Porous Titanium Scaffolds by Dynamic Freeze Casting for Bone Tissue Engineering

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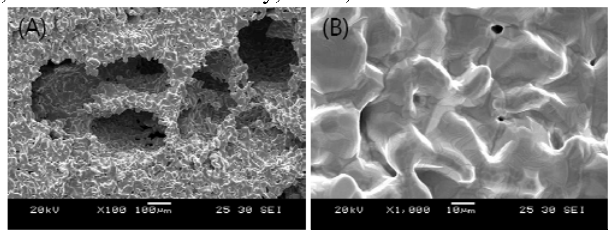

Fig 1. SEM micrographs of the porous Ti scaffold (15 vol.% of Ti contents) (A) low magnitude (B) high magnitude

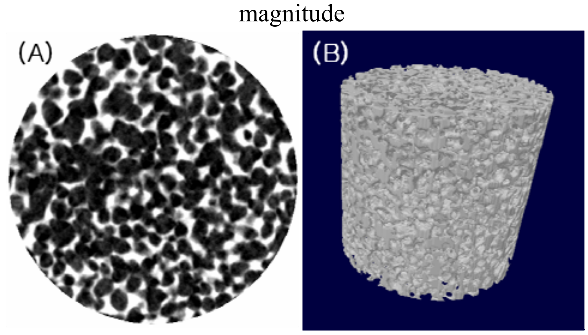

Fig 2. (A) 2-D and (B) 3-D reconstruction of porous Ti scaffold using the micro- CT

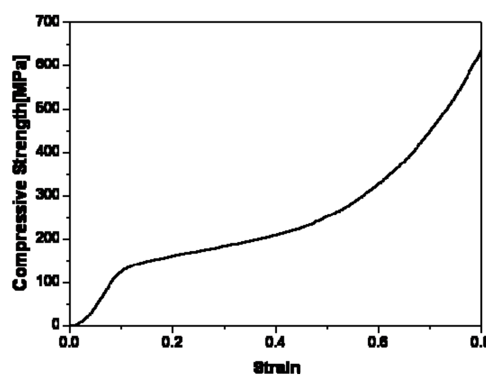

Fig 3. Typical stress versus strain response of the porous Ti scaffold produced with an initial Ti content of 15 vol.%.

Statement of Purpose:

Titanium (Ti) and its alloys are used extensively for orthopedic and dental implants, owing to their have good mechanical properties, chemical stability, and biocompatibility [1]. To date, a range of manufacturing methods have been developed for the production of porous Ti-based materials because they can provide not only favorable environments for bone ingrowth, but also matching mechanical properties to those of the surrounding bones [2]. Among various manufacturing methods, freeze casting has recently demonstrated to be a useful method for the production of porous titanium. However, this method can be applied only ceramic powders, not metal powders [3]. Because dispersant can be activated by electrostatic effect when using ceramic powders. Therefore, in this study, we fabricated porous Ti using Ti powder by dynamic freeze casting technique [4].

Methods:

Titanium (Ti)/camphene slurries with Ti content (15vol.%) were prepared by stirring at 50 °C for 30min. Prepared slurries were poured into cylindrical aluminum molds and frozen at 45 °C dynamically in order to avoid segregating powder from camphene [3]. After de-molding, the green bodies were pressed using a cold isostatic press(CIP) at 200 MPa to produce the green compact specimens. They were then freeze dried to remove the frozen camphene. Thereafter, the samples were heated up to 1300°C at a fast heating rate, and heat treated for 2 h. The porous structures and morphology of the samples were characterized using scanning electron microscopy and a micro–computed tomography (micro-CT). In order to evaluate their mechanical properties, their compressive stress–strain behaviors were also monitored.

Results:

The fabricated sample had highly porous structures as shown in Fig. 1(A). It should be noted that the scaffold had a pore size of about 300 μm and a porosity of about 67%. The microstructure of the Ti wall was shown in Fig. 1(B). It showed excellent consolidation of the Ti walls without any noticeable cracks. Figure 2 (A) shows micro-CT image of the cross section of fabricated Ti scaffolds. Pore size is uniform and homogeneous. 3-D image of the scaffold was constructed using the micro-CT in Figure 2 (B). It should be noted that the porous structure was uniform throughout the entire sample without any noticeable defects, such as cracking or large voids. The mechanical properties of the samples were evaluated using compressive strength tests. The typical stress versus strain response of the sample produced using an initial Ti content of 15 vol.% is shown in Fig. 3, corresponding with that of ductile metallic foam.

Conclusions:

The dynamic freeze casting technique was used to produce biomedical porous Ti scaffold. It had a pore size of about 300 μm and a porosity of about 67%, and was well-sintered without any noticeable cracks. Its strength is about 130 MPa and stress – strain curve showed the typical curve corresponding with that of ductile metallic foam. These results indicate that the dynamic freeze casting technique is a promising method for producing porous Ti scaffolds for applications in bone tissue engineering.

References:

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2. Ryan G et al. Biomaterials 2006; **27**; 2651-2670
3. Jung HD et al. Materials letters 2009; **63**; 1545-1547
4. St-Pierre JP. Biomaterials 2005; **26**; 7319-7328