RATIONAL DESIGN OF TUBULAR FIBER SCAFFOLDS FOR A SMALL DIAMETER VASCULAR GRAFT

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Introduction

Coronary artery and peripheral vascular damage are major contributors to cardiovascular disease, and prove particularly challenging to treat due to their relatively small vessel diameters (≤6 mm), their tortuosity, and their high hemodynamic demands. Synthetic grafts are a promising treatment, but in the longer term, they result in neointimal hyperplasia and reduced patency, largely due to mechanical mismatch and a lack of biologically adaptive properties. In this study, we rationally designed fiber scaffolds to provide mechanical properties that withstand hemodynamic pressure upon implantation while allow cellular infiltration and promote the formation of new tissue. In this preliminary investigation, we explored the different strategies of designing and fabricating tubular scaffolds with hexagonal microstructures using melt electrowriting (MEW) that could result in native-like stiffness and compliance.

Methods

Fiber tubular scaffolds (Ø2mm, length 3.5-5.1mm, thickness 0.2mm) were fabricated using an in-house built MEW setup. Scaffolds were manufactured from poly(ε-caprolactone) (PCL) [1], by extruding the molten PCL (88°C) by air pressure (2bars) through a 27G needle and depositing it on a computer-controlled cylindrical collector at high voltages (5.5-7.5kV). Four different strategies for designing tubular scaffolds hexagonal microstructure were explored (Fig. 1). The printed constructs were evaluated for their printing accuracy using optical microscopy and mechanical performance under the uniaxial ring test [2,3].

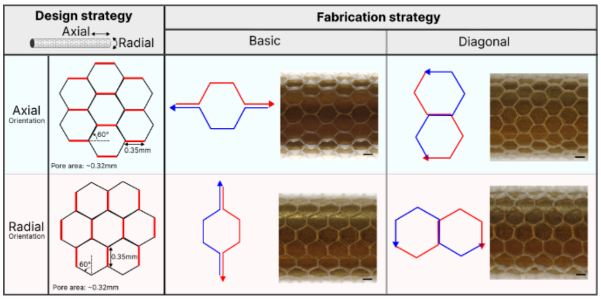

Figure 1: Four different design strategies for creating tubular scaffolds with hexagonal microarchitectures using MEW: axial-basic, axial-diagonal, radial-basic, and radial-diagonal (scale bar: 300µm).

Results

The proposed strategies effectively produced high porosity scaffolds with a fiber diameter of ~10µm and pore sizes of ~350µm with minimal deviation from the programmed path (Fig. 1). All scaffolds in radial group and axial-diagonal design presented a 3 to 5 fold increase in modulus compared to the axial-basic scaffolds (Fig. 2). Additionally, the axial-basic and radial-diagonal scaffolds ruptured at strains between 0.5-1 while most of the axial-diagonal and radial-basic scaffold underwent plastic deformation within this strain region and only failed at strains greater than 2 .

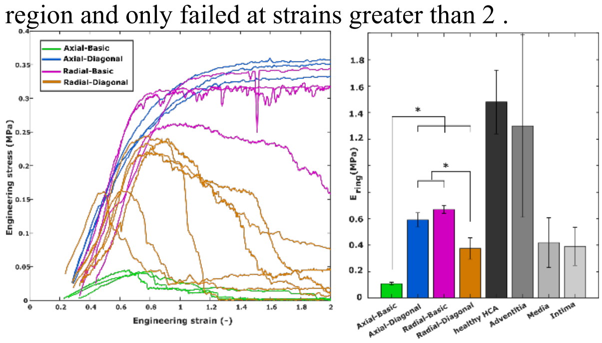

*Figure 2: The stress-strain curves (left) and their $E_{ring,}$ compared with human coronary arteries (HCA) (right). (*p<0.01)*

Discussion

Well-organized tubular constructs with native-like stiffness and high porosity were developed. The impact of printing direction demonstrated that aligning the fibers in the loading direction by using both design and fabrication strategies can improve the final scaffold's modulus. Although E_{ring} of all scaffolds were lower than the healthy HCA of young patient [4], the scaffolds from radial orientation design resulted in comparable strength of media and intima layer in HCA [5]. Based on these findings, the axial-diagonal and radial-basic designs were chosen for future in vitro cell studies under dynamic loading,

References

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