Fibrous membrane of nano-hybrid poly-L-lactic acid (PLLA)/silica xerogel for guided bone regeneration

Tae-Sik Jang, Eun-Jung Lee, Hyoun-Ee Kim
Department of Materials Science and Engineering, Seoul National University, Seoul, Korea

Introduction: Poly-L-lactic acid (PLLA) is a FDA-approved biodegradable polymer that is applicable for guided bone regeneration (GBR). However, its bioactivity and rigidity need to be improved further for application as effective GBR membranes [1]. Herein, a silica xerogel was hybridized with PLLA using the sol-gel process to make a strong, bioactive GBR membrane by electrospinning process. The silica xerogel has been considered to be a promising bone regenerative material, owing to its excellent bioactivity and high stiffness [2]. The electrospinning is a useful technique for fabricating nano-fibrous and porous membranes, which are particularly desirable for tissue regeneration applications [3]. Therefore, this study was aimed to fabricate nano-fibrous hybrid membrane, and to examine the effect of the hybridization of PLLA and silica xerogel on the mechanical and biological properties of the fibrous membrane for GBR.

Materials and Methods: The silica xerogel sol prepared by sol-gel process and PLLA sol dissolved in 1,1,1,3,3,3-hexafluoro-2-propanol (HFP) were mixed with the silica xerogel at different weight ratios up to 60 % of the silica xerogel. These PLLA-silica xerogel hybrid mixtures were loaded into a glass syringe and electrospun under a high DC electric field. After electrospinning, the fibrous membranes were stored in a desiccator under vacuum to remove any residual HFP. Fabricated membranes were characterized by SEM and TEM, and their properties for guided bone regeneration were evaluated in terms of tensile strength and the *in vitro* cellular responses.

Results and Discussion: Fig. 1 shows the morphology and internal structure of the PLLA-silica xerogel hybrids generated by electrospinning. As presented in Fig. 1(a), the fiber had fine and continuous morphology without the formation of any beads. Moreover, the hybrid fiber revealed uniform and nano-sized microstructure [Fig. 1(b)].

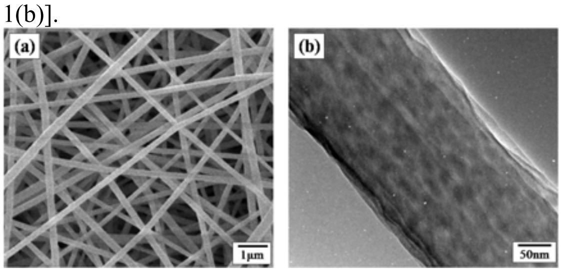

Fig. 1. (a) SEM and (b) TEM image of the PLLA-40% silica xerogel electrospun nanofiber.

The stress-strain curves of the membranes are shown in Fig. 2. The mechanical properties such as the tensile strength and elastic modulus were improved with increasing the content of the silica xerogel. However, the addition of excess silica xerogel (≥60 %) induced decrease of the mechanical properties of the hybrid membrane. Thereby, the highest mechanical properties was obtained for the hybrid membrane containing 40 % silica xerogel, and this value was more than triple the strength of the pure PLLA one.

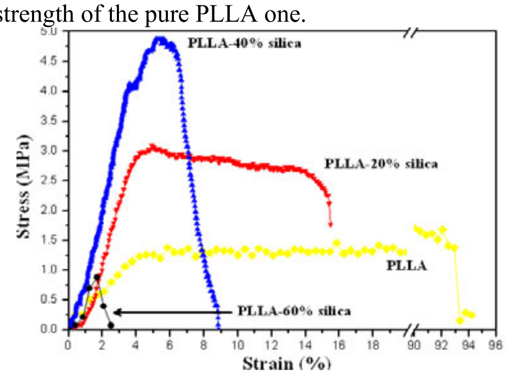

Fig. 2. The stress-strain curves of the nanofibrous membranes with different compositions.

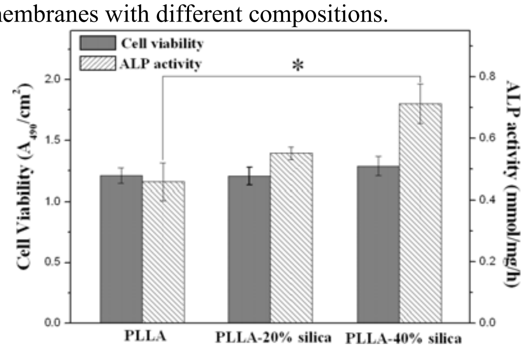

Fig. 3. The cell viability and ALP activity of cells cultured on the nanofibrous membranes with different compositions (*p<0.01, n=3).

Fig. 3 shows the biological properties of the membranes assessed by the *in vitro* cell test. All of the membranes exhibited a good proliferation level for 3 days. In the result of the ALP activity assessed after culturing for 10 days, the cells cultured on the hybrid membranes revealed a significantly higher level of differentiation than those on the pure PLLA membrane. These results demonstrate the feasibility of the hybrid membranes for efficient guided bone regeneration.

Conclusions: The fibrous PLLA-silica xerogel hybrid membranes were fabricated using a sol-gel process via electrospinning technique. The fibers consisting of the membrane have a continuous and uniform nanostructure. The PLLA-silica xerogel hybrid membranes showed excellent mechanical properties and bioactivity when compared to the pure PLLA membrane. These results confirm that hybridization of the silica xerogel effect on improving the properties of the PLLA for GBR and then the PLLA-silica xerogel hybrids has potential as a bone regenerative material.

Reference

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2. Vogel M et al. Biomaterials 2001;22:357-362.
3. Chen F et al. Mater Sci Eng 2007;27:325-332.