Production of Novel Dense Composites of Hydroxyapatite-Bioglass by Hot-Pressing Technique

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Introduction

Hydroxyapatite (HA) is a promising candidate for the repair and regeneration of hard tissues [1]. However, sintered HA has normally slow dissolution rate and thus low bioactivity. On the other hand, bioglass (BG) is more resolvable and active in vivo, responding to the surrounding tissues more rapidly. Many studies have been devoted to producing BG-added HA composites to improve biocompatibility [2]. However, when BG was incorporated to HA, particularly at higher amounts, significant level of reaction occurred between the two. As such, there were no satisfactory results on the production of HA-BG composites. It is required to solve the problems in order to product HA-BG composites: 1) reactions between HA and BG and consequent phase degradation, 3) poor sinterability due to their different sintering temperatures (HA >> BG). Therefore, this study aims to fabricate HA-BG composites by applying high pressure under reduced sintering temperature. By introducing hot-pressing technique, it is expected to obtain dense and phase-stable composites.

Materials and Methods

HA and bioglass ($53SiO_2$-21.8Ca0-22.6$Na_2$0-1.7P_2O_5) mixture powder was prepared. Hot-pressing was carried out at temperatures (700-800 ^oC) in ultrahigh vacuum furnace under a pressure of 30MPa. Conventionally sintered HA-BG composites were also prepared to observe the effect of hot-pressing. The sinterability, morphology and phase of the composites were investigated. Mechanical properties of the specimens were measured using 4-point bending test fixture. The biological performance of the HA-BG composites was addressed in comparison with pure HA ceramic.

Results and Discussion

The reaction products between HA and bioglass depended on the sintering method and temperature. In case of conventional sintering, thermal reaction occurred at temperatures over 750℃. However, with hot-pressing, the degree of reaction was reduced significantly. As a result, the conventionally-sintered composites showed poor densities without regard to sintering temperature. However, with the help of hot-pressing, densification was significantly improved (almost fully densified, Fig. 1). This enhancement in densification improved mechanical properties of the composites. The flexural strength of the hot-pressed composites was as high as twice that of conventionally sintered one. The hot-pressed HA-BG composite showed excellent cellular responses. In practice, cell could not proliferate on the conventionally sintered composite due to the high porosity of substrate. Therefore, further cellular assays could not be carried out on this composite any more. However, the hot-pressed HA-BG composite showed favorable cellular attachment and proliferation. Of particular note, the hot-pressed HA-BG composite showed significantly improved ALP activity as compared to sintered HA ceramic (Fig. 2).

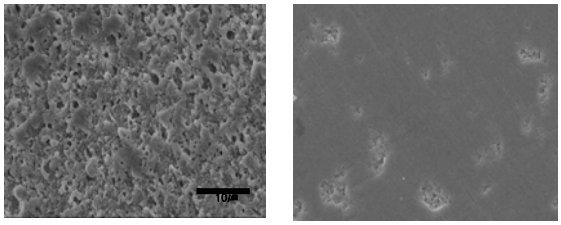

Fig. 1. SEM image of HA-BG composites: conventional (left) and hot-pressed (right).

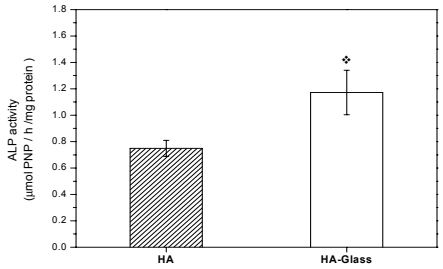

Fig. 2. ALP activity of osteoblastic cells (7 d).

Conclusions

HA-bioglass biomedical composite was fabricated successfully without thermal degradation by introducing hot-pressing technique. This has been a challenging issue by the conventional thermal sintering methods. The hot-pressed composite showed improved mechanical properties with respect to conventional composite. Moreover, the HA-BG composite recruited proliferation of osteoblast well, and stimulated cellular activity with respect to sintered HA. This study suggests the novel-developed HA-BG composite by hot-pressing possesses improved potential with respect to pure HA in hard tissue applications.

References

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