Fabrication, Mechanical and *In vitro* Biological Properties of Porous Tantalum for Bone Implants

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Statement of Purpose: Relatively high cost of manufacturing and inability to produce a modular all tantalum implant has limited its widespread acceptance, in spite its excellent *in vitro* and *in vivo* biocompatibility. In this presentation, we report how to process Ta to create net shape porous structures with varying porosity using Laser Engineered Net Shaping (LENS) for the first time. Porous Ta samples with relative densities between 45 to 73% have been successfully fabricated and characterized for their mechanical properties. *In vitro* cell materials interactions, using human osteoblast cell line hFOB, have been accessed on these porous Ta structures and compared with porous Ti control samples.

Methods: Ta metal powder with 99.5% purity and particles size between 45 and 75 μm was used. Porous Ta samples were deposited on a substrate of 3mm thick rolled, commercially pure (CP) Ti plates using LENS™-750 (Optomec Inc. Albuquerque, NM) equipped with a 500W continuous wave Nd:YAG laser. Detailed description of LENS™ operation and capabilities can be found elsewhere [1]. Laser powers of 125 and 350W, scan speeds between 10 and 20 mm/s, and powder feed rates of 126 and 141 g/min were used. All the samples were characterized in terms of bulk density, open pore volume, microstructure and mechanical properties. *In vitro* cytotoxicity behavior of laser processed porous Ta with 27% and 45% porosity, and porous Ti control sample with 27% porosity was evaluated and compared for a maximum incubation period of 11 days using human fetal osteoblast cell (hFOB) line (CRL-11372, ATCC, VA, USA). Proliferation of viable hFOB cells attached on porous Ta and Ti sample surfaces was assessed by the MTT assay (Sigma, MO, USA) after 3, 7 and 11 days of incubation period. Vinculin and alkaline phosphatase (ALP), the specific protein expressions respectively relevant to focal adhesion formation and osteoblast cell differentiation, have been assayed for test samples by fluorescent staining and confocal laser scanning microscopy (CLSM) observation. Detailed description of these *in vitro* biocompatibility tests is provided in [2]. MTT assay results are presented as mean ± standard deviation. Statistical analysis was performed on the experimental data using Student's t-test, and $p < 0.05$ was considered statistically significant.

Results: The relative density of porous Ta samples varied between 45 and 73% depending on specific energy input which has been changed by tailoring the LENS™ processing parameters. Increasing the energy input from 23.9J/mm^3 to 361.7J/mm^3 increased the density of porous Ta samples from 45.7±1.7% to 73.2±2.2%. **Table 1** shows the influence of energy input on relative density of LENS™ processed porous Ta samples. In general, total porosity increased with increasing powder feed rate or scanning speed and decreasing the laser power. Also, both closed and open pore volume decreased with increasing laser energy input. The open pore volume in present samples varied between 38% and 64% of the total volume % porosity.

Table 1 Relative density and mechanical properties of porous Ta samples.

Specific Energy, J/mm^3	Density, %	0.2% Proof Strength, MPa	Young's Modulus, GPa
361.7	73.2 ± 2.2	746 ± 27	20 ± 1.9
96.9	55.3 ± 1.5	192 ± 7	7 ± 0.6
23.9	45.7 ± 1.7	100 ± 10	1.5 ± 0.3

The surface chemistry, pore volume fraction and the surface morphology of porous samples shown to have significant influence on hFOB cell adhesion, growth, motality, and differentiation. Superior cell adherence with numerous cellular micro extensions were observed on porous Ta samples compared to Ti samples, which suggests that Ta surfaces are biocompatible and cause no inhibition to bone cells adhesion and growth. MTT results (**Figure 1)** showed that cell attachment and proliferation depends on sample's porosity in addition to materials chemistry. Significantly high number of living cells was observed on Ta samples than Ti samples for all culture durations.

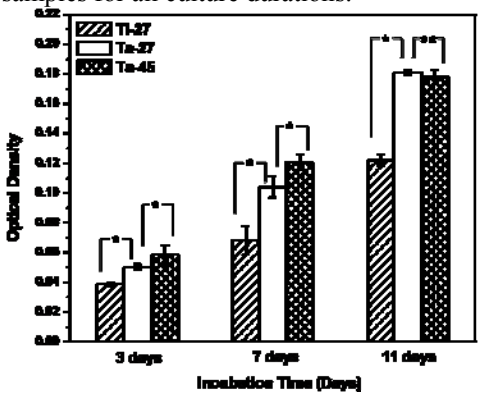

Figure 1 MTT assay of cells on 27% porous Ta (Ta-45), 45% porous Ta (Ta-45) and 27% porous control Ti samples after 11days of incubation time.

Immunochemistry and confocal microscopy results showed strong green fluorescence indicating excellent focal adhesion sites on Ta samples compared to Ti samples. Moreover, the higher wettability and higher surface energy of Ta (55 mN m^{-1}) than Ti (42 mN m^{-1}) [3] enhanced *in vitro* cell-materials interactions on Ta surfaces than on Ti.

Conclusions: Our experimental results on fabrication and *in vitro* biocompatibility of porous Ta indicate that modular all tantalum implants with tailored porosity can be fabricated using LENS™. The *in vitro* biocompatibility results show that these porous Ta samples have better hFOB cell adhesion, growth and differentiation than Ti.

References:

1. Balla VK et al., *J Biomed Mater Res B* 2009;89-B:481-490.
2. Balla VK et al., *Biomaterials*, Submitted Oct. 2009.
3. Balla VK et al., *Acta Biomater* Submitted Sept. 2009.