The influence of PLGA coating on the structure and compressive strength of bredigite scaffolds

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Abstract

One of the important parameters for bone regeneration scaffolds is their mechanical properties, which is the subject of this study in terms of a calcium magnesium silicate, namely bredigite. In this regard, bredigite powders were synthesized by a sol-gel process and then porous bredigite scaffolds were prepared using a polymer sponge method. Sintered bredigite scaffolds were afterwards coated with poly(lactic-co-glycolic acid) (PLGA), and the influence of the PLGA coating on the morphology, porosity and mechanical properties of the bredigite scaffold was investigated. The results showed that the PLGA-coated bredigite scaffolds maintained their porosity size and level required for bone tissue engineering. Typically, the compressive strength of the bredigite/PLGA scaffold was significantly improved compared to the pure bredigite scaffold due to the alteration of porosity.

Keywords: Tissue Engineering Scaffolds, Compressive strength

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1. Introduction

Ideal scaffolds for bone tissue engineering require both three-dimensionally interconnected porous structures and enough mechanical strength, to provide structural support and a degradation rate that matches that of new bone formation [1]. Our previous study showed that bredigite ($Ca_7MgSi_4O_{16}$) scaffolds have potential for bone tissue regeneration, since they possess excellent bone regeneration ability and biodegradability [2-5]. However, their mechanical strength is not enough.
PLGA, a biodegradable aliphatic polyester, has been widely used for biomedical and pharmaceutical applications, such as tissue engineering scaffolds [6-8], due to its excellent biodegradability, biocompatibility and nontoxicity properties [9-11]. Like most of polymers, PLGA possesses generally good toughness and ductility [12]. Therefore, our hypothesis is that if we can coat a PLGA layer on the surface of pore walls of bredigite scaffolds, it will reinforce the mechanical strength of the bredigite scaffolds.

2. Experimental

2-1- Preparation of bredigite powder

Bredigite powders were prepared by a sol-gel process according to the previously reported method [13]. Briefly, 0.5 mol TEOS was mixed with deionized water and 2 M HNO_3 (mol ratio: TEOS/H_2O/HNO_3 = 1:8:0.16) and hydrolyzed for 30 min under stirring at room temperature. Then, 0.125 mol magnesium nitrate hexahydrate and 0.875 mol calcium nitrate tetrahydrate were dissolved into the solution. The homogeneous solution was stirred for 5 h at room temperature to yield a precursor wet gel. The wet gel was dried at 120°C for 36 h to obtain a dry gel. The dry gel was calcined at 850°c for 2 h with a heating rate of 3°c/min to obtain bredigite powder.

2-2- Preparation of bredigite scaffold

Bredigite powders were suspended in sodium alginate solution (3% wt.%) and stirred in a glass beaker to obtain a well-dispersed slurry. The ratio of the powder to sodium alginate solution mass was 1:2. Polyurethane foam templatse (density: 25 ppi, porosity >97%) were cut into desired shapes and sizes, and the prepared sponge was immersed in the glass beaker containing the bredigite slurry and compressed with glass stick to force the bredigite slurry to migrate into the pores of the foams. The struts of the foams were uniformly coated with ceramic slurry while the pores were maintained open. Then, the impregnated forms were dried at 60°C for 12 h, heated at 300°C for 1 h to remove the polymeric struts and then sintered at 1360°C for 3 h at a heating rate of 3°C/min.

2-3- Preparation of porous PLGA–bridigite scaffold

PLGA (copolymer ratio of 50:50, viscosity of 0.4 dl/g, Carbion, Netherlands) was dissolved in acetone under stirring at room temperature at 10% w/v. Then, the PLGA-coated samples were dried at 60°C for 12 h to remove the solvent.

2-4- Materials characterization

2-4-1- Porosity measurement

The apparent (interconnected) and true (total) porosity levels of the scaffolds were measured according to the Archimedes method [14]. The apparent porosity was also determined using Eq. (1):

$$\text{Apparent porosity} = [(W_w - W_d)/(W_w - W_s)] \times 100 \quad (1)$$

where W_w is the weight of the scaffold after it is removed from water, W_d is the weight of the scaffold in air, and W_s is the weight of the suspended scaffold.

2-4-2- Morphology

The morphology of the prepared scaffolds was observed by Field emission scanning electron microscopy (FESEM; HITACHI S-4160, Japan).

2-4-3- Mechanical testing

The compressive strength of the bredigite and bredigite/PLGA scaffolds was tested by using a universal mechanical machine at 0.5 mm/min crosshead speed (SANTAM STM-1, Iran) with the scaffold dimension of ~25 ×12.5×12.5 mm^3. At least three samples were tested, and the mean value of strength was determined.

3. Results and Discussion

The porosity level of the bredigite and bredigite/PLGA scaffolds was measured to be 90.9 and 72 %, respectively, which is appropriate for bone tissue engineering. Fig. 1 shows the FESEM microstructure of the prepared bredigite and bredigite/PLGA scaffolds. The bredigite scaffolds present porous structures with open macro-pores ranging from 0.8-1 mm (Fig. 1(a)). After coating by PLGA, the bredigite scaffolds still retain large pore structures (Fig. 1(c)). It is noticeable that the size of pores in both the samples is in the acceptable range for tissue engineering [15].

