic biomaterials, have attracted growing interest as a promising alternative for medical implant and device applications due to their advantageous mechanical and physiological properties. The implants/devices made from magnesium alloys can achieve the desired modulus and mechanical strength to prevent breakage during implantation, as well as provide optimal initial fixation. Moreover, magnesium is biodegradable in the physiological environments and its degradation products are non-toxic and can be metabolized and secreted through the kidney. Magnesium forms a thick stable oxide which is protective in a dry environment. However, in the body, the oxide layer is permeable to water, allowing for magnesium dissolution through the corrosion reaction: Mg + 2H₂O → Mg(OH)₂+H₂. Chlorides react with magnesium to form MgCl₂, which is highly soluble in aqueous solutions, leaving no resistance to further degradation. Therefore, the present key challenge of using magnesium alloys for medical applications is in controlling their degradation rate in the physiological environment. The objective of this study is to develop a nHA coating on Mg implants to control the degradation and tissue integration of the implants.

HA coatings are deposited using the patented Spire TPA process on Mg to moderate the aggressive degradation of Mg and to improve fast osseointegration between Mg and natural bone, thus allowing orthopedic devices to maintain mechanical strength and structural integrity throughout the healing process, and then to degrade after the tissue grows in strength. The nHA coating was characterized using scanning electron microscopy (SEM) and energy dispersive x-ray (EDX) analysis. The degradation of HA coated Mg and uncoated Mg was investigated by incubating samples in phosphate buffered saline (PBS) under standard cell culture conditions.

The scanning electron micrographs (SEM) showed that the nHA coatings deposited on magnesium were uniform before the degradation study. SEM image of the nHA coated Mg showed that the surface feature became irregular after 12 days of degradation and the EDX analysis suggested that the surface composed of O, Na, Mg, and Cl (Fig. 1 c,d). The degradation results suggest the nanocoatings positively mediated magnesium degradation (Fig. 1a,b).

Nanostructured hydroxyapatite coatings are promising for controlling the biodegradation of magnesium-based orthopedic implants and devices and need to be further studied in vitro and in vivo.