Characterization and preparation of bio-tubular scaffolds for fabricating artificial vascular grafts by combining electrospinning and a 3D printing system

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Statement of Purpose: In biomaterials fields, many biomedical engineering researchers are currently developing alternative strategies incorporating bio-functional materials for the regeneration of live blood vessels. An elecrospun nanofibers (EN), which can range in size from the sub-macroscale to the nanometer scale and are fabricated using an electrospinning method, are commonly used as biomaterial scaffolds due to their large surface area and ability to mimic the extracellular matrix. Among the various polymer nanofibers that have been developed, chitosan (CTS) ENs are particularly well-suited for regenerating vascular tissue because of the intrinsic bioaffinity of CTS, a natural amino polysaccharide (poly(1,4-D-glucosamine)). Recently, many researcher demonstrated the merits of artificial vascular systems composed of electrospun CTS blended with synthetic polycaprolactone (PCL) nanofibers in in vitro and in vivo studies. The introduction of PCL enhanced the physical strength of the artificial vessels. However, to obtain scaffolds with sufficient strength, the CTS content was reduced to levels that are unsuitable for healthy vascular repair. In this study, we designed and printed 3D artificial blood vessels composed of CTS/PCL ENs covered with PCL strands. This approach introduces a new paradigm with regard to the use of rapid prototyping for tubular vascular scaffolds.

Methods: The CTS blended with PCL was fabricated combining ELSP and rapid prototyping methods. The outcomes were characterized by Fourier transform infrared spectroscopy (FT-IR) and scanning electron microscopy (SEM). Surface contact angles, water absorption, and the mechanical properties of the artificial vessels were also evaluated. The detailed experimental procedure of including materials, methods, synthesis were described as references.

Results: The surface chemistry of the fabricated CTS and CTS/PCL ENs was analyzed by FT-IR absorbance. The spectrum of the CTS EN film contains a characteristic peak at 1659 cm^{-1}, corresponding to an amide bond (N–H). The spectrum of PCL EN contained peaks corresponding to C–H bonds and an ester carbonyl group at 2938 cm^{-1} and 1725 cm^{-1}, respectively. The spectrum of CTS/PCL (9:1) EN contained bond amide and ester carbonyl peaks, indicating that CTS and PCL were well blended. The surface morphologies of the final products of the aforementioned procedure were characterized by SEM. The micrographs figures show the three-dimensional, layer-by-layer structure of the PCL strands atop films of CTS, CTS/PCL, and PCL EN, respectively. The results of tensile stress testing of each material. The ultimate tensile strength of pure CTS EN was considerably lower than that of PCL-coated CTS EN, and that of CTS/PCL EN was much lower than that of PCL-coated CTS EN. These results indicate that the strength of the scaffold increases significantly with the presence of the PCL strand coating. The above results show that the method described herein may be useful as a means of producing strong artificial vessels.

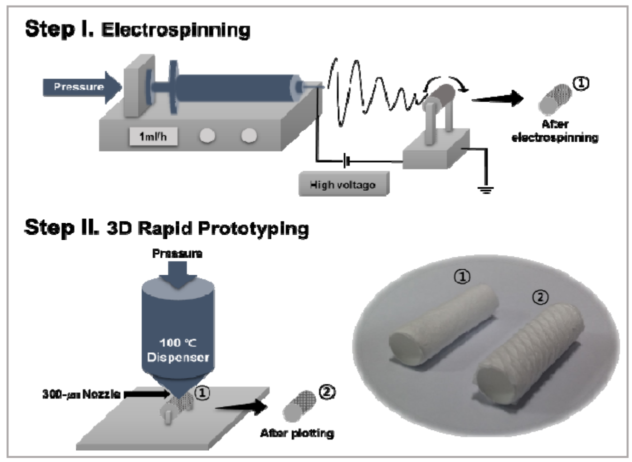

Figure 1. Schematic illustration of the fabricating 3D tubular artificial vascular scaffolds

Conclusions: In summary, novel and strong artificial blood vessels were fabricated using ELSP and a 3D bioprinting system. CTS, PCL, and blended CTS/PCL EN scaffolds were fabricated and evaluated by FTIR and SEM. Water absorption, and therefore hydrophilicity, increased with increasing proportions of CTS. The fabricated tubular scaffolds were suitable in terms of both surface morphology and mechanical properties, both of which were significantly enhanced by the printing of PCL strands on the EN substrate. Our results demonstrate the synthesis of artificial vessels composed of EN reinforced with 3D-printed PCL strands.

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