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FINITE ELEMENT ANALYSIS OF BIORESORBABLE CORONARY STENTS

Nic Debusschere[1], Matthieu De Beule[1], Patrick Segers[1], Peter Dubruel[2] and Benedict Verhegghe[1]

[1] IBiTech-bioMMeda-iMinds, Ghent University, De Pintelaan 185 Gent Belgium, nic.debusschere@ugent.be
[2] PBM, Ghent University, Krijgslaan 281 Gent Belgium

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Introduction

Biodegradable stents carry the potential to avoid long-term complications of conventional stents such as in-stent restenosis and late stent thrombosis, and could allow for a restoration of vasomotion and vessel growth which makes them suitable for e.g. pediatric applications [1]. To investigate the mechanics of this new type of stent via finite element simulations, advanced material models need to be incorporated to be able to capture the stent's time-varying material properties. This study focusses on the viscoplastic mechanical behaviour of bioresorbable polymeric stents.

Materials and methods

As a case study, we considered the commercially available Absorb Bioresorbable Vascular Scaffold (BVS) of Abbott Vascular (*Abbott Laboratories, Illinois, USA*). This stent is being produced via laser cutting out of poly-L-lactic acid (PLLA) tubes. A micro-CT-image based reversed engineering approach was applied to obtain the stents initial geometry and to construct a high-quality hexahedral mesh, using the in-house developed open-source software pyFormex.

To be able to use the implicit finite element solver Abaqus/Standard (*Dassault Systmes, Rhode Island, USA*) we adopted the strategy as described in [2] to simulate the balloon inflation of the stent, which involves the implementation of an anisotropic hyperelastic material model for the balloon. The balloon pressure vs. stent diameter relation was fit to the BVS manufacturer data.

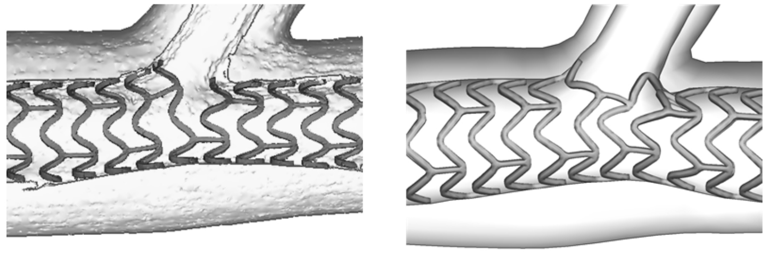

Figure 1: Comparison of the in vitro expansion of a BVS in a bifurcated silicone model and the virtual deployment of the stent

A visco-plastic material model was used to model the strain rate dependent mechanical behaviour of the biodegradable polymer PLLA. The constitutive model can be represented as a hyperelastic Langevin-type spring in parallel with a visco-plastic damper. A backward Newton iteration approach was used to update the plastic deformations, as described in [3], and the material model was implemented as a Fortran suboutine to be applicable to the Abaqus/Standard solver. The BVS stent was virtually balloon inflated inside a stenotic bifurcated hyperelastic blood vessel.

For validation of the simulations, a series of BVS-stents were balloon expanded inside 3D-printed silicone bifurcation models in a water bath at 37°C. A detailed examination of the expanded stent geometries was performed via micro-CT imaging. Figure 1 shows a comparison of the finite simulation with the in vitro stent deployment.

Results

The outcome of the virtual bench tests show good resemblance with the in vitro bench tests and the implemented visco-plastic material model is well capable of capturing the mechanical characteristics of the stent. Future work will include state of the art mechanical and degradation tests to further validate the material model.

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