Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2025, Vol. 7, No 1, Suppl. 1, Article ID 2111, 1 Page

Infinite Science Publishing

Abstract

Evaluation of tensile properties of 3D-printed aortic models

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Cardiovascular diseases are the primary cause of mortality globally, underscoring the necessity for realistic vascular models to aid in the development of endovascular devices and training for interventionalists. While 3D printing holds promise for generating anatomically accurate blood vessel models, there is limited information on how well 3D-printed materials can replicate the elastic characteristics of the aortic wall. 3D-printed models that closely emulate native tissue provide environments for interventionalist training and testing of novel methods and devices. Consequently, this work aims to characterize the stiffness of 3D-printed composite materials in relation to biological vascular tissue.

The mechanical properties of homogeneous and composite 3D-printed multilayer samples, both with and without additional embedded helical structures, were tested and compared to porcine aortic samples and values for human aortic tissue gleaned from literature. The 3D printing materials had a hardness of either Shore 30A (Stratasys Agilus) or 70A (Stratasys Agilus/VeroClear blend). All six sample combinations were printed with a Stratasys J850 PolyJet 3D printer (Stratasys Ltd., Eden Prairie, Minnesota, U.S.A). Uniaxial tension tests were conducted on ring-shaped samples using a Galdabini Quasar 100 universal testing machine (Galdabini SPA, Cardano al Campo, Italy) equipped with a 50 N load cell. Samples were deformed at a rate of 500 mm/min until they reached 10% deformation of the initial diameter, simulating the strain experienced by aortic tissue in the body.

The deformation results yielded stiffness values ranging from 1.16 N/mm to 4.83 N/mm for 3D-printed materials, while both porcine samples and healthy human aorta stiffness values from literature ranged from 0.22 N/mm to 0.45 N/mm. The homogeneous 30A material, as well as multilayered 30A and 70A materials lacking helical structures, come closest to reaching the stiffness ranges of biological tissue, yet are still not optimal, as they are still stiffer than the reference values. Although 3D-printed composite materials used here are generally stiffer than biological tissue, the 3D-printed materials in this work could be used to emulate diseased tissue, such as vasculature afflicted by atherosclerosis. Further evaluation to compare these 3D-printed materials to atherosclerotic tissue is on the horizon, as disease models are necessary in training and furthering the development of devices and methods in endovascular surgery.

AUTHOR'S STATEMENT
Conflict of interest: Authors state no conflict of interest. Research funding: This study was partially supported by the Federal Ministry of Education and Research (BMBF), grant number 13GW0608F. The Fraunhofer IMTE is supported by the EU (EFRE) and the State Schleswig-Holstein (Project: IMTE 2 – Grant: LPW21-L/2.2/262, 125 24 009).

DOI: 10.18416/AMMM.2025.25062111