Porous Poly(ε-caprolactone)/Hydroxyapatite Scaffold with Highly Aligned Pore Structure using Unidirectional Freeze Drying

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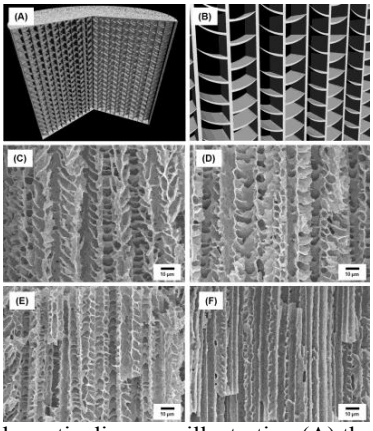
Introduction: Porous scaffolds have received a great deal of attention in the field of tissue engineering, since their interconnected pores, biocompatible surfaces, and large surface area can provide a favorable environment for bone ingrowth, when implanted. Fundamentally, the mechanical and biological properties of these materials should be strongly affected not only by the intrinsic characteristics of the scaffolding material, but also by the pore structure, such as porosity, pore size, and pore alignment[1]. Thus, considerable effort has been recently made to tightly control the pore structure of porous materials[2,3]. One of the most promising approaches is to unidirectionally freeze a polymeric solution, which can allow the creation of aligned pores, consequently, endowing porous materials produced with advanced functions[4]. Therefore, in this study, we fabricated poly(ε-caprolactone) (PCL)/hydroxyapatite(HA) scaffolds with aligned pores using unidirectional freeze drying, where the bioactive HA particles were dispersed uniformly in the biodegradable PCL polymer[5], and measured their mechanical and biological properties to evaluate their potential applications as the scaffold.

Methods: PCL pellets were dissolved in dichloroethane at a concentration of 10% w/v and stirred for 6 hours at room temperature. Subsequently, HA particles were added to the prepared PCL solution with various HA contents and sonificated for 1 hour. After stirring for additional 2 hours, the solution was poured into polyethylene cylinder molds with a diameter of 12.5 mm attached to a copper plate. The cylinders were placed in a dip-coater and gradually submerged into liquid nitrogen with constant dipping rate to induce the unidirectional freezing. Frozen samples were freeze-dried for 24 hours.

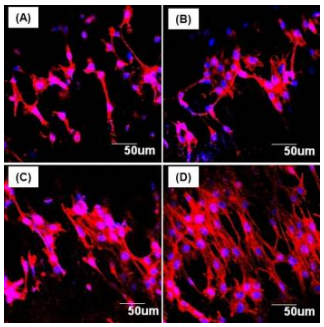
Results: Vertical heat transfer while freezing process is responsible for the isotropic morphology of pore alignment as shown in Figs 1.(A),(B). The typical SEM images of the PCL/HA scaffolds produced with various HA contents(0,5,10, and 20wt%) are shown in Figs.1(C)-(F). All the fabricated samples had a highly aligned pore structure owing to the use of unidirectional freeze drying. In addition, the HA particles were dispersed well in the PCL walls without noticeable agglomerations. However, the pore size became narrow with increasing the initial HA content. The mechanical properties of the PCL/HA scaffolds increased remarkably with increasing the initial HA content, as summarized in Table I. The incorporation of the bioactive HA particles into the PCL polymer significantly enhanced the biocompatibility, as assessed by the *in vitro* cell test using a pre-osteoblast cell line(Figs. 2(A)-(D)), where the red and blue fluorescent represent the actin and nucleus, respectively.



Figs 1. Schematic diagrams illustrating (A) the PCL/HA scaffold and (B) the pore structure at higher magnification, scanning microscopy images of the samples produced using initial HA contents of (C) 0, (D) 5, (E) 10, and (F) 20wt%, respectively.

HA wt%	0	5	10	20
E(MPa)	0.12	1.17	2.05	2.65

Table I. Elastic modulus of scaffolds



Figs 2. CLSM images of the PCL/HA scaffold with HA contents of (A) 0wt%, (B) 5wt%, (C) 10wt%, and (D) 20wt%, respectively

Conclusions: Porous PCL/HA scaffold with aligned pores were produced successfully by unidirectionally freezing PCL/HA solutions with various HA contents. Regardless of the initial HA content, all the fabricated samples showed a highly aligned porous structure, where the fine HA particles were dispersed uniformly in the PCL walls. In addition, the mechanical and biological properties of the PCL/HA scaffolds were improved significantly with increasing the HA content.

References:

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