Nanophase Hydroxyapatite Coated Metals for Orthopedic Applications

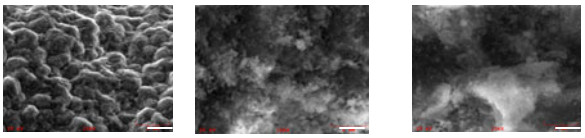
Michiko Sato[1], Qian K. Kang[2], Yuehuei H. An[2], Marisa Sambito[3], Arash Aslani[3], Nader Kalkhoran[3], Elliott Slamovich[1], Eric Nauman[4], and Thomas J. Webster[1,4]
[1]School of Materials Engineering and [4]Weldon School of Biomedical Engineering, West Lafayette, IN 47907
[2]Department of Orthopedic Surgery, Medical University of South Carolina, SC 29425
[3] Spire Biomedical, Inc., Bedford, MA 01730

INTRODUCTION

Many engineers and surgeons trace orthopedic implant failure to the current inability of biomaterials to match the physical properties of surrounding bone [1]. For instance, immature bone has an average inorganic mineral grain size of 10-50 nm while mature bone has an average inorganic mineral grain size of 20-50 nm and is 2-5 nm in diameter [2]. However, most modern implants are smooth at the nanometer level since they are composed of constituent micron grain sizes [1]. Importantly, researchers have shown that nanostructured, or materials composed of grains/particles less than 100 nm, enhance cell function [2, 3]. Materials well-tested to date include ceramics, polymers, metals and composites thereof. However, novel coating techniques are needed to further advance the use of nanoparticles in orthopedics. The objective of the present study was to determine the in vitro and in vivo efficacy of common orthopedic implant materials (specifically, tantalum and titanium) on osteoblast (bone-forming cell) function leading to new bone formation.

MATERIALS AND METHODS

Nanocrystalline and microcrystalline hydroxyapatite (HA) were prepared through a well-established wet chemical process. After precipitation, nanocrystalline HA powders were hydrothermally-treated at 200ºC for 20 hours while microcrystalline HA powders were sintered at 1100ºC for 1 hour. HA powders were then coated onto titanium and tantalum scaffolds by the IonTite™ process developed at Spire Biomedical. Properties of the starting powders and the powders after coating were determined by XRD, AFM, SEM, and EDS.



(a) Uncoated Ta (b) Microcrystalline HA (c) Nanocrystalline HA

Figure 1: SEM pictures of uncoated and coated tantalum. (Ta) Scale bar = 2 microns.

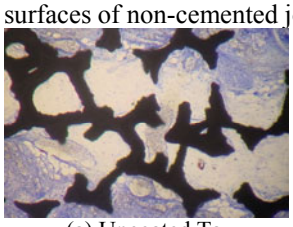
For in vitro analysis, human osteoblasts were purchased from ATCC and were seeded (3500 cell/cm^2) onto the substrates of interest and cultured under standard cell culture conditions for 4 hours. In addition, long-term functions of osteoblasts (such as alkaline phosphatase and calcium deposition) were determined after 7, 14, and 21 days of culture under standard conditions. Commerically available kits were utilized to determine alkaline phosphatase and calcium deposition. Experiments were completed in triplicate at three separate times.

For the preliminary in vivo analysis, the well-established athymic mouse subcutaneous (SC) implantation model was used. For this purpose, the materials of interest to the present study were implanted in the SC tissue with 1.5 million (per implant) seeded fetal bovine osteoblasts for 6 weeks. At the conclusion of the time periods, ground sections were obtained, stained with Sanderson's stain and were measured for bone growth.

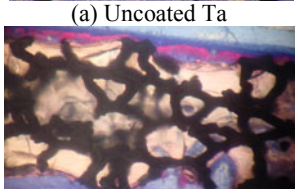
RESULTS AND DISCUSSION

Material characterization studies revealed similar properties between the HA powders before and after being coated on the metals. More importantly, in vitro results of the present study demonstrated increased functions of osteoblasts on metals coated with nanocrystalline compared to microcrystalline HA.

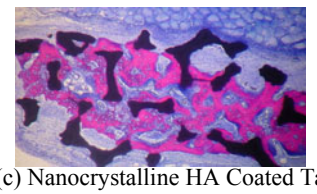
Moreover, preliminary in vivo analysis also indicated increased new bone infiltration into metal scaffolds only when coated with nanocrystalline HA (Figure 2). In this manner, the present study suggests that metals coated with nanocrystalline HA should be further investigated for orthopedic applications such as fabrication of bone scaffolds and surfaces of non-cemented joint prostheses.



(a) Uncoated Ta



(b) Microcrystalline HA Coated Ta



(c) Nanocrystalline HA Coated Ta

Figure 2: Increased bone ingrowth for Ta coated with nanocrystalline HA. Areas in pink red are new bone. (Implantation Time = 6 weeks.)

ACKNOWLEDGEMENTS

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