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Development of cylindrical microfibrous scaffold using melt-spinning method for vascular tissue engineering

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ABSTRACT

In this report, we demonstrated fabrication of cylindrical scaffold made of poly (lactide-co-caprolactone) (PLCL) fibers for vascular tissue engineering by the melt-spinning method with use of a commercially available cotton candy machine. This method was able to generate microfibrous cylindrical scaffold with the fiber diameter ranged of 1–17 μm. It was found that the microfibrous scaffold showed greater mechanical properties including elastic modulus and ring tensile strength than those of cylindrical microporous PLCL scaffold prepared by the phase separation method. Biological test using hMSCs also demonstrated that the microfibrous scaffold exhibited better cells growth behavior including larger cell area and aspect ratio than the microporous scaffold after 3 h culture. Cell proliferation on the microfibrous scaffold was significantly higher than that on the microporous scaffold during 7 days culture. In conclusion, microfibrous scaffold with improved mechanical and biological properties was successfully fabricated using the melt-spinning method.

1. Introduction

Vascular Tissue Engineering (VTE) is projected as an alternative graft for treatment of vascular diseases. Scaffold plays an important role as a structural support for cell adhesion and tissue development in VTE [1]. Among various methods [2], phase separation and electrospinning have widely been used to fabricate scaffolds. The phase separation method has widely been used to prepare porous scaffold with pore sizes in the order of a few to hundreds of microns. However, the pores formed using this technique are usually not uniformly distributed which may affect the mechanical properties and cell binding and spreading [3]. To mimic the fibrous structure of the natural extracellular matrix in tissue, electrospinning method is developed to engineer fibrous scaffold. Micro/-nanofibrous structures obtained by electrospinning have large surface area, providing more surface anchorage for cell binding and proliferation [3]. Although the electrospinning have extensively been studied, its low production rate and complexity of control parameters of electrospinning method may limit its clinical application [4]. In addition, the electrospinning often uses toxic organic solvents during the fabrication process and therefore, their residue in the products may harm the human body [5]. To overcome those problems, other alternative techniques must be developed to fabricate fibrous scaffolds without toxic solvents.

On the other hand, the melt-spinning method, known as the production method of cotton candy, has been utilized to fabricate scaffolds with cotton-like fibrous structures [6]. One of the main advantages of this technique is that commercially available cotton-candy machines may be directly used to fabricate scaffolds for medical applications. In the cotton-candy machines, melted polymer is centrifugally forced through a small hole to make fibers. Although this technique allows us to fabricate polymeric fibers in a simple cost-effective way and free from toxic solvents, to the best of our knowledge, few attempts have been made to fabricate fibrous cylindrical scaffolds using the melt-spinning method [7].

The aim of this study is therefore to produce fibrous cylindrical scaffolds for VTE using the melt-spinning method with biocompatible and biodegradable polymer. A commercially available cotton-candy machine was utilized to fabricate microfibrous cylindrical structures. As the fundamental properties, tensile mechanical properties and cellular activities were examined. Furthermore, the fabricated microfibrous cylindrical scaffold was compared with the microporous cylindrical scaffold previously developed using the phase-separation and freeze-drying method in our laboratory [8].

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2. Methods

2.1. Fabrication of cylindrical scaffolds

Microfibrous cylindrical scaffolds were fabricated from PLCL (75/25) (BMG Co., Japan) with the melting temperature of 163 °C using a commercial cotton candy machine (EA-WA2805, Azuma Engineering Co., Japan). Two gram of PLCL granules were put into the spinning head of the machine. The spinning head has a fixed rotating speed of 1800 rpm and a heating temperature of 180 °C. The temperature was measured using a digital thermometer (Custom, Japan) during fabrication process of PLCL fibers. They

