Nanocrystalline Hydroxyapatite Coating with Improved Mechanical and Biological Properties for Dental/Orthopedic Implants

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Statement of Purpose: Hydroxyapatite (HA) has been widely used as a coating material for dental/orthopedic applications due to its excellent biocompatibility and bioactivity to promote natural bone-implant integration. It has been reported that HA with nano-scale crystalline features and controlled porosity and pore size could promote osseointegration (that is, direct bonding to natural bone). So far, a number of methods have been developed or used commercially to deposit HA on metal implants, such as electrophoretic deposition, sol-gel, sputter, dip coating, spin coating and plasma spray. It is, however, very challenging to produce a high quality nanocrystalline HA coating with desirable nano-features and surface roughness as well as controlled pore size and porosity for biomedical implants. It is also necessary for nano-HA coating to have excellent adhesion strength on metallic substrates to prevent coating delamination. Therefore, in this study, a novel hybrid coating process, combining NanoMech's patented Nanospray® coating technology with a non-conventional sintering process, was developed to meet mechanical and biological requirements for dental/orthopedic implants.

Methods: HA nanoparticles were deposited on titanium substrates using NanoMech's patented Nanospray® coating system and the produced HA coating was then sintered in a non-conventional furnace for maximal consolidation without significant grain growth. The produced HA coating was characterized for grain size and pore size using an environmental scanning electron microscope (ESEM), the composition and Ca/P ratio using Energy Dispersive X-ray (EDX) analysis, and crystalline phases using X-ray diffraction (XRD). Such HA coating was further characterized for its mechanical properties, such as adhesion strength (scratch resistance), hardness and toughness. Human palatal mesenchymal cells (HEPM 1486; ATCC) attachment and proliferation on the nano-HA coated titanium implants were tested in vitro under standard cell culture conditions.

Results: The results demonstrated that a nanocrystalline HA coating with a grain size from 50 to 300 nm and a gradient of nano-to-micron pore sizes were fabricated successfully using this novel coating process (Figure 1). The controlled nano-scale grain size and a gradient of pore size are expected to promote bone cell functions and facilitate bone healing. XRD results confirmed that the nano-HA coating was highly crystalline after sintering. EDX results showed that the nano-HA coating had a Ca/P ratio of 1.6, very close to natural bone.

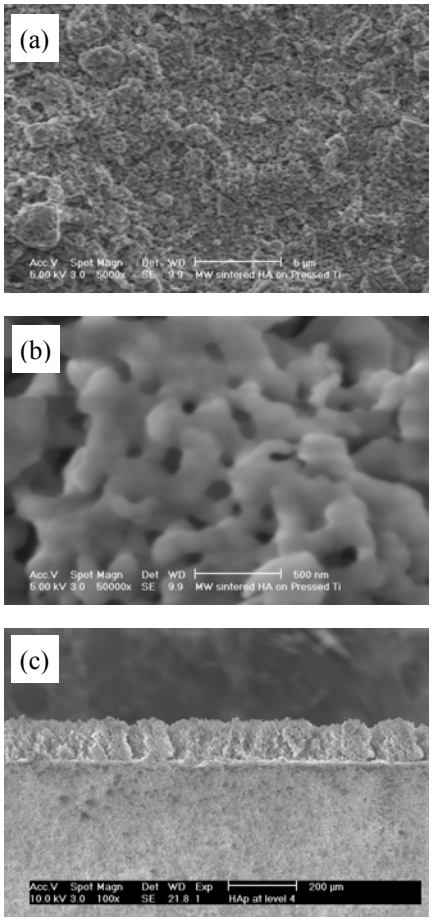

Figure 1. (a) HA coating on cp-Ti dental implants. Low magnification to show uniformity.(b) HA coating on cp-Ti dental implants. High magnification to show nano-scale features and nano-porosity. (c) Cross-section of HA coating to show the thickness of coating (~ 60 μm) and its uniformity.

Microscratch test results showed that the critical load of coating de-lamination reached as high as 10 N. In vitro studies demonstrated that human palatal mesenchymal cell attachment on the nano-HA coated titanium implants reached 88.20 ± 2.03 %, much higher than traditional calcium phosphate materials (~50%).

Conclusions: This study demonstrated that it is very promising to scale up this novel hybrid coating process (Nanospray® coating followed by a non-conventional sintering) for commercial dental/orthopedic implants.