Physical and Mechanical Characteristics of a Porous Structured Titanium Biomaterial

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Statement of Purpose: Highly porous bone fixation materials have become a key element in successful orthopedic device designs. New manufacturing processes provide for a design versatility and manufacturing repeatability not achievable with conventional porous material to solid substrate bonding techniques or other porous material fabrication methods. For the first time, a broad range of properties can be engineered into a titanium porous material.

Methods: Direct metal laser sintering (DMLS) of Ti-6Al-4V alloy was used to create a random porous structure technology (PST) which mimics trabecular bone. This additive manufacturing method has been used to produce a new porous material for orthopedic applications. Figure 1 illustrates the random strut and pore nature of this material. Three dimensional computer modeling and the DMLS manufacturing method allow for unique designs and variations of this porous material. Five different configurations were modeled and built. In all samples, the porous structure strut size is approximately 185 µm. The pore size was varied from approximately 285 to 530 µm. Using these designs, cylindrical compression plugs measuring 10.4 mm in diameter and 11.7 mm in height were produced with an EOS 280 laser sintering machine. The variations in porous construct of these test samples can be seen in Figure 2. A Micrometrics helium pycnometery was used to measure porosity. Ten measurement cycles were run for each sample with the average value reported. Compressive testing was performed on an MTS electromechanical load frame. Loading was applied until the deformation of the specimen was greater than 30%. Yield strength was determined as the point at which an inflection of the stress strain slope occurred. Modulus of elasticity was determined by measuring the slope of the stress strain curve. Five replicates of each design were tested.

Results: Pycnometry indicated that the samples varied in average porosity from a high of 71% down to a low of 27%. Compressive yield strength and modulus were found to be, as expected, inversely related to porosity. Compressive yield strength results varied from 55.60 ± 1.02 to 679.20 ± 4.66 MPa. Compressive modulus values ranged from 1.66 ± 0.03 to 11.63 ± 0.26 GPa. These results are shown in Figure 3. For comparison purposes the compressive strength of human bone has been reported as 162 MPa for cortical[1] and 30 MPa for trabecular[2]. The modulus values are 16 GPa for cortical and 2 GPa for trabecular.

Conclusions: The ability to design specific porous materials for orthopedic applications is now available. Varying the pore size of a porous material yields varying mechanical properties. This study focused on only the pore size of the PST but it is likely that engineering the strut size and random nature of the material would also produce a spectrum of properties. For the first time, porous materials can be tailored to better match the strength and/or stiffness of cortical and/or cancellous bone. With the DMLS process of manufacturing, it is even possible to produce an orthopedic implant with non-uniform porous materials if required by the application. The DMLS process also assures that a PST material once designed will be identically produced on every part. Future implant designs should be able to benefit from this new material / process.

References: 1. Öhman, C, et al. *J Biomech* **41**(S1), 2008
2. Black, J, Hastings, G (Eds.). (1998). *Handbook of Biomaterial Properties*. London UK: Chapman & Hall

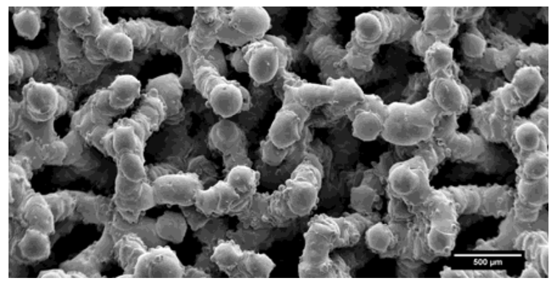

Figure 1: SEM of typical PST material

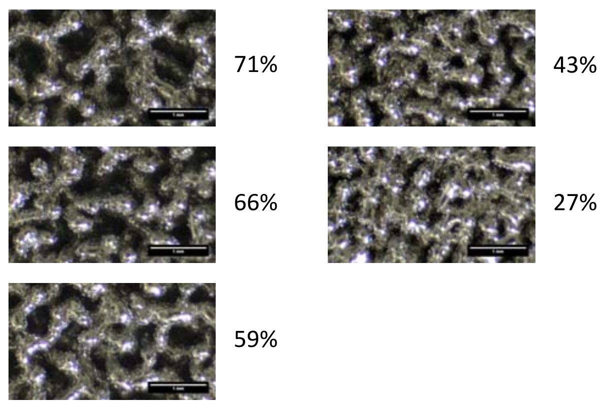

Figure 2: Photomicrographs of PST Variations Tested

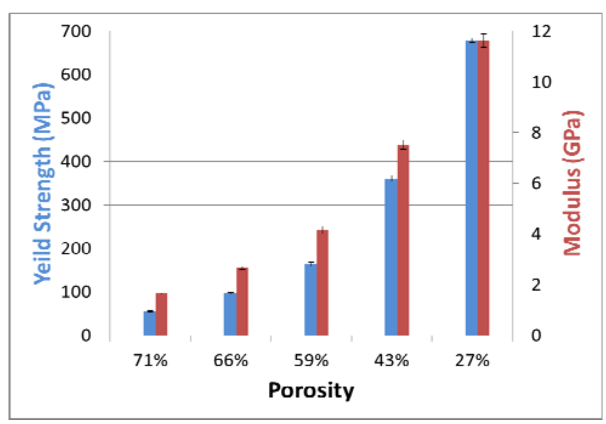

Figure 3: Yield Strength and Modulus vs. Porosity