Fabrication of Customized Porous Hydroxyapatite (HA) implants for Osteotomy

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Introduction : Treatment of complex fractures of long bones is a challenging matter, often involving large osseous defects that are difficult to reconstruct. The limitations of traditional bone grafts or bone graft substitutes have prompted the development and use of some new synthetic biomaterials. Porous hydroxyapatite (HA) scaffolds have been explored as bone substitute materials since they have excellent permeability and a large surface area, as well as excellent biocompatibility [1]. Many investigators reported that porous HA scaffold has the capability to induce incorporation at the interface of bone with ingrowth of regenerated bone into the pores through histological observations. Their poor machinability, however, limits their clinical application especially for a large bone defect. In this study, we fabricated porous HA with various pore sizes and complex shapes by dynamic freeze casting technique [2].

Methods : HA/camphene slurries with HA contents of 15 vol% were prepared by ball-milling at 60 °C for 24 h. The prepared slurry was poured into cylindrical molds and dynamically frozen at 44 °C for various periods of time (1~7 days) to allow an excessive growth of camphene dendrites. After casting, the green bodies were machined into wedges, plates and rods. The samples were freeze dried to remove the frozen camphene crystals, which would create 3-dimensionally interconnected large pores. Thereafter, the samples were sintered at 1300 °C for 2 h. The porous structures and morphology of the samples were characterized using scanning electron microscopy.

Results and Discussion : Regardless of the casting time, all of the fabricated samples showed a highly porous structure with large spherical-like pores, as shown in Fig. 1 (A)–(C). This suggests that camphene crystals are likely to grow isostatically during the freezing process in rotation, which differs from the conventional freeze casting, in which camphene dendrites grow preferentially along the direction of heat conduction, creating elongated pores. It should be noted that the pore size was increased remarkably with increasing the freezing time. However, regardless of the freezing time, all of the fabricated samples showed a similar porosity of 60%, indicating no sedimentation of the HA particles during freezing. As expected, the pore size was increased remarkably 271 to 986 μm with increasing the freezing time from 1 to 7 days, as shown in Fig. 2. A longer freezing time might lead to a larger pore size because of the very slow solidification rate of the Ti/camphene slurry with the assistance of rotation. Fig. 3 shows HA wedges and plates for osteotomy. Green body before removing camphene can be machined easily because of flexibility of camphene.

Conclusions: The dynamic casting technique was used to produce porous HA implants. All the fabricated samples showed uniform spherical-like pores after removing the camphene crystals grown during freezing in rotation as well as dense HA walls after sintering at 1300 °C for 2 h. As the casting time increased, pore size of the scaffold increased, and HA wedges of various thicknesses were fabricated. This method could be expanded to the production of customized implants for different controlled or non-controlled defect sites. Further work to validate and extend the dynamic freeze casting for other medical application such maxillofacial, dentistry, and orthopedic surgeries is currently in progress.

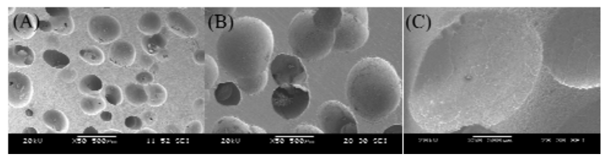

Fig 1. SEM micrographs of the porous HA implants with various casting time (A) 1 day, (B) 4 days, and (C) 7 days

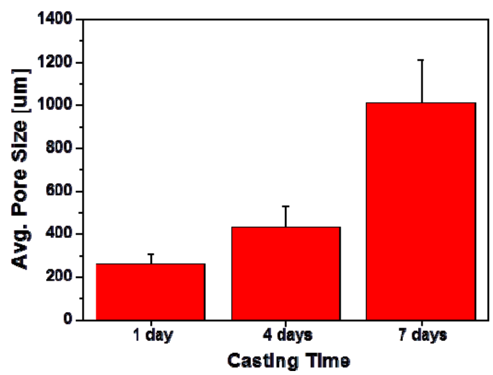

Fig 2. Pore sizes of porous HA implants as a function of casting time

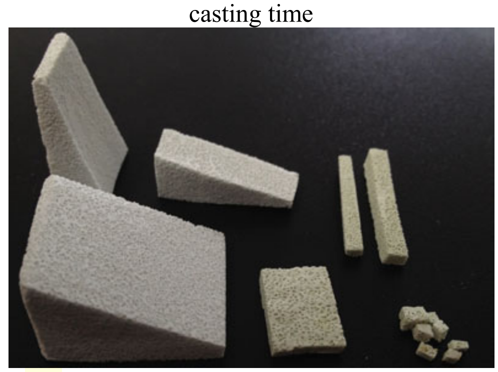

Fig 3. HA wedges and plates of various thicknesses. Note the visible macroporosity.

References:
1. Zhang F et al. Acta Biomaterialia 2007; **3**; 896-904
2. Jung HD et al. Materials Science and Engineering C 2012; **63**; 1545-1547