STRENGTH AND FRICTION CHARACTERISTICS OF A POROUS STRUCTURED TITANIUM BIOMATERIAL

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Statement of Purpose: In the last 15 years, orthopedic implants have incorporated into their design highly porous bone fixation materials. The clinical benefits of these materials are a greater volume of porosity for bone ingrowth and a resultant increase of fixation strength. New porous metal materials have been created to have greater strength and a higher coefficient of friction. Manufacturing processes only recently available also provide for a design versatility not achievable with conventional porous material to solid substrate bonding techniques.

Methods: Direct metal laser sintering (DMLS) of Ti64 alloy was used to create a random porous structure technology (PST) which mimics trabecular bone. Three dimensional computer modeling and the DMLS manufacturing method allows for unique designs of porous materials. The porous construct of these test samples can be seen in Figure 1. The strut size is 185.7 ± 8.4 µm. The pore size is 408.6 ± 89.5 µm and the overall porosity is 65.2 ± 3.1 %. Using this design, compression plugs measuring 10.4 mm in diameter and 11.7 mm in height and friction discs measuring 25.4 mm square with 1.5 mm thickness were produced with an EOS 280M laser sintering machine. Compressive testing was performed on an MTS. 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. Friction testing was performed using bi-axial MTS. The porous material was mounted parallel in contact with 0.16 g/cm^3 density polyurethane foam. A vertical load of 65 N was applied normal to the contacting surfaces and a horizontal displacement was applied to the foam at a rate of 0.025 mm/sec. Vertical and horizontal loads were recorded and used to calculate the coefficient of friction by dividing peak horizontal load by the nominal normal force. Samples of commercially available titanium plasma spray and diffusion bonded beads were also tested for comparison purposes.

Results: Compressive yield strength was found to be 176.13 ± 1.00 Mpa. The average Modulus of Elasticity was 3.48 ± 0.26 GPa. The failure mode of these specimens as shown in Figure 2 is a highly ductile collapse of the specimen upon itself. No debris was shed by the specimens as they were tested to high strains. The Coefficient of friction results for PST was 0.97 ± 0.04.

Conclusions: The compressive strength of PST is as strong as cortical bone and has a compressive modulus very similar to trabecular bone giving it both strength and flexibility as shown in Figure 3. These results indicate that a component such as an acetabular cup made from PST would share loading with bone in a physiological manner and yet would be strong enough to take impact loading during implantation and survive in-vivo loads. A high friction surface is desirable in an orthopedic implant, such as an acetabular cup, to provide better initial bone fixation. The coefficient of friction in PST is superior to other standard commercially available orthopedic materials as shown in Figure 4. PST should provide an ideal orthopedic material for novel future implant designs.

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

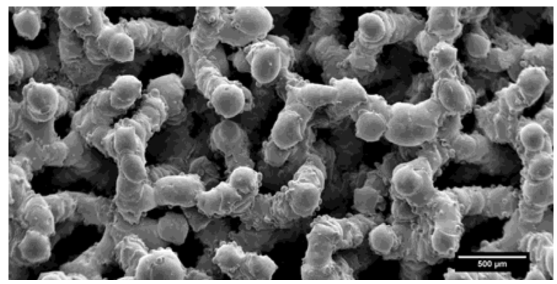

Figure 1: SEM of Porous Structure Technology (PST)

Figure 2: Compression ductility of PST

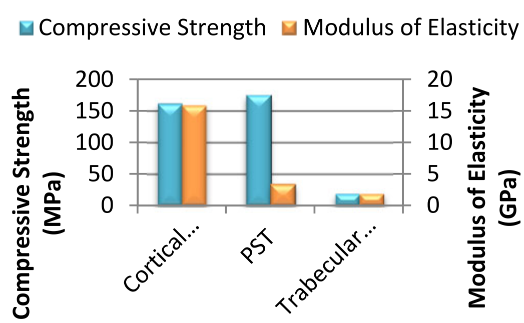

Figure 3: Compressive strength and modulus compared to cortical[1] and trabecular[2] bone

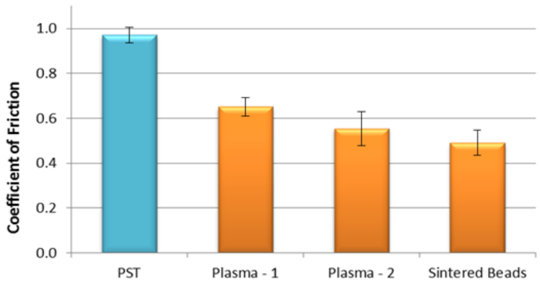

Figure 4: Coefficient of friction of PST compared to commercially available coatings