Nanohydroxyapatite-Titanium Coating Created by Novel Molecular Plasma Deposition for Bone Tissue Engineering

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Abstract: In bone tissue engineering, the beneficial effect of hydroxyapatite (HA) coating on titanium (Ti) is unambiguous. In order to prepare an improved biomaterial in such application and to mimic the natural environment bone, the objective of this in vitro study was to synthesize nano-HA powders to coat Ti using the proprietary molecular plasma deposition (MPD) process [1]. The method is based on generating a charged corona plasma which is introduced into a vacuum chamber to deposit the nano-HA onto a biased substrate. The aim was to determine whether MPD coated nano-HA (that was processed at a reduced sintering temperature while providing enough interfacial strength) provide better osteoblast (bone-forming cell) density compared to the micron-HA coated (that was processed at high sintering temperature) and uncoated Ti control. In this respect, to improve the bond strength between the HA coating and Ti, we used porous Ti (with nano-tubular structures that was prepared by electrochemical anodization) because it is expected that the porous structure contributes to an increase of contact area with HA.

Methods: Donut shaped nanotubes were fabricated on Ti coupons using electrochemical anodization process [2]. Nano-HA was synthesized through a wet chemical process followed by hydrothermal treatment (using Parr Acid Digestion Bombs 4748; Parr Instrument) at 120° C for 20 h. Figure 1illustrates the MPD process for nano-HA coating on anodized Ti. During the MPD coating process, the vacuum chamber was pumped down and a high voltage of 20 kv was applied to needle that contain the above nano-HA solution which was fed at a constant rate.

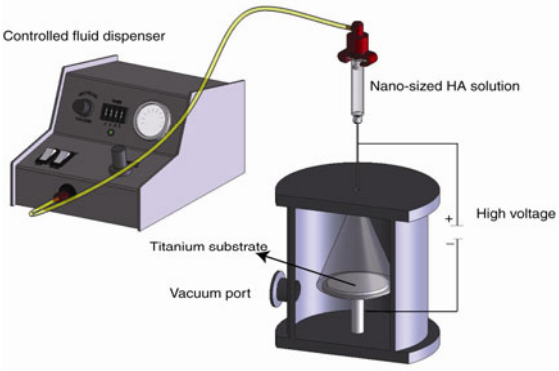

Figure 1. Illustration of MPD process used in this study.

Due to very high potential gradient, a corona discharge was generated at the tip of the needle causing the surrounding fluid to ionize. The ionized plasma was drawn in the vacuum chamber towards the biased substrate. After the coating process, the substrates were heated to 200° C for 2 h, dried in vacuum and stored in a dessicator until further use. Micron-HA coating was prepared by sintering above nano-HA coatings at 900°C for 2 h. The coating characterization of the substrates before and after sintering was conducted by using scanning electron microscopy (SEM), atomic force microsopy (AFM), and X-ray diffractometer (XRD). All substrates were sterilized under UV light for 4 hours prior to cell experiments. Human osteoblasts were seeded at a density of 3500 cells/cm^2.

Results: SEM, AFM, and XRD were used to study the stability, structural and topographical integrity of nano-HA coatings (data not shown). In order to determine the biological responses of MPD coated surfaces, the attachment and spreading of osteoblast on the plain, anodized, nano-HA coated and micron-HA coated anodized Ti was investigated. After 1 day, the nano-HA coated anodized Ti supported a larger number of adherent cells than the micron-HA coated and uncoated surfaces (Figure 2). A similar trend was observed after 7 days of osteoblast culture. The morphology of these cells was assessed by SEM and the appearances observed were different on each substrate types (data not shown). In particular, anodized Ti and nano-HA coated anodized Ti showed well-spread cell morphology, where as plain Ti and micron-HA coated anodized Ti displayed condensed cell morphology.

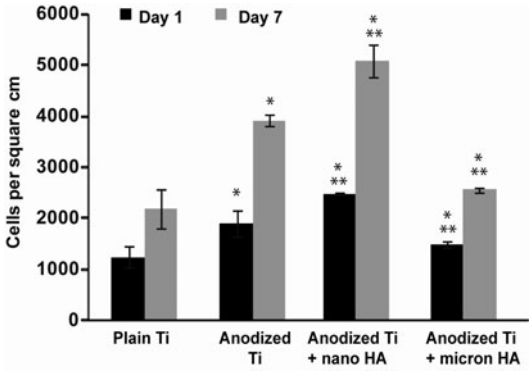

Figure 2. Increased osteoblast density on MPD coated nano HA on anodized Ti.

Conclusions: Our results, to the best of our knowledge, are the first reports using MPD in the framework of nano-HA coatings on Ti with modified osteoblast response. While numerous methods have coated HA (micron or nano-sized) on Ti to modify osteoblast responses, MPD is a robust, inexpensive, effective process to accomplish the same. Thus, this novel bimolecular coating method offers an alternative way to possibly generate new implant devices in bone tissue engineering.

References:

1. Storey DM, McGrath TS, Shimpi TM. 2007, U.S. Patent No 7,250,195.
2. Balasundaram G, Yao C, Webster TJ. J Biomed Mater Res A 2008;84:447-453.