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Influences of doping mesoporous magnesium silicate on water absorption, drug release, degradability, apatite-mineralization and primary cells responses to calcium sulfate based bone cements

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ABSTRACT

In this study, composite cements containing mesoporous magnesium silicate (m-MS) and calcium sulfate (CS) were fabricated. The results revealed that the setting time of the m-MS/CS composite cements (m-MSC) slightly prolonged with the increase of m-MS content while the compressive strength suffered a little loss. The doping of m-MS improved the water absorption, drug release (vancomycin) and degradability of the m-MSC in Tris-HCl solution (pH = 7.4). In addition, addition of m-MS facilitated the apatite-mineralization of m-MSC in simulated body fluid (SBF), indicating good bioactivity. For cell cultural experiments, the results revealed that the m-MSC promoted the cells adhesion and proliferation, and improved the alkaline phosphatase (ALP) activity of MC3T3-E1 cells, revealing good cytocompatibility. It could be suggested that the m-MSC might be promising cements biomaterials for bone tissue regeneration.

1. Introduction

Bone cements, such as calcium phosphates, acrylic bone cements, calcium sulfates, *etc.*, have been widely exploited to repair bone defects [1–3].Among these biomedical materials, calcium sulfate has a long history in clinical applications as bone filling material for its self-setting property, degradability and good biocompatibility and so on [4,5]. Calcium sulfate hemihydrate (CSH, $CaSO_4 \cdot 1/2H_2O$) mixed with water has the ability to undergo *in situ* setting, because CSH can react with water immediately and transform into calcium sulfate (CS, $CaSO_4 \cdot 2H_2O$), which is in the form of solid and hard cement [6,7]. However, calcium sulfate (CS) cement has some drawbacks that significantly limit its clinical application, such as too quick setting, lower water absorption, producing acidic degradable products, and slower bone-formation ability because of its poor bioactivity [8]. Mesoporous silicate-based bioactive materials have received significant attentions for bone regenerations due to their excellent apatite-mineralization ability and osteostimulation [9,10]. Moreover, the mesoporous materials can facilitate cell adhesion, adsorption of bioactive metabolites and suitable degradability to match that of bone tissue regeneration [11]. Li developed a bone cement with sustained drug release by mixing alpha-hemihydrate and vancomycin loaded mesoporous silica nanoparticle but did not report the setting time, water adsorption, degradability, bioactivity and cytocompatiblity of the cement [12].

Magnesium (Mg) may improve bone mineral density and affect the absorption of bone, which is the component of bones and teeth [13,14]. Some Mg-based biomaterials have been reported, such as Mg-containing bioactive glasses/ceramics, degradable magnesium alloys, and Mg-substituted calcium phosphate bone cements [15–17]. The previous study have showed that a silicate-based biomaterial of mesoporous magnesium silicate (m-MS) with high surface area and pore volume had high water adsorption, rapid degradability, good *in vitro* bioactivity, and cytocompatibility [18]. In order to further improve the performances of calcium sulfates cements, novel bone cement should be developed. Therefore, in the study, the novel bone cement of m-MS/CS composite (m-MSC) was prepared by using the m-MS/CSH mixture powder and water. It is expected that the m-MSC bone cement might possess better bone regeneration performances by doping m-MS into CS. The objective of this study was to investigate the influences of doping m-MS on water absorption, drug release, degradability, apatite-mineralization and primary cells responses to calcium sulfate based bone cement.

