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Abstract

Biomechanical characterization of MEW-manufactured synthetic scaffold structures for tissue-engineered vascular grafts

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The limitation of synthetic vascular implants due to the risk of thrombosis leading to graft failure as well as the frequent lack of transplantable tissue highlights the necessity for tissue-engineered constructs to provide safe, durable, and long-lasting alternatives for tissue replacement. 3D printing methods like melt electrowriting (MEW) [1] provide a promising technique to produce highly precise and reproducible scaffold structures. Printing parameters were optimized to produce reproducible, and potentially patient-specific tubular scaffolds on a custom-made rotating printing bed by using a 3D Printer R-Gen 200 [2].

We present a biomechanical characterization of 3D printed tubular scaffold designs using uniaxial testing (radial and longitudinal) to determine the Young´s modulus: n= 5-15 per design, 13 designs total, five with varying winding angles (15 to 75°), five with increasing fiber diameter (43-129 µm), two with different strand distances (0.2/0.5 mm), one with an alternating winding angle (45°/60°). These should mimic porcine blood vessels with a diameter < 6 mm (native vessels, n=36, 6.4-19. MPa (long.), 1.6-7.5 MPa (rad.)/decellularized vessels, n=15, 1.9-8.0 MPa (long.), 3.2-8.8 MPa (rad.)). Increasing the winding angle of the fibers in rotational 3D printing showed an increasing effect on Young's modulus in radial testing (from 0.1 ± 01 MPa at 15° to 4.6 ± 0.9 MPa at 60°), whereas there was no reinforcing effect in longitudinal testing. A bigger strand diameter led to an increased Young's modulus in radial testing (from 0.6 ± 0.1 MPa at 43 µm to 2.7 ± 0.2 MPa at 129 µm). A lowered strand distance of 0.2 mm enabled an increased Young´s modulus in radial testing (3.8 ± 0.4 MPa.), approaching the range of decellularized vessels. The hydrolytic degradation rate of ε-polycaprolactone (45 or 80 kg* mmol^{-1}) and poly-L-lactic acid was observed over a three-month period. Tensile strength determination favored the use of longer-chained polymers. These results indicate a critical interdependency between fiber orientation and strand diameter in determining the biomechanical characteristics of 3D printed tubular scaffolds. The mechanical adaptations of tubular scaffolds for cardiovascular grafts led to a successful adjustment of the radial Young´s modulus to match that of native vessels. We suggest that the radial biomechanical properties of vascular grafts are more relevant for the later use as a vascular implant, due to pulse wave dynamics, while still enabling patient-specific adaptations.

Author's statement and acknowledgment

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References

[1] S. Loewner et. al., *Successful endothelial monolayer formation on melt electrowritten scaffolds under dynamic conditions to mimic tunica intima*, in International Journal of Bioprinting, 5th edition, vol. 10, issue 1, 1111, 2023, pp. 477-491.
[2] T. Baroth et. al., *An Intelligent and Efficient Workflow for Path-Oriented 3D Bioprinting of Tubular Scaffolds*. 3D Print Addit Manuf. 2024 Feb 1;11(1):323-332.

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