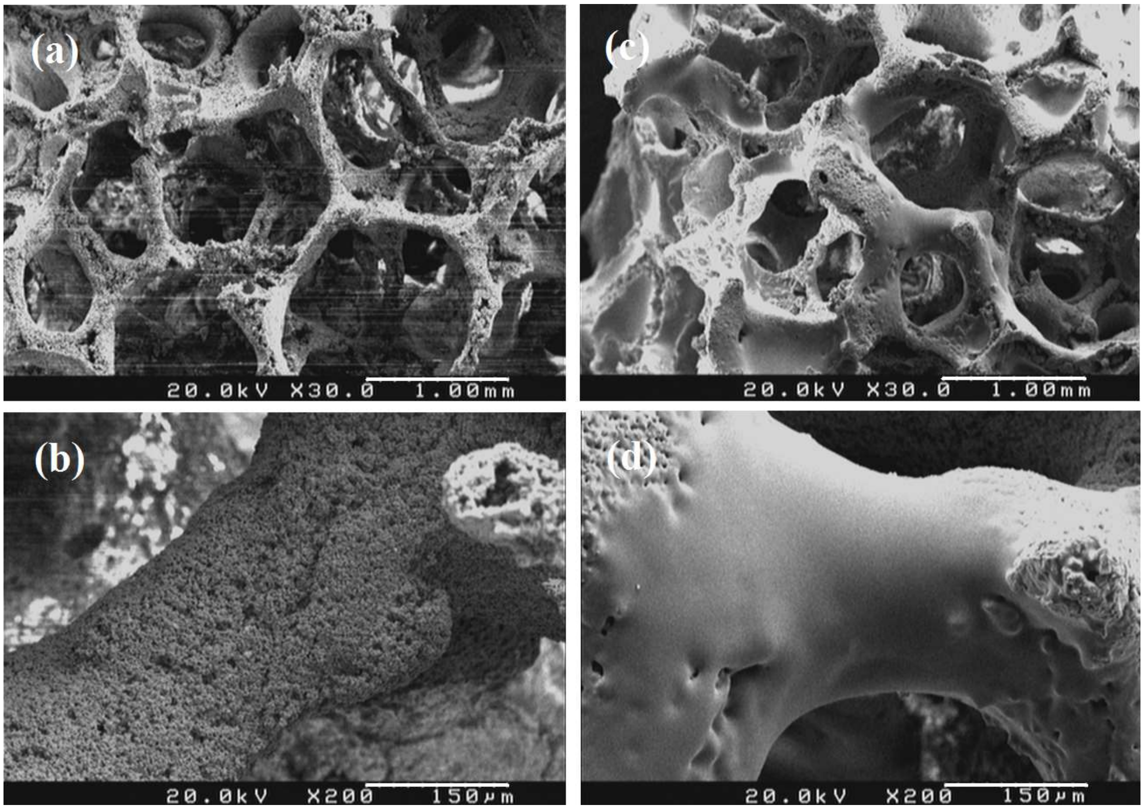

Fig. 1. FESEM images of the bredigite (a,b) and bredigite/PLGA (c,d) scaffolds.

The compressive stress-strain curves of the scaffolds are presented in Fig. 2. The extracted compressive strength of the samples is also listed in Table 1. It can be seen that the optimized compressive strength for bredigite/PLGA scaffold in this study is around 0.75 MPa (Table 1).

Table 1**:** Mechanical compressive strength of the scaffolds.

	Scaffold type	
	Bredigite	**Bredigite-PLGA**
Compressive strength (MPa)	0.15	0.75

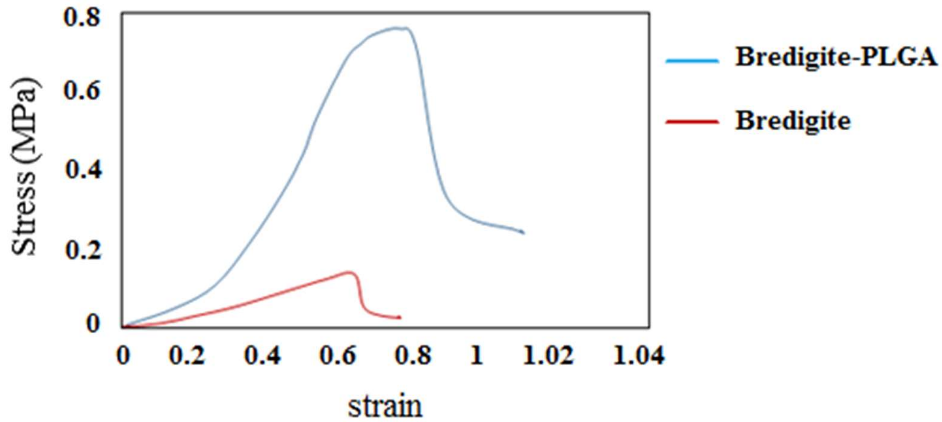

Fig. 2. Compressive stress-strain curves of the scaffolds.

There are a number of micro-pores in the inside of pore walls of the bredigite scaffolds, which are detrimental to their mechanical strength. There are two reasons for improving the compressive strength of PLGA scaffold compared to the bredigite scaffold.

I. PLGA can fill some of the micropores, leading to a more uniform and continuous network in the scaffold.
II. PLGA possesses certain mechanical strength [12] and may form an intertexture inside the bredigite scaffolds, which links the inorganic phase together and reinforces the scaffolds.

4. Conclusions

Porous bredigite/PLGA scaffolds with a porosity level of about 72% and pore size in the range of 0.6-0.8 mm were successfully prepared by coating a PLGA layer on the surface of bredigite scaffolds. The PLGA coating significantly improved the compressive strength of bredigite scaffolds by 400%. These highly porous scaffolds could be used as a good candidate for bone tissue engineering applications, benefiting from interconnected porosity and appropriate compressive strength.

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