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Cell compatibility and mechanical property of poly(lactic acid)-based electrospun fibremats

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1. Introduction

A composite consisting of poly(lactic acid) (PLLA) and vaterite containing silicon species was developed and its fibermat were successfully prepared via an electrospinning process in our previous work. The silicon species released from the composite are expected to enhance the new bone formation through gene-activation of osteoblasts [1]. In fact, the composite showed excellent cell and tissue compaitibilities by the results of *in vitro* and *vivo* tests [2]. The composite fibremats are expected to be applicable to the use in bone reconstruction.

Cell migration into pores in biomaterials is regarded to be one of the important factors for achieving bone reconstruction in body, when porous materials like the fibremats are used. In addition, mechanical properties and apatite-forming ability are also important for the biomaterials used in the bone reconstruction.

In the present work, the cell migration in the electrospun PLLA fibermats with various fiber-diameters were fundamentally examined by culture tests using osteoblast-like cells. After finding an appropriate fiber-diameter, the composite fibremats were also prepared and evaluated in their mechanical properties and apatite-forming ability in SBF.

2. Experimental Procedures

Polymer solutions used for electrospinning were prepared by dissolving PLLA (PURAC® (Mw:20~30 kDa), LACTY® or LASIA® (Mw:15~17 kDa)) in chloroform and methanol solution with various PLLA concentrations. The fibermats with 3 different fibre-diameters were prepared by an electrospinning method. The prepared fibermats were observed by scanning electron microscopy (SEM).

An average for the fiber diameter was estimated by measuring the diameters of 20 fibers randomly selected from SEM photographs. The porosity of the fibermats was measured by gravimetry and mercury porosimetry.

Fibermats were cut into a circular membrane with 15 mm in diameter and fixed on a cover glass with the same diameter. The samples were sterilized using ethylene oxide gas and then placed in a 24-well culture plate. Mouse osteoblast-like cells were seeded on the samples at a density of 1×10^4 cells/well and incubated at 37 °C in a humidified atmosphere of 95 % air and 5 % carbon dioxide for 1, 6, and 13 d. The thickness of the cell layer was estimated by laser confocal microscopy (LCM).

The PLLA/siloxane-doped vaterite composite fibremats were prepared with the same method as our previous report [2]. Tensile tests were used according to the Japanese Industrial Standard (JIS L1015) to measure the tensile strengths of the fibermats (sample dimension: 5 x 40 mm with 100-150 μm-thickness, n=10-15) using an Autograph (AGS-J, Shimadzu) tensile tester.

The composite fibermats with dimensions 10 x 10 mm were soaked in 70 % ethanol/distilled water solution for 5 min at room temperature, rinsed with distilled water, and then soaked in 10 ml of 1.5 SBF at 37 ºC for 1 and 3 d. The bone-like apatite formations in the samples were determined by SEM, XRD and FTIR.

3. Results and Discussion

There were no significant differences in the porosities among the three samples, but the fibermat with larger fiber diameter tends to have a larger pore size. The fiber diameter and the pore size of the fibermat were co-related; the sizes of the pores in fibermats could be controlled by regulating the fiber diameters. The cells on the fibermat with large fiber diameter were adhered on the single fiber and migrated into the fibermat. On the other hand, the cells on the fibermat, consisting of thin fibers, proliferated over the several fibers and did not migrate into the fibermat. These results reveal that fibermats with fibers more than 10 μm in diameter have a potential in the application for bone tissue-engineering scaffolds.

The composite fibermats with 20 and 30 wt% of siloxane-doped vaterite particles content showed higher tensile strength than the other samples. Although the composites fibermats with more than 40 wt% of particles content were brittle, the ones with less than 30 wt% of particles content showed improved ductility. The composite fibermats with more than 30 wt% of particles content showed rapid apatite formation on the fiber surfaces in 1.5 SBF. It is concluded that the apatite-coated fibermat containing 30 wt% of particles is the most suitable among the series in the present work as novel materials to promote bone regeneration.

4. Conclusions

The cell migration on/in the electrospun PLLA fibermats with various fibre-diameters were examined by the cell culture tests using the osteoblast-like cells. The cells were found to migrate into the fibermat with 10 μm in fiber-diameter, although they did not do for the fibermats consisting of thinner fibers. The fibermats out of the PLLA and vaterite-containing silicon species composites with around 10 μm were fabricated and investigated in their tensile strength and apatite-forming ability. The composite fibermats with 30 wt% of particles showed an excellent strength and the apatite-forming ability.

References

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