Developing a Tissue-Engineered Aortic Heart Valve Based on an Electrospun Scaffold

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Abstract : Commercially available mechanical or biological heart valve prostheses both tend to fail long-term due to thrombosis, calcific degeneration, infection, or immunogenic rejection. Moreover, these prostheses are non-viable and do not grow with the patients, which is a problem for young patients. As a result, patients often need to undergo redo-operations. Tissue-engineered (TE) heart valves based on degradable electrospun fiber scaffolds represent a promising approach to overcome these limitations. Such scaffolds need sufficient mechanical properties to withstand the hydrodynamic stress of intracardiac hemodynamics. Additionally, the scaffolds should be colonized by autologous or homologous cells to facilitate the in vivo remodeling of the scaffolds to a viable structure. This study investigates how process parameters of electrospinning and degradation affect the mechanical properties of electrospun scaffolds made of FDA-approved, biodegradable polymer polycaprolactone (PCL). Fiber mats were produced from a PCL/tetrafluoroethylene solution by electrospinning. The e-spinning process was varied in terms of scaffold thickness, fiber diameter, fiber orientation, and fiber interconnectivity. The morphology of the fiber mats was characterized with a scanning electron microscope (SEM). The mats were degraded in different solutions (cell culture media, SBF, PBS and 10 M NaOH-Solution). At different time points of degradation (2, 4 and 6 weeks), tensile and cyclic loading tests were performed. Fresh porcine pericardium and heart valves served as a control for the mechanical assessment. The progression of polymer degradation was quantified by SEM and differential scanning calorimetry (DSC). Primary Human aortic endothelial cells (HAECs) and Human induced pluripotent stem cell-derived endothelial cells (iPSC-ECs) were seeded on the fiber mats to investigate the cell colonization potential. The results showed that both the electrospinning parameters and the degradation significantly influenced the mechanical properties. Especially the fiber orientation has a considerable impact and leads to a pronounced anisotropic behavior of the scaffold. Preliminary results showed that the polymer became strongly more brittle over time. However, the embrittlement can initially only be detected in the mechanical test. In the SEM and DSC investigations, neither morphological nor thermodynamic changes are significantly detectable. Live/Dead staining and SEM imaging of the cell-seeded scaffolds showed that HAECs and iPSC-ECs were able to grow on the surface of the polymer. In summary, this study's results indicate a promising approach to the development of a TE aortic heart valve based on an electrospun scaffold.

Keywords : electrospun scaffolds, long-term polymer degradation, mechanical behavior of electrospun PCL, tissue engineered aortic heart valve
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