A BIOMIMETIC APPROACH FOR VASCULAR PROSTHESES FOR UNIVENTRICULAR HEARTS

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Introduction

Avoiding kinking of vascular prostheses poses a particular challenge for complex surgical procedures such as in Fontan patients[1]. In this study a biomimetic approach is pursued and combines it with electrospinning to produce a novel vascular scaffold with anti-kinking properties (Fig. 1a).

Methods

Two different electrospinning collectors (Fig. 1c, d=10 mm; l=150 mm) inspired by the caterpillar structure were used, combining the deposition of unaligned fiber segments (stability) with gap-spinning segments (flexibility). The groove depth to ensure the gap spinning effect was varied (Fig. 1c, 1.5 mm vs. 3 mm).

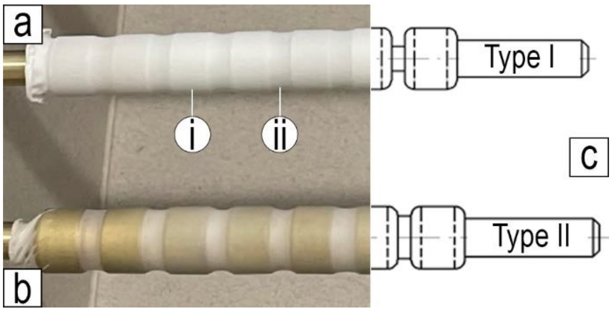

Figure 1: Custom made electrospinning collector for the fabrication of anti-kinking vascular scaffolds. Evaporation of the solvent was completed after 48 h of drying (a) and was previously evident in transparent fibers (b). Scaffolds show a combination of randomly deposited (i) and orientated fibers (ii, gap-spinning).

Electrospinning was performed with a 6 w/w% polyurethane-polycaprolcatone copolymer (MDI-Polyester/Polyether Polyurethane, Sigma Aldrich) in a 1:1 v/v mixture of dimethylformamide and tetrahydrofuran (Carl Roth). The flow rate was kept at 1.5 ml/h, voltage at 18 kV, distance at 170 mm and the spinning duration was 120 min. In a subsequent process, the unaligned fiber segments were additionally coated with silicone. Fiber diameter and morphology were examined via scanning electron microscopy (SEM, S3400-N, Hitachi), wall thickness, delamination and quality of the silicone reinforcement via light microscopy (Axio Discovery V12, Carl Zeiss). To determine the flow properties under bending, a test setup (double distilled water, 37 °C, p=50 mmHg) was used to measure the change in flow rate as a function of the bending angle. The flow rate was measured for 30s for bending angles from 0° to 120° in 15° steps.

Results

The use of different collector types resulted in mean fiber diameters of 1.8 µm and 2.3 µm respectively. Clear morphological differences between the segments could be detected, with the gap spinning areas showing an expected alignment of the fibers. No delamination was detected between the fiber layer and the silicone reinforcement. The mean wall thicknesses for the electrospun layer were 80 µm and 85 µm respectively and was increased to 200 mm for both types by the silicone reinforcement. Both types showed a linear decrease in flow rate (R^2=0.95 and 0.99) as a function of the bending angle (Fig. 2). The decrease in flow rate was at its maximum for both prostheses at a bending angle of 120°. The decrease was only 95.5 % and 94.5 % of the initial value at 0° bending.

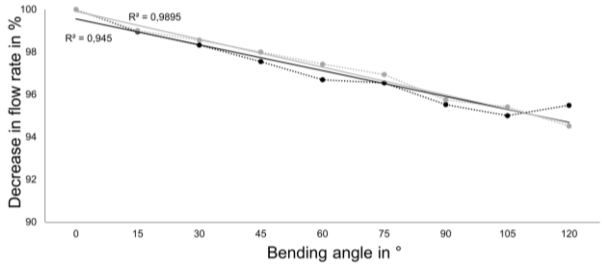

Figure 2: Bending properties of both collector types showed a linear relationship between bending angle and decrease in flow rate (n=3).

Discussion

The collector design used has been successful both in the modification of the fiber microstructure and in the optimization of the bending properties. No influence of the groove depth on the bending properties was observed. The additional reinforcement structure using silicone showed high integrity and no signs of delamination. It further improved the bending properties as well as the resistance to compression. At the same time, it is potentially a suitable reinforcement for suturing to the vascular system.

Further investigations are focusing on the transfer of the process to the medical grade polyurethane Carbothane 3585A (Lubrizol) and further performance testing.

References

1. Escher A. et al. Semin Thorac Cardiovasc Surg. 2022 Spring;34(1):238-248.

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