IX International Conference on Computational Bioengineering
ICCB 2022
P. R. Fernandes and J. Folgado (Editors)

Abstract ID 77

EXPERIMENTAL AND COMPUTATIONAL FRAMEWORK TO DESIGN WELL-ORGANIZED FIBROUS SCAFFOLDS FOR CARDIAC TISSUE ENGINEERING

Nicolás Laita[1], Gerardo Cedillo-Servin[2], Andrei Hrynevich[2], Miguel Ángel Martínez[1], Miguel Castilho[2], Manuel Doblaré[1], Estefanía Peña[1]
[1]Aragón Institute of Engineering Research (I3A), University of Zaragoza, Zaragoza, Spain
[2]Regenerative Medicine Centre Utrecht, University Medical Center Utrecht, Utrecht, The Netherlands
nlaita@unizar.es, g.cedilloservin@umcutrecht.nl, a.hrynevich@uu.nl, miguelam@unizar.es, M.Dias.Castilho@tue.nl, mdoblare@unizar.es, fany@unizar.es

Keywords: Biologic Ventricular Assistant Device, Finite Element Modeling, Myocardium mechanical characterization

Summary: Myocardium infarction (MI) provokes the necrosis of an area of cardiac muscular tissue. This results in a reduction of myocardium mechanical and electrical properties and a consequent loss of pumping capacity. One of the most standardized treatments is the application of a ventricular assistant device (VAD), though these devices do not constitute a long lasting solution. One recent promising approach consists on the development of a Biologic VAD (BioVAD) that can restore the myocardium pumping capacity. This device consists of a polycaprolactone (PCL) fibrous scaffold, printed by Melt Electrowritting (MEW), that is then filled with a cell laden hydrogel. In this work, we focused on the designing process of the BioVAD scaffold, aiming to optimize its mechanical response regarding the physiological requirements that will withstand once implanted. PCL hexagonal-shaped-fibrous scaffold samples were fabricated as previously described [1]. Their mechanical response was evaluated by uniaxial and biaxial testing, in order to guarantee an appropriate three-dimensional characterization at different loading scenarios. An elastoplastic constitutive material model was selected considering the obtained results for the preconditioned scaffolds. Great fit of our material model was observed at physiological strain range (15-25%). A parametric finite element computational model was created and validated. We also developed scaffold + hydrogel models to study the influence of the hydrogel on the global mechanical response. 5% GelMA hydrogel was considered, using an hyperelastic model with an overall stiffness of 5 kPa [2]. To study the mechanical influence that the BioVAD will have on the heart, we also performed an experimental characterization of myocardium tissue, aiming to understand the requirements that the BioVAD will have to satisfy at operating conditions. Biaxial and shear tests were performed into healthy and infarcted myocardium [3]. Scaffold + Hydrogel models obtained a significantly stiffer response, suggesting that the hydrogel may have a great impact on the global mechanical behaviour. The mechanical trials performed with cardiac tissue reflected an orthotropic behaviour respect to the muscular fiber direction, which agrees with the results observed at the literature [3,4]. A computational model of a BioVAD-specific PCL scaffold was created and validated, including scaffold + hydrogel models. Hydrogel consideration has proved to be essential for a proper mechanical design. We also performed an experimental characterization of cardiac tissue, obtaining a similar response to the previous studies. With all this data, we are able to analyse the mechanical interaction between the BioVAD and the infarcted heart, which will allow us to improve the BioVAD design and to assure its success once implanted.

References

[1] Castilho, M. et al. Advanced Functional Materials, 2018. 28(40): p. 1803151.
[2] Schuurman, W. et al. Macromolecular bioscience, 2013, vol. 13, no 5, p. 551-561.
[3] Holzapfel, G.A. et al. Tr. of the Royal Society A, 2009, vol. 367, no 1902, p. 3445-3475.
[4] Sommer, G. et al. Acta biomaterialia, 2015, vol. 24, p. 172-192.

Acknowledgments: Funding provided by the European Economic Community through project BRAV3, C1-BHC-07-2019, H2020 and the Spanish Ministry of Economy and Competitiveness through research project PID2019-107517RB-I00