Comparison of β-tricalcium phosphate foam made using Mg stabilizer and by heat treatment

Kunio Ishikawa, Taro Nikaido, Kanji Tsuru
Department of Biomaterials, Faculty of Dental Science, Kyushu University

Introduction: β-tricalcium phosphate (βTCP) is widely used in clinical application as a bone replacement. Therefore, βTCP foam with fully interconnected porous structure allowing cell penetration and tissue ingrowth could be especially effective bone replacement. One of the methods to fabricate the foam is to employ the so-called ceramics foam method in which polyurethane foam is used as a template. Unfortunately, βTCP foam can not be fabricated directly using the ceramic foam method since the method require relatively high temperature and βTCP transforms to αTCP at temperature higher than 1,180^{o}C. In this investigation, Mg stabilizer addition and heat treatment of αTCP foam was compared to find a method suitable for the fabrication of βTCP foam bone replacement.

Methods: In one method, polyurethane foam was immersed in suspension made with MgO, calcium carbonate and dicalcium phosphate dihydrate so that the amount of MgO became 0, 1, 2, 3, 4, 6 and 8 mol%□ with (Ca□+Mg)/P molar ratio of 1.5. After drying, the foams were sintered at1500^{o}C for 5 h and cooled down to room temperature inside the furnace. In the other method, αTCP foams made by sintering at 1500^{o}C were heat treated at 600°C, 700°C, 800°C, 900°C, 1,000°C and 1,100°C for up to 300 h. Composition of the foam was analyzed with powder X-ray diffraction (XRD) and mechanical strength of the foams were evaluated using a universal testing machine in terms of compressive strength. Replacement of the foam to bone was evaluated by implanting the foam to the bone defect made at rat tibia..

Results and discussion: Fig. 1 summarizes the XRD patterns of the TCP foam containing 0-8mol% Mg when heated at 1,500^{o}C for 5 h. When the TCP contains 0 or 1 mol% Mg, it transforms to αTCP. The composition became mixture of α and βTCP when the TCP contained 2 mol% Mg. When the TCP contains 3 mol% or higher Mg, the composition was βTCP. Since larger amount of Mg has no advantage, 3 mol% Mg may be enough for the stabilization of βTCP foam. Fig. 2 summarizes the transformation ratio of α to βTCP when the αTCP foam was heat treated at 600°C - 1,100°C. As shown, heat treatment at 900°C resulted in the fastest transformation from α to βTCP. Heat treatment higher or lower than 900°C resulted in the slower transformation from α to βTCP. No transformation was observed when the treatment temperature was 600°C or 1,100°C. The α− β transition temperature of TCP is 1,180°C. No transformation from α to βTCP at 1,100°C may due to the limited driving force since 1,100°C is close to 1,180°C. Compressive strength of the βTCP was the same regardless of the Mg content or the heat treatment temperature and was approximately 50kPa. When the

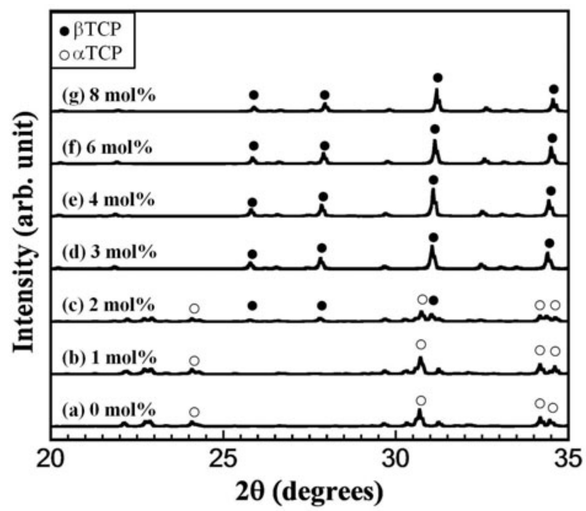

Fig. 1 Powder XRD patterns of ceramic foams containing different amount of Mg.

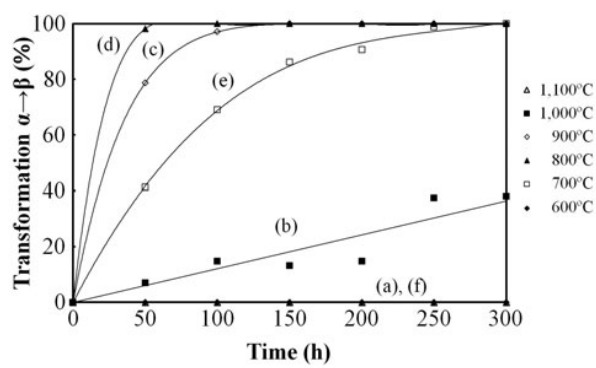

Fig. 2 Isothermal transformation curves for αTCP to βTCP when αTCP foams were heat treatment at 600°C (a), 700°C (b), 800°C (c), 900°C (d), 1,000°C (e) and 1,100°C (f) for various periods.

βTCP foam was implanted in the bone defect made at tibia of rat, βTCP foam made by heat treatment ws replaced to bone whereas βTCP foam made with Mg addition remained at the bone defect after 5 month. Mg may stabilize not only βTCP at high temperature but also solubility at the physiological condition.

Conclusions: βTCP foam that has structure similar to cancellous bone was fabricated based on so-called ceramics foam method using polyurethane foam as a precursor, and using Mg as stabilizer or heat treatment. βTCP foam made by heat treatment may be better for its use as bone replacement.