EFFECT OF THE SR-CONTAINING HYDROXYAPATITE NANOPARTICLES DOPING ON THE POLYMER FIBER MORPHOLOGY WITHIN THE 3-D ARTIFICIAL SCAFFOLDS FOR BONE TISSUE REGENERATION

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Functionalized 3-D scaffolds based on polycaprolactone (PCL) with strontium-containing hydroxyapatite (Sr-HA) were prepared *via* electrospinning technique. Scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FTIR) were used to investigate the structure and morphology of the scaffolds. The experimental results revealed that due to incorporation of Sr-HA particles into the polymer fibers, the surface of PCL/Sr-HA hybrid 3-D polymer scaffolds possessed porous and rough structure, which potentially should provide stimulation of adhesion and growth of bone cells.
Keywords: strontium-containing hydroxyapatite, polycaprolactone, electrospinning, fiber morphology, tissue engineering.

Introduction

HA is the major inorganic component of bone, and also reveals bioactive, biodegradable and osteoconductive properties [1]. The use of strontium in the regeneration of bone stimulates bone formation decreases bone resorption and reduces the risk of vertebral fractures in postmenopausal osteoporosis [2]. Thereby, the combination of these components is a perspective for application in the treatment of bone diseases. However, the poor mechanical properties are typical for pure Sr-HA. Thus, it is expedient to mix Sr-HA material with biodegradable polymer such as PCL since it is non-toxic and possesses the mechanical properties, which are appropriate for bone tissue engineering. In this paper, electrospinning is used for synthesis PCL/Sr-HA hybrid scaffolds. The structure and morphology of scaffolds are investigated and compared with pure PCL scaffolds as a control.

Materials and methods

PCL and Sr-HA hybrid scaffolds with randomly oriented (r/o) fiber structure were fabricated using electrospinning process. The electrospinning parameters for synthesis of the scaffolds were: voltage = 8 kV, feeding rate = 3.6 ml/h, distance = 80 mm, the inner diameter of spinneret = 0.8 mm. For obtaining PCL/Sr-HA hybrid polymer composition, Sr-HA particles and PCL polymer were dispersed in chloroform. The pure PCL solution was prepared at the same time with the concentration of 9 wt%. At first, these suspensions were achieved by stirring the mixture for 24 hours, and then, were stabilized in ultrasonic bath for 0.5 h. The morphology of polymer fibers was investigated by JOEL JSM-7500F SEM an accelerating voltage of 10 kV. Fiber chemical bonding structure of PCL, PCL/Si-HA scaffolds and Si-HA powder as a control was analysed using FTIR (Bruker Tensor 37).

Results and discussion

The morphology of 3-D scaffolds are shown in Figure 1. SEM micrographs were analysed by ImageJ software, where the average diameters of fibers and particles in PCL and PCL/Sr-HA were measured.

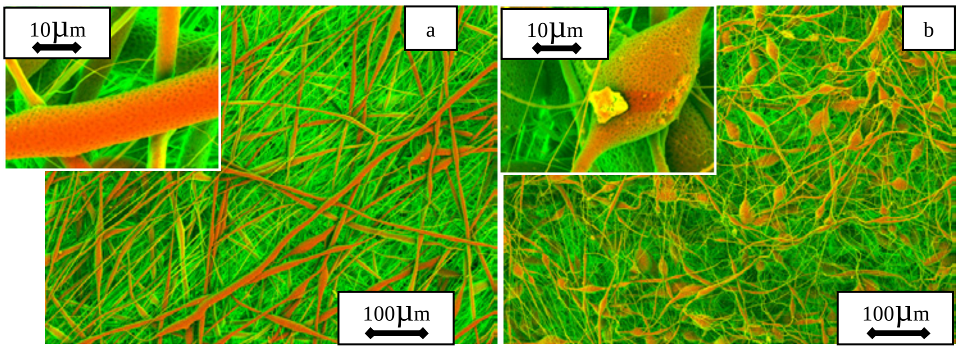

Fig. 1. SEM micrographs of the polymer fiber of a) PCL r/o, b) PCL/Sr-HA r/o 3-D scaffolds

The scaffolds, which are synthesized from the pure PCL solution, have the fiber with the diameter of 10.86±1.19 µm. The average fiber diameter for PCL/Sr-HA scaffolds is of 20.29±4.93 µm and average particle diameter is of 5.91±1.62 µm. In the sample with pure PCL, the homogeneous fiber structure is observed. However, it can be seen that the most of the fiber diameters on the samples with PCL/Sr-HA are less than 1 µm. It should be mentioned that Sr-HA particles introduced inside the polymer fiber. Moreover, Sr-HA nanoparticles embed and accumulated within the fibers. As a result, hybrid scaffolds have the rough surface, which can stimulate the adhesion and growth of bone cell [3].

FTIR spectroscopy is a powerful tool for characterization of the bonding configuration in the PCL and PCL/Sr-HA composite scaffolds. Sr-HA powder was analyzed as a control. In the case of Sr-HA modified scaffolds, several characteristic bands of PCL were observed. Moreover, the typical infared bands of HA phase were identified. However, the main stretching mode at 1021 cm^{-1} assigned to functional group PO_4^{3-} was overlapped by the bands correspond to PCL. These results confirmed a successful introduction of Si-HA particles into the polymer fiber structure [4].

Conclusion

PCL/Sr-HA hybrid scaffold was prepared by electrospinning. In comparison with pure PCL scaffold PCL/Sr-HA 3-D scaffold demonstrated rough and uniform surface due to the incorporation of Sr-HA particles. As a result, addition of Si-HA nanoparticles had a significant influence on the final fiber morphology of the scaffolds prepared by electrospinning process. Furthermore, the presence of Sr-HA nanoparticles in the fabricated composites was confirmed by FTIR analysis.

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References

1. Suganthi R.V., Elayaraja K., Joshy M.A. et al. Fibrous growth of strontium substituted hydroxyapatite and its drug release // Materials Science and Engineering. – 2011. – Vol. 31. – P. 593–599.
2. O'Donnell M.D., Fredholm Y., De Rouffignac A., Hill R.G. Structural analysis of a series of strontium-substituted apatites // Acta Biomaterialia. – 2008. – Vol. 4. – P. 1455–1464.
3. Deng X.L., Sui G., Zhao M.L. et al. Poly (L-lactic acid)/hydroxyapatite hybrid nanofibrous scaffolds prepared by electrospinning // Journal of Biomaterials Science. Polymer Edition. – 2007. – Vol. 18. – P. 117–130.
4. Kim H.W., Kim H.E. Nanofiber generation of hydroxyapatite and fluor-hydroxyapatite bioceramics // Journal of Biomedical Materials Research. Part B: Applied Biomaterials. – 2006. – Vol. 77. – P. 323–328.