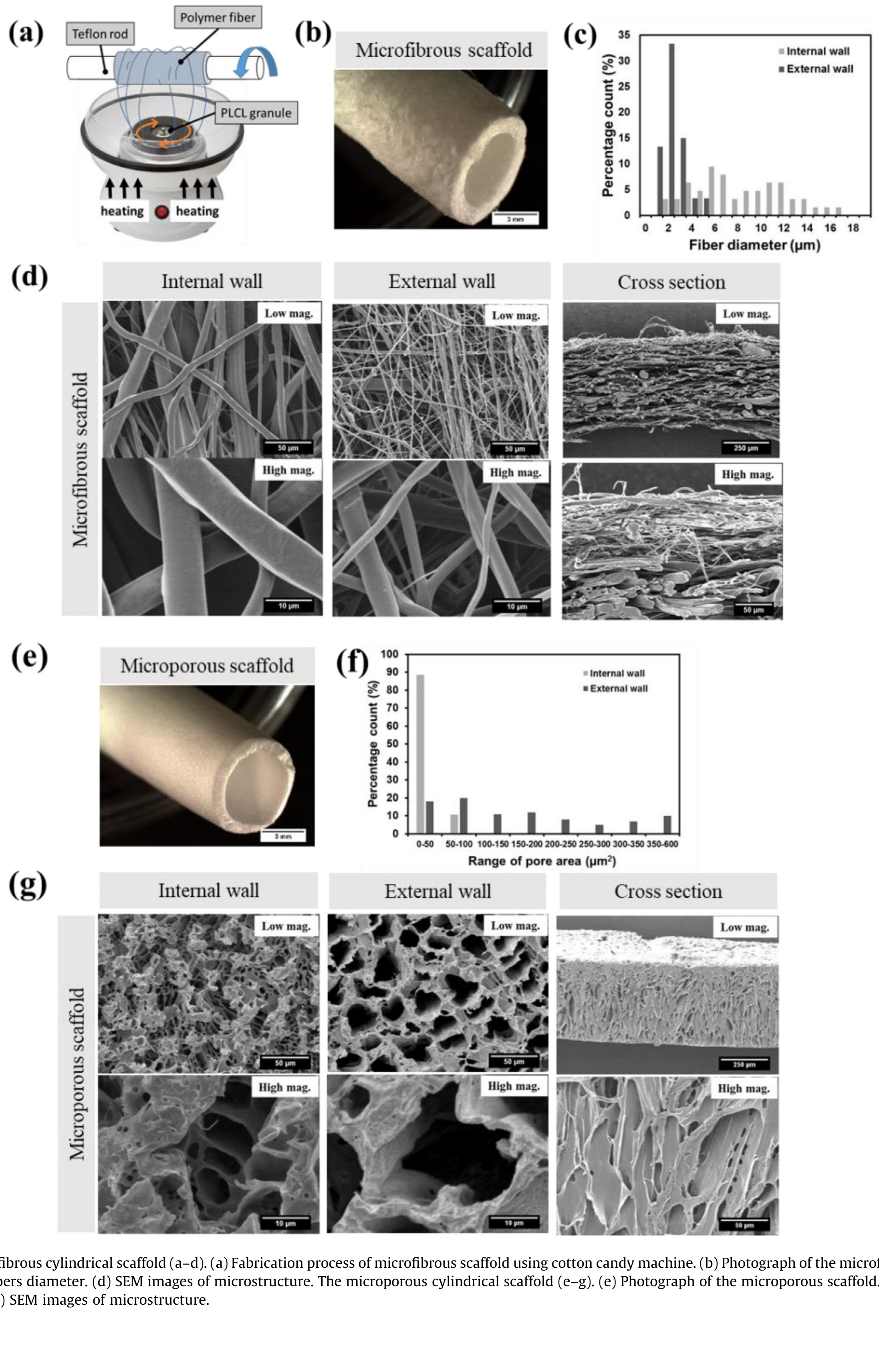

Fig. 1. The microfibrous cylindrical scaffold (a–d). (a) Fabrication process of microfibrous scaffold using cotton candy machine. (b) Photograph of the microfibrous scaffold. (c) Distribution of fibers diameter. (d) SEM images of microstructure. The microporous cylindrical scaffold (e–g). (e) Photograph of the microporous scaffold. (f) Distribution of pore diameter. (g) SEM images of microstructure.