VIRTUAL BENCH TESTING OF BIODEGRADABLE STENTS

Nic Debusschere[1], Matthieu De Beule[1], Patrick Segers[1], Peter Dubruel[2], Benedict Verhegghe[1]
[1] IBiTech-bioMMeda, Ghent University, Belgium; [2] PBM, Ghent University, Belgium

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. paediatric applications [Ormiston, 2009]. To investigate the mechanics of this new type of stent via finite element simulations, we developed a numerical framework that is able to incorporate the stent's complex time-varying material properties. In this study, we set up a virtual bench test to compare the mechanical behaviour of a biocorrodible magnesium stent and a bioresorbable polymeric polylactic acid (PLA) stent.

Methods

Material models for