Compositionally Graded Hydroxyapatite/Tricalcium Phosphate Coating on Ti using Laser and Induction Plasma Spray for Load Bearing Implants

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Introduction: Though hydroxyapatite (HA) coated implants are commercially available, it's acceptance is still not wide spread due to challenges related to weaker interfacial bonding between metal and ceramic phases, and low crystallinity of HA. The ***objective*** of this research is to test our ***hypothesis***, which is chemistry and microstructure in functionally graded HA/tri calcium phosphate (TCP) coating on Ti can both (1) eliminate the interfacial strength problems of current coating technologies and (2) promote intimate implant - tissue integration and better bone remodeling around the implant. The ***rationale*** of this is that the elimination of the sharp Ti-coating interface will decrease the thermal mismatch stress at the interface, and thereby improve the stability of the coating *in vivo*. In the present work, compositionally graded HA/TCP coating was prepared by the application of laser engineered net shaping (LENS™) and radio frequency (RF) induction plasma spray and *in vitro* biocompatibility was evaluated.

Methods: The optimized parameters of LENS™ were selected from previous optimization study and used to prepare the TCP coating on Ti metal. The coating was prepared at 400W laser power, 15mm/s scan speed and 13g/min powder feed rate [1]. The LENS™ processed TCP coated Ti was used as the substrate for RF induction plasma sprayed HA coating preparation. The plasma sprayed HA coating was prepared at 25 kW plasma power and 110mm working distance, which has been optimized to minimize phase decomposition and amorphous phase formation in HA. The coatings were cross sectioned, polished and etched and looked in FESEM to reveal the coating microstructure. *In vitro* biocompatibility study using human osteoblast cell line hFOB was aimed to evaluate any possible toxic effect of laser and plasma processing of HA/TCP graded coating on Ti and compared to that of widely used Ti as control sample. The cell proliferation assay was done using MTT. Currently *in vivo* studies are being performed.

Results: Figure 1 shows the cross sectional microstructure of graded HA/TCP coating. The coating smoothly transitioned from Ti to HA with a Ti+TCP layer in between. The interface between Ti- Ti+TCP was coherent with no sharp interface. The top HA layer was well bonded to the Ti+TCP composite region with no sign of delamination or cracking. The hardness profile of the coating showed a maximum hardness of 706±25 Hv in the Ti+TCP composite region, which dropped in both Ti substrate and HA layer. Initial attachment, growth and spreading of hFOB cells on uncoated Ti, LENS™ TCP coated Ti, and plasma sprayed HA coating were analyzed using FESEM and is shown in Figure 2. At day 3, cells on LENS™ TCP coated Ti surface and plasma sprayed HA coatings had a spread like morphology with more filopodia extensions, as shown in Figure 2, suggesting significantly better cell attachment and spreading compared to control Ti. After 11 days of culture, cells on both the coatings covered the surface. However, a dense and confluent cellular layer was formed on plasma spayed HA coating, signifying a more bioactive surface compared to both uncoated Ti and LENS™ TCP coated Ti surface. In contrast, Ti control surface showed no confluent layer formation even after 11 days [3]. The cell proliferation assay was determined by MTT assay, which showed improvement in cell proliferation from uncoated Ti to LENS™ TCP coated Ti and reached maximum in plasma sprayed HA coating.

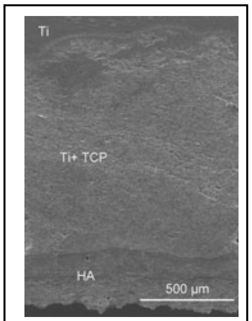

Figure 1. Microstructure of HA/TCP coating

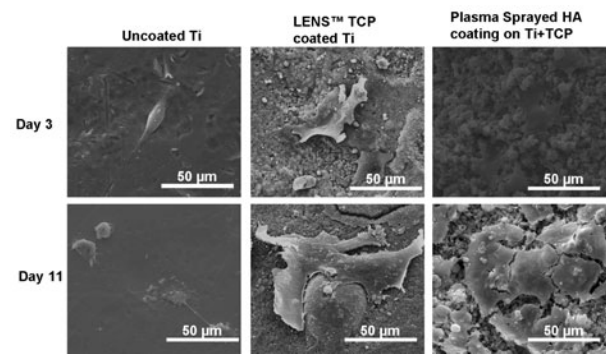

Figure 2. hFOB cell morphologies after 3 and 11 days of culture.

Conclusions: HA/TCP graded coating was successfully prepared by using laser and RF induction plasma spray on Ti with strong interface. Microstructure of graded HA/TCP coating showed smooth transition between the superficial HA layer and Ti+ TCP layers. The hFOB cell material interaction showed that the top HA layer significantly improves the cell proliferation compared to both uncoated Ti and LENS™ TCP coated Ti surface. The authors gratefully acknowledge the financial support from NIH (Grant # Ro1EB 007351).

References:

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