Porous titanium scaffolds with controlled pore size by combination of freeze casting and space holder methods

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Introduction : Porous titanium has been studied widely to promote osteogenesis, as well as to overcome stiffness mismatch of titanium with bones [1]. We have recently fabricated porous titanium by camphene-based freeze casting method [2]. However, there was a limitation in the titanium scaffolds fabricated by the freeze casting method because the pore size was limited to smaller than 300μm [2]. The optimal pore size for orthopedic implants is known to be larger than 300μm considering cell binding sites, formation of new bone, and vascularization [1]. Therefore, in this study, the porous Ti scaffolds were fabricated by combining the freeze casting and space holder methods. The pore size became significantly larger than that of scaffolds fabricated by the camphene-based freeze casting method.

Methods : 15 vol% TiH_2 powder was ball-milled with molten camphene at 55°C for 24h. Thereafter, the prepared warm slurries with various urea content (10, 15, and 20 vol%) were poured into the cylindrical copper molds and the molds were rotated at 43.5°C for 24h. After de-molding and freeze drying, the green bodies were heated at 200°C for 12 h in air to burnout the urea. Thereafter, the samples were heated to 400 °C for 2 h, followed by sintering at 1300 °C for 2 h in a vacuum. The porous structures were evaluated by micro-CT and SEM, and their compressive strength was evaluated.

Results and Discussion : Fig. 1(A)-(C) shows the typical 2D image and pore size distribution. The porosities of each sample were 60-62% regardless of the urea content. The samples fabricated by combining freeze casting and space holder methods were highly uniform due to the fact that the green bodies fabricated by camphene-based freeze casting method have uniformly overgrown camphene dendrites [2]. As the urea content increased from 10 to 20vol%, the percentage of pores larger than 300μm increased**.** Fig. 1(D) shows the interconnection between pores obtained by camphene and those by urea. All samples had highly interconnected pores. The results of micro-CT analysis showed that open pores were more than 99% of total pores. As the urea content increased from 10 to 20vol%, the compressive strength decreased from 78 to 51 MPa, as shown in Fig.2. However, these compressive strengths were still similar or higher than those fabricated by the space holder methods [1]. It was attributed to the fact that the relatively small pores coexisted with large pores and the uniformity increased by using space holder method together with camphene-based freeze casting method.

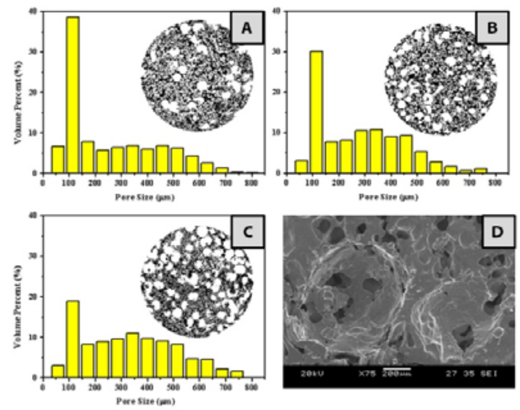

Fig. 1. The typical 2D image and pore size distribution with urea content of (A) 10 vol%, (B) 15 vol%, (C) 20 vol% (D) SEM micrograph of interconnection between pores obtained by camphene and urea

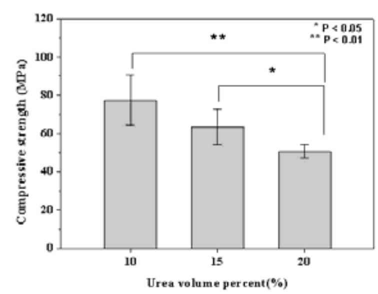

Fig. 2. Compressive strength of the porous Ti scaffolds as a function of the initial urea content

Conclusions : Ti scaffolds with interconnected and increased pores were fabricated by camphene-based freeze casting together with space holder method. From the results, it is clear that the porous Ti bodies with large pores and high strength can be generated by combining the freeze casting method and space holder method.

Reference :

1. Wen CE et al., J Mater Sci-Mater M; 2002; 13; 397-401
2. Yook SW et al., Mater Lett; 2008; 62; 4506-4508