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Influence of sodium on the properties of sol-gel derived hydroxyapatite powder and porous scaffolds

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ABSTRACT

This study investigates the properties of sol-gel derived sodium (Na)-doped hydroxyapatite (HA) powder. Different amounts of Na (1, 5, 10 and 15 mol%) were prepared and the sintered bodies were characterized to determine the current phases, microstructural evolution and mechanical properties. X-ray diffraction analysis reveals that a phase pure HA of crystallite sizes, which varied from 35 nm to 65 nm, was obtained in the synthesized powder after calcining from 500 °C to 1000 °C. Scanning electron microscopy examination shows evidence of larger particle sizes, particularly in samples that contain higher amounts of Na concentration. The resultant powders were subsequently used to prepare porous NA-doped HA bodies through a polymeric sponge method. The addition of 5% Na resulted in a porous body with 27% porosity and was beneficial in enhancing the compressive strength of HA 17-fold compared with undoped HA. The prepared scaffold also shows suitable pore interconnectivity with pore sizes that vary between 100 and 300 μm which is suitable for use as porous bone substitutes.

1. Introduction

Synthetic calcium phosphate bioceramics have been investigated for their biomedical applicability in several medical-related applications, including as drug carrier [1], cell culture [2] and most extensively in bone defect reconstruction [3,4]. These bioceramic were prepared in different forms, such as powders and granules [5–8], coating films [9] and dense [10,11] and porous ceramics [2,12–15]. Among the different types of calcium phosphates, hydroxyapatite (HA) [$Ca_{10}(PO_4)_6(OH)_2$] and β-tricalcium phosphate (TCP) [$Ca_3(PO_4)_2$] [16] have been used extensively in bone substitute applications due mainly to their similarity in bone composition.

Recently, interest in calcium phosphate bioceramics have been directed to the development of modified synthetic apatites, which involves the incorporation of trace chemical species in natural bone because of its effect on the physical, chemical and biological properties of the bone [17]. Sodium (Na) has been traced as an abundant element in natural bone and tooth mineral [18]. The incorporation of Na into hydroxyapatite powder can effectively improve the powder characteristics unlike Na-free HA; it enhances the diffusion coefficient upon sintering, which results in the enhanced sinterability of HA [19]. Na plays an important role in cell adhesion and the bone metabolism and resorption processes [20].

Several methods, such as hydrolysis, double decomposition and wet precipitation methods, have been employed to incorporate Na into HA [21]. The current study synthesizes Na-doped HA powder through the sol-gel method. This method allows for the molecular mixing of calcium and phosphorus monomers, which could enhance chemical homogeneity and decrease the synthesis temperature. The product from the sol-gel recipe is commonly of high purity due to the possibility of a strict control of the process parameters. The sol-gel product is also characterized by nano-sized dimensions of the primary particles; this small domain is a highly important parameter that improves the contact reaction and stability at the artificial/natural bone interface

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