Biomimetic structure of hydroxyapatite scaffolds by camphene-based freeze casting for bone tissue engineering

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Introduction : Porous hydroxyapatite (HA) bioceramics have been explored as bone substitute materials since they have excellent permeability and a large surface area, as well as excellent biocompatibility. However, porous HA has poor mechanical strength, which has restricted their usages to low- or non-load-bearing parts [1-2]. It was observed that a scaffold with a gradient porosity, just like the architecture of natural bone, could induce a fast bone in-growth into the high-porosity portion while withstand high mechanical stress [1]. In this study, we fabricated HA scaffolds with two distinct porosities, i.e., highly porous inner core and dense outer shell, by freeze casting technique.

Methods : Hydroxyapatite (HA)/camphene slurries with HA contents (10 and 38 vol.%) were prepared by ball-milling at 60°C for 24 h [3]. Slurries of 38 vol% were poured polyethylene (PE) molds and kept at 44°C for 5 min. After casting, the hole was made at the center of green bodies using a drill. The green bodies with inner holes were transfered to the larger molds. The gap between green bodies and PE molds was filled with 10 vol% slurries. After keeping at 44°C for 1 day and de-molding, the green bodies were then freeze dried. Thereafter, the samples were sintered at 1300°C for 2 h in air. After sintering, the outer porous portion of the scaffold was removed. The porous structures and morphology of the samples were characterized using scanning electron microscopy. The interaction of porous parts and dense parts in the samples was characterized using a micro–computed tomography (micro-CT). In order to evaluate their mechanical properties, their compressive stress–strain behaviors were also monitored.

Results and Discussion: Figure 1 shows SEM image of the cross section of fabricated HA scaffolds. In the view of radial direction and axial directions, the boundary between the dense and porous parts is very compact and tight. 3-D image of the scaffold was constructed using the micro-CT in Figure 2. It should be noted that the porous core had a pore size of about 100 µm and a porosity of about 60%. The shell part was dense and uniform throughout the entire sample without any noticeable defects, such as cracking or large voids. The compressive strength of scaffolds with dense shell was remarkably higher than that of scaffolds without dense shell as shown in Fig. 3. These values are comparable or even much higher than those reported in the literature [2]. These excellent mechanical properties were attributed to the HA shell and controlled pore structure.

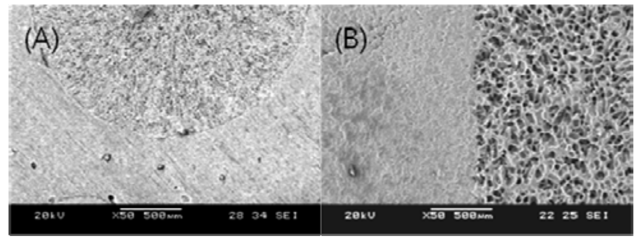

Fig 1. SEM micrographs of the porous HA scaffolds with dense shell; cross section of (A) radial direction (B) axial direction

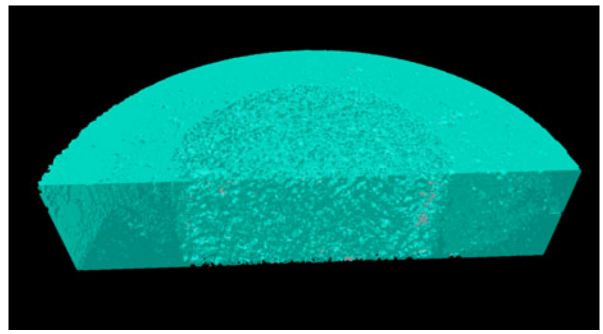

Fig 2. 3-D reconstruction of HA scaffolds using the micro- CT

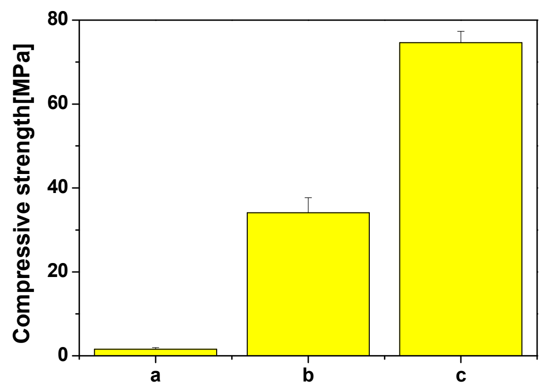

Fig 3. Compressive strength of the porous HA scaffolds ((a) scaffold fabricated using 10vol% slurry (b) scaffold fabricated to have same porosity with c using appropriate slurry (c) scaffold with dense shell fabricated using 10vol% slurry)

Conclusions: The camphene-based freeze casting technique was used to produce porous HA bioceramics with load- bearing parts. The boundary between the dense and porous parts was very compact and tight. The porosity and mechanical property of the scaffold were controlled by the relative thickness of dense/porous parts. From a consideration of the results, it is indicated that the porous HA scaffolds with load-bearing parts have a potential as bone grafts in hard tissue engineering.

References:

1. Zhang F et al. Acta Biomaterialia 2007; **3**; 896-904
2. Lee EJ et al. Materials letters 2007; **61**; 2270-2273
3. Jung HD et al. Materials letters 2009; **63**; 1545-1547