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Original Research Paper

The in vitro bioactive of sol–gel bioactive glass powders with three-dimensional lamellar structure

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ABSTRACT

In this study, three-dimensional lamellar structured bioactive glass powders were prepared using non-ionic block copolymer surfactants as structure-directing agents through a sol–gel method. The characterization methods such as X-ray diffraction (XRD), Fourier transform infrared spectrograph (FTIR), transmission electron microscopy (TEM) and field emission scanning electron microscopy (FESEM) were used for determination of the particles structure before and after immersion in simulated body fluid (SBF) for various numbers of days. The results show that the biomineralized products on the surfaces of the bioactive glass powders were apatite microcrystals with a low crystallinity, the composition and morphologies of the apatite microcrystals changed with the immersion time increased. The presence of the apatite layer indicates biomineralization.

1. Introduction

Since L.L. Hench first invented Bioglass® in 1969 [1], various type and preparation methods of bioactive glasses (BG) have been extensively studied for 40 years. The sol–gel process as a wet-chemical technique has been widely used in the fields of materials science and ceramic engineering. Because of their unique structure and excellent biocompatibility, resorbability, and bioactivity, the sol–gel derived bioactive glasses have been used in bone tissue engineering such as non-load bearing bone and periodontal fillers [2–4] (e.g., applied as pastes by mixing with physiological buffer solutions), drug delivery agents and tissue engineering scaffolds.

Hench represented Bioglass® can be bond to bone by formation of an apatite layer in 1996. After immersion in SBF, four general processes will occur on the surface as follow [5]: (1) formation of SiOH bands; (2) polycondensation of SiOH + SiOH → Si—O—Si; (3) absorption of amorphous Ca + PO_4 + CO_3; (4) crystallization of hydroxyl carbonate apatite (HCA). As we known, the formation of bone-like apatite layer occurs not only in vitro, but also in vivo. The in vitro and in vivo bioactivity and degradability of particulate sol–gel bioactive glasses also have been reported in previous studies [6–9]. However, the biomineralization of three-dimensional lamellar structured bioactive glasses is rarely reported.

In this study, we concentrated on the effect of the morphology of 58S bioactive glass by adding P123 as structure-directing agents through a sol–gel method and the performance of in vitro biomineralization. First, the three-dimensional lamellar structured 58S particles were prepared using the template technique through a sol–gel processing. In addition, we study its biomineralization performance in order to determine the mechanisms of HCA formation on the 58S particles. Since the 58S bioactive glass particles exhibit a promising biological behavior, they could be used in hard tissue engineering scaffolds.

2. Materials and methods

2.1. Sample preparation

58S bioactive glass, with the composition (weight percent): 58SiO_2, 33CaO and 9P_2O_5, was prepared by a sol–gel method. Tetraethyl orthosilicate (TEOS), Triethylphosphate (TEP) and calcium nitrate tetrahydrate (CN) were purchased from Guanghua Chemical Factory Co., Ltd. (Shantou, PR China). Pluronic P123 was supplied by Sigma–Aldrich Co (Missouri, USA). All chemical reagents were analytical grade. Deionized water was obtained from a water purification system (Millipore S.A.S., France).

The sol–gel 58S bioactive glass was prepared by hydrolysis and polycondensation of TEOS, TEP and CN. In a typical synthesis, 1 g P123, 6 ml of 0.5 M HCl, 10 ml of TEOS, 1 ml of TEP, and 6.34 g of CN were gradually dissolved in 20 ml of ethanol (Si/Ca/P = 60:36:4,

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