Finite element modelling of coated biodegradable stents

Nic DEBUSSCHERE[1], Matthieu DE BEULE[1], Patrick SEGERS[1], Peter DUBRUEL[2], Benedict VERHEGGHE[1]

[1]bioMMeda, Ghent University, De Pintelaan 185, Ghent, Belgium

[2]PBM, Ghent University, Krijgslaan 281, Ghent, Belgium

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Biodegradable stents represent a promising alternative to permanent metallic stents, as they temporarily support the stenotic blood vessel during its healing period, leaving no obstacle for possible future interventions and avoiding long term side effects [1]. Finite element computer simulations have shown to be of great benefit in the design and mechanical characterization of bare metal and drug eluting stents [2]. However, biodegradable stents have created new challenges in the study of stents via computer simulations because of the complex materials they are made of, ranging from bioresorbable polymers such as polylactic acid to biocorrodible metals such as magnesium alloys. To obtain realistic results, a computational framework must be developed that incorporates all characteristics of the stent's material, including the effect of mechanical load upon degradation and the effect of a possible coating. When modelling interaction of the stent with the stenotic blood vessel, also the change in mechanical properties of the blood vessel should be taken into account. We have developed the base for such a computational environment in which the mechanical behaviour of coated biodegradable stents can be investigated. Several material models have been proposed to model degradation of bioresorbable polymeric stents and biocorrodible metallic stents, based on continuum damage theory [3], [4], [5]. We combined and extended these material constitutive equations to study the radial strength of biodegradable stents as a function of time. As a proof of concept, we investigated a generic coated bioabsorbable magnesium stent's scaffolding abilities by the virtual expansion and degradation of the stent in a stenotic artery. Material properties for stent, coating and arterial tissue were obtained from literature and material mechanical behaviour was fit to the available experimental data. Also arterial tissue damage caused by angioplasty was taken into account [6]. The different material models were implemented in fortran user subroutines to be compatible with the accurate Abaqus/Standard (Simulia, Providence, USA) finite element solver. Stent and artery geometry and meshes were created using the pyFormex open source software. The stent was crimped and expanded in the stenotic artery and subsequently subjected to degradation. The stent's ability to withstand the load of the artery was plotted as a function of degradation time. We were able to develop a computational framework to simulate the mechanical behaviour of polymeric and metallic biodegradable stents. This virtual environment allows to assess the time-varying radial strength and vessel scaffolding potential. In order to obtain clinically relevant information future work will include further experimental validation to quantitatively calibrate the degradation model.

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