Development of a Composite Scaffolding System for Vascular Graft Applications

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Statement of Purpose: Numerous scaffolds that possess ideal characteristics of vascular grafts have been fabricated for clinical use [1]. However, many of these scaffolds may not show consistent properties when they are exposed to physiologic vascular environment with high pressure and flow, and eventually fail due to the unexpected rapid degradation and low shear stress resistance. There is a demand to develop a more durable scaffold that could withstand these conditions until vascular tissue matures *in vivo* [2]. In this study we fabricated a vascular composite scaffold by electrospinning poly(ε-caprolactone) (PCL) and collagen. These composite scaffolds are designed to provide sufficient biomechanical properties and are configured to accommodate vascular endothelial cells and smooth muscle cells for the use of vascular tissue engineering.

Methods: Vascular composite scaffolds were fabricated by electrospinning with a polymer blend of PCL and type I collagen with the ratio of 1:1 in weight. The PCL/collagen solution was delivered through a blunt tip at a constant flow rate of 3 mL/hr by using a syringe pump. The mandrel was a stainless steel rod. The distance between the syringe tip and the mandrel was 10 cm and the rotating rate was 1000 rpm. The biomechanical properties including tensile properties, suture retention strength, burst pressure strength, and compliance and biological activity of the composite scaffolds for their use in vascular scaffold using bovine endothelial cells (*b*ECs) and smooth muscle cells (*b*SMCs) were evaluated.

Results: The electrospun PCL/collagen composite scaffolds, with fiber diameters of approximately 520 nm, possessed appropriate tensile strength (4.0±0.4 MPa) and adequate elasticity (2.7±1.2 MPa). The elasticity and elongation of the hydrated PCL/collagen scaffolds were more close to those of native vessels (Figure 1). The suture retention strength of the composite scaffolds was more than adequate for suturing during implantation, which is generally accepted to be greater than 2.0 N. The burst pressure of the composite scaffolds was 4912±155 mmHg, which is much greater than that of the PCL only scaffolds (914±130 mmHg) and native vessels. The tensile strength of the composite scaffolds maintained 86.3% of the initial tensile strength after 4 weeks in the physiological vascular conditions (flow, pressure, and temperature) (Figure 2). The composite scaffolds seeded with *b*ECs and *b*SMCs showed the formation of a confluent layer of *b*ECs on the lumen and *b*SMCs on the outer surface of the scaffold. These results indicate that the PCL/collagen scaffold is biocompatible and can support cell growth and proliferation *in vitro*. The PCL/collagen based composite scaffolds can be used in conjunction with vascular cells to create an engineered vessel that could withstand physiological vascular conditions.

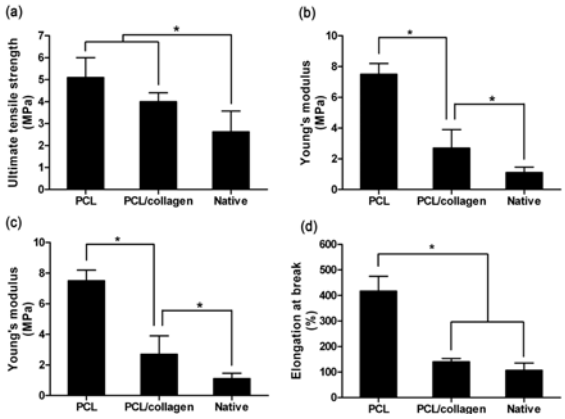

Figure 1. Tensile properties of electrospun PCL/collagen composite scaffolds; (a) ultimate tensile strength, (b) yield tensile strength, (c) young's modulus, and (d) elongation at break of electrospun PCL/collagen composite scaffolds compared to electrospun PCL scaffolds and porcine coronary artery as native control (*$P < 0.05$).

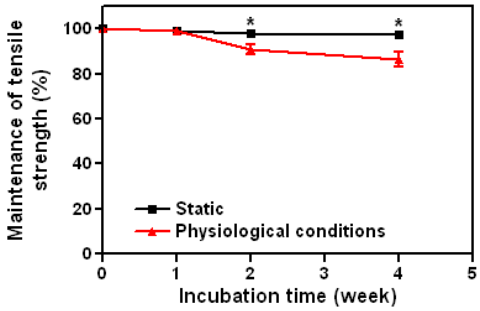

Figure 2. Maintenance of tensile strength of electrospun PCL/collagen scaffolds under physiological vascular condition.

Conclusions: We have developed a composite scaffold that can withstand physiological vascular conditions consisting of high pressure and flow. The composite scaffolds, fabricated by hybridizing a high molecular weight PCL and type I collagen using electrospinning techniques, possess excellent biomechanical properties and demonstrate a long-term stability under a continuous perfusion bioreactor system for up to 4 weeks. In addition, the composite scaffolds provide a favorable environment that supports the growth of vascular cells.

References:

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2. Greenwald SE, Berry CL, Improving vascular grafts: the importance of mechanical and haemodynamic properties. J Pathol 2000;190:292