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Characterization and antibacterial performance of bioactive Ti-Zn-O coatings deposited on titanium implants

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Abstract

Titanium (Ti)-based materials have been used for dental and orthopedic implants because of their excellent biological compatibility, superior mechanical strength, and high corrosion resistance. To improve osseointegration, a better anti-bacterial performance of Ti-based implants avoiding any possible microorganism infection is beneficial for patients during and after implantation surgery. Because zinc (Zn) has an effect in reducing bacterial colonization and infection, the hypothesis of this present study was to manufacture the Zn-doped TiO_2 ($TiZnO_2$) layer possessing the effects of biocompatibility and antibacterial ability on the surface of Ti specimens. TiO_2, ZnO, and $Ti(Zn)O_2$ coatings were deposited on polished pure Ti substrates using a cathodic arc deposition system. Murine osteoblasts (MC3T3-E1) and human *Staphylococcus aureus* (*S. aureus*) were cultured onto the surface with different deposited layers, respectively. The biocompatibility was examined by cell viability and osteogenic gene expression. The antibacterial ability was determined by SYTO9 nucleic acid staining. The XPS analyses showed that a porous Zn-doped TiO_2 layer was successfully produced and formed as the $Ti(Zn)O_2$ layer with a higher contact angle (84^o-85^o) than uncoated Ti (approximately 78^o). The ZnO exhibited a fibrous structure with nanorods showing a hydrophobic feature (contact angle approximately 89^o). These material properties affected the following biological performance. The antibacterial testing found no apparent difference between the uncoated Ti plate and the TiO_2 coating. However, significantly lower numbers of *S. aureus* were observed on ZnO and $Ti(Zn)O_2$ coatings compared to that on the uncoated Ti. The biocompatible testing exhibited that TiO_2 and $Ti(Zn)O_2$ coatings enhanced greater cell viability and proliferation than the uncoated Ti plate and ZnO coating. The osteogenic gene expression of Dlx-5 and osterix also improved for the TiO_2 and $Ti(Zn)O_2$ coatings. However, a significant inhibition of cell viability was found for the ZnO coating. These findings suggested that the composite $Ti(Zn)O_2$ coating with lower content of Zn (7.6±1.3 at. %) not only improved antibacterial activity, but also maintained the biocompatibility to bone cells.

Keywords: Antibacterial activity; Biocompatibility; Osteoblasts; *Staphylococcus aureus*; Zinc-doped titanium dioxide