



Antibacterial and biological characteristics of silver containing and strontium doped plasma sprayed hydroxyapatite coatings

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ABSTRACT

Infection in primary total joint prostheses is estimated to occur in up to 3% of all surgery. As a measure to improve the antimicrobial properties of implant materials silver (Ag) was incorporated into plasma sprayed hydroxyapatite (HA) coatings. To offset potential cytotoxic effects of Ag in the coatings strontium (Sr) was also added as a binary dopant. HA powder was doped with 2.0 wt.% Ag₂O, 1.0 wt.% SrO and was then heat treated at 800 °C. Titanium substrates were coated using a 30 kW plasma spray system equipped with a supersonic nozzle. X-ray diffraction confirmed the phase purity and high crystallinity of the coatings. Samples were evaluated for mechanical stability by adhesive bond strength testing. The results show that the addition of dopants did not affect the overall bond strength of the coatings. The antibacterial efficacies of the coatings were tested against *Pseudomonas aeruginosa*. Samples that contained the Ag₂O dopant were found to be highly effective against bacterial colonization. In vitro cell-material interactions using human fetal osteoblast cells were characterized by 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay for cell viability, field emission scanning electron microscopy for cell morphology and confocal imaging for the important differentiation marker alkaline phosphatase (ALP). Our results showed evidence of cytotoxic effects of the Ag-HA coatings, characterized by poor cellular morphology and cell death and nearly complete loss of functional ALP activity. The addition of SrO to the Ag-HA coatings was able to effectively offset these negative effects and improve performance compared with pure HA-coated samples.

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1. Introduction

Hydroxyapatite (HA) has been used commercially as a coating on metallic implants since the 1980s. It has excellent biocompatibility due to its compositional similarity to natural bone and exhibits a surface chemistry that supports bone in-growth [1–3]. Currently, in the orthopedic setting, HA coatings are used in hip and knee applications as an alternative to cemented implants or uncoated press fit implants. Cemented implants are usually recommended for patients that are less likely to put stress on the cement that could lead to fatigue fracture, such as older patients or younger patients with compromised bone health. Uncemented, porous coated implants are generally recommended for patients that are likely to lead more active lifestyles. The use of HA as a coating material has been highly criticized in the past for fear of two possible failure mechanisms: (1) delamination of the coating causing aseptic loosening of the implant; (2) due to the natural dissolution of HA free particles or grit may become a third party wear accelerant between the femoral head component and the acetabular cup

component of the implant. Because of the relative newness of HA-coated implants in clinical use, advocates of the coating have been hard pressed until recently to allay the concerns of skeptics. Several long-term clinical follow-ups have shown that implants that have been coated with HA perform just as well as or outperform their cemented or cementless uncoated counterparts, with 98% survival after 10 years and an estimated 96% stem survival at 20 years [4–7]. Of several extensively researched coating methods [8] plasma spray deposition is regarded as the most efficient and economical and is the only method currently used in industry.

The current surgical strategy for preventing infection is to minimize contamination during surgery and to administer peri-operative antibiotic prophylaxis. The estimated risk of infection of an implant after total joint replacement surgery is fairly low, 0.5–5%, but the consequences are very serious [9]. For severe infections the standard protocols include implant removal, surgical debridement and long-term treatment with full spectrum antibiotics. It has been estimated that the treatment costs for a single occurrence of infection exceeds \$50,000 [10]. Because infections can be due to many different causes and can happen at several stages of the implant lifetime [11] preventative treatments, such as peri-operative prophylaxis and decontamination procedures,

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