PHYSICAL AND MECHANICAL CHARACTERISTICS OF A POROUS STRUCTURED TITANIUM BIOMATERIAL

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INTRODUCTION

Cementless implants were developed to decrease the incidence of loosening observed with cemented implants. Longevity of cemented implants suffered as a result of poor cementation technique, particularly for younger, more active patients which have a reported revision rate at 16 years of 67%[1,2]. Highly porous bone fixation materials have become a key element in successful cementless orthopedic device designs. Historically, various surfaces to allow biological fixation or on-growth have been applied as a coating to a pre-formed solid metal substrate. Representative coating surfaces include sintered beads, diffusion-bonded fiber metal, plasma sprayed titanium and tantalum porous metal. New manufacturing processes, however, provide for a design versatility and manufacturing repeatability not achievable with conventional porous materials. The ability to manufacture both a solid and a porous portion of an implant offers an advantage over secondary porous attachment processes such as diffusion bonding[3]. For the first time, a broad range of properties can be engineered into a titanium porous/solid monoblock 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. Three dimensional computer modeling and the DMLS manufacturing method allows for unique designs of porous materials. Using these concepts, compression plugs measuring 10.4 mm in diameter and 11.7 mm in height were produced using an EOS 280 laser sintering machine. The porous construct of these test samples can be seen in Figure 1. The strut size was 185.7 ± 8.4 µm. The pore size was 408.6 ± 89.5 µm and the overall porosity is 65.2 ± 3.1 %. Compressive testing was performed with an MTS machine. Modulus of elasticity was determined by measuring the slope of the stress strain line.

RESULTS

The Yield Strength was determined to be 176.13 ± 1.00 Mpa. The average Modulus of Elasticity was 3.48 ± 0.26 GPa, the failure mode of these specimens is a highly ductile collapse of the specimen upon itself. No debris was shed by the specimens as they were tested.

DISCUSSION

The compressive strength of PST is between that of trabecular and cortical bone and superior to other forms of advanced porous materials[4,5]. The compressive modulus of PST is very similar to advanced porous materials. 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. For the first time, monoblock porous/solid 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 properties 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 may be able to benefit from this new material / process. Long term clinical follow-up studies are required to confirm safety and effectiveness of PST.

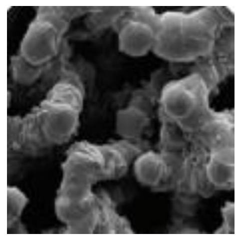

Figure 1.Porous construct of Porous Structure Technology (PST)

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DISCLOSURES

All authors are employees of Stryker Corp.