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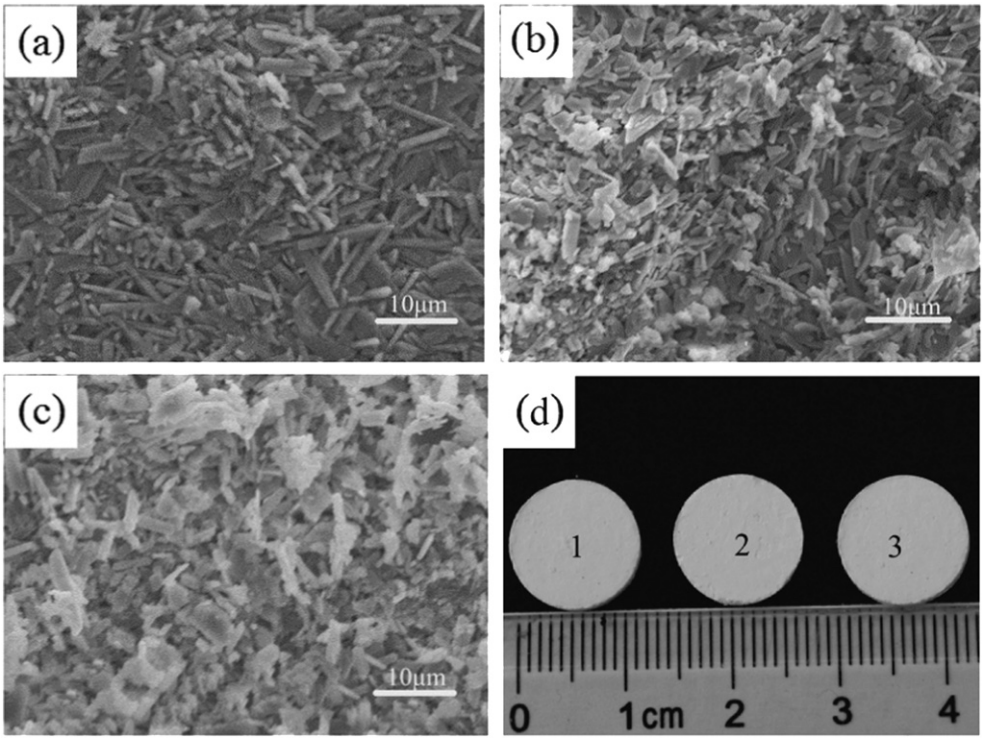

Fig. 1. SEM images and photos of the cements: (a) CS, (b) 15 m-MSC and (c) 30 m-MSC; (d) photos of the cements (1:CS, 2:15 m-MSC and 3:30 m-MSC).

2. Materials and methods

2.1. Preparation and characterization of m-MSC

The m-MS powder was prepared according to the previous research [18]. CSH powders were prepared by sintering calcium sulfate dehydrate (CSD) at 120 °C for 8 h, then raised to 160 °C at a heating rate of 1 °C min^{-1} and kept for 4 h. The cement powder was prepared by mixed CSH powder and m-MS with different ratio (0 wt% m-MS, 15 wt% m-MS and 30 wt% m-MS). The cement powder was mixed with deionized water at different ratio of powder to liquid with stirring for 60 s to obtain the homogeneous cement paste. The as-prepared cement paste was cast into Teflon molds under a pressure of 2 MPa for 1 min to prepare cylinder samples. The cements samples (Φ10 × 2 mm) were then cured in the condition of 100% air humidity and 37 °C for 2 days. After hardening, CSH powder without m-MS changed into calcium sulfate (CS) cement, CSH powder containing 15 wt% m-MS changed into 15 wt% m-MS/CS composite cement (15 m-MSC) and CSH powder containing 30 wt% m-MS changed into 30 wt% m-MS/CS composite cement (30 m-MSC), and the solid/liquid ratio is 1:1 (g/mL). The phase composition and microstructure of the composite cements were characterized by X-ray diffractometer (XRD; Geigerflex, Rigaku Co. Ltd., Japan) and scanning electron microscopy (SEM; S-3400N, Hitachi, Japan), respectively.

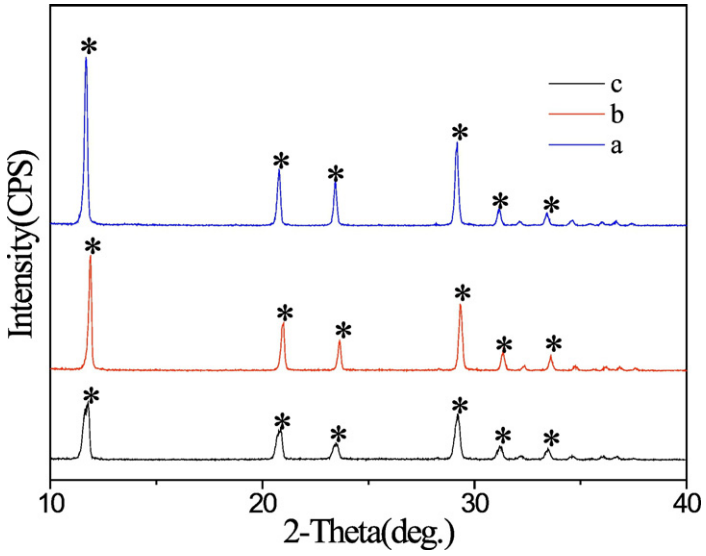

Fig. 2. XRD of the cements: CS (a), 15 m-MSC (b) and 30 m-MSC (c); asterisks (*) represent the peaks of calcium sulfate (CS).