Basic Properties of Carbonate Apatite Cement Consisting of Vaterite and Dicalcium Phosphate Anhydrous

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Abstract. The aim of the present study is to fabricate bone cement that could transform to carbonate apatite (CO\(_3\)Ap) completely at body temperature. The powder phase of vaterite and dicalcium phosphate anhydrous (DCPA) was mixed with 0.8 mol/L of NaH\(_2\)PO\(_4\), Na\(_2\)HPO\(_4\), and Na\(_3\)PO\(_4\) aqueous solution, respectively, with liquid to powder ratio (L/P ratio) of 0.45, 0.55, and 0.65. The paste was packed into split stainless steel mold, covered with the glass slide and kept at 37°C and 100% relative humidity for up to 96 hours (h). XRD analysis revealed that the cement became pure CO\(_3\)Ap within 24 h for Na\(_3\)PO\(_4\), 72 h for Na\(_2\)HPO\(_4\), and 96 h for NaH\(_2\)PO\(_4\), respectively. FT-IR results showed that all of the obtained specimens could be assigned to B-type CO\(_3\)Ap. CHN analysis showed the carbonate content of the specimen were 10.4 ± 0.3% for NaH\(_2\)PO\(_4\), 11.3 ± 0.7% for Na\(_2\)HPO\(_4\), and 11.8 ± 0.4% for Na\(_3\)PO\(_4\), respectively. Diametral tensile strength of the set CO\(_3\)Ap cement was 1.95 ± 0.42 MPa for NaH\(_2\)PO\(_4\), 2.53 ± 0.53 MPa for Na\(_2\)HPO\(_4\), and 3.45 ± 1.53 MPa for Na\(_3\)PO\(_4\), respectively. The set CO\(_3\)Ap cement had low crystallinity similar to bone apatite since it was synthesized at body temperature. We concluded, therefore, that CO\(_3\)Ap cement prepared from the present method has higher possibility to be used as an ideal bone replacement.

Introduction

Calcium carbonate and dicalcium phosphate anhydrous (DCPA) are candidates for starting material to carbonate apatite (CO\(_3\)Ap) cement. However, Takagi \textit{et al.} reported that the cement formed from the mixture of calcite and DCPA mixed with Na\(_2\)HPO\(_4\) solution failed its full transformation to apatite \cite{1}. This may be due to the limited solubility of calcite. Vaterite is one of the polymorph of calcium carbonate and also known to have higher solubility than calcite. CO\(_3\)Ap in the different form has been conducted by Daitou \textit{et al.} In their study, CO\(_3\)Ap block was obtained by mixing calcite and DCPA with distilled water in 70°C \cite{2}. Unfortunately, this method could not be employed in the case of apatite cement because its difficult to apply in 70°C. The key issue of apatite cement required body temperature to apply and to set. It has been reported that the inorganic element of bone is CO\(_3\)Ap (Ca\(_{10}(PO_4)_{6-x}(CO_3)_x(OH)_{2-x}\)) that contains of 4-8 wt% carbonate in apatitic structure \cite{3}. The carbonate content in apatitic structure has a close relationship with osteoclastic resorption, that is, CO\(_3\)Ap shows higher solubility in the weak acidic condition produced in Howship’s lacuna formed by the osteoclasts. Therefore, CO\(_3\)Ap is expected to become an ideal bone replacement material. On these bases, this study is assigned to examine the basic properties of CO\(_3\)Ap cement consisting vaterite and DCPA.

Materials and methods

Preparation of apatite cement (AC). Vaterite (Yabashi Industries Co., Ltd, Ohgaki, Japan) and DCPA (J.T. Baker Chemical Co., NJ, USA) were employed as AC powder. Average particle size of vaterite powder was approximately 0.7 µm. Particle size of commercially obtained DCPA powder was not specified. The powders were mixed with NaH\(_2\)PO\(_4\), Na\(_2\)HPO\(_4\), and Na\(_3\)PO\(_4\) aqueous solution, respectively, with liquid to powder ratio (L/P ratio) of 0.45, 0.55, and 0.65. The paste was packed into split stainless steel mold, covered with the glass slide and kept at 37°C and 100% relative humidity for up to 96 hours (h). XRD analysis revealed that the cement became pure CO\(_3\)Ap within 24 h for Na\(_3\)PO\(_4\), 72 h for Na\(_2\)HPO\(_4\), and 96 h for NaH\(_2\)PO\(_4\), respectively. FT-IR results showed that all of the obtained specimens could be assigned to B-type CO\(_3\)Ap. CHN analysis showed the carbonate content of the specimen were 10.4 ± 0.3% for NaH\(_2\)PO\(_4\), 11.3 ± 0.7% for Na\(_2\)HPO\(_4\), and 11.8 ± 0.4% for Na\(_3\)PO\(_4\), respectively. Diametral tensile strength of the set CO\(_3\)Ap cement was 1.95 ± 0.42 MPa for NaH\(_2\)PO\(_4\), 2.53 ± 0.53 MPa for Na\(_2\)HPO\(_4\), and 3.45 ± 1.53 MPa for Na\(_3\)PO\(_4\), respectively. The set CO\(_3\)Ap cement had low crystallinity similar to bone apatite since it was synthesized at body temperature. We concluded, therefore, that CO\(_3\)Ap cement prepared from the present method has higher possibility to be used as an ideal bone replacement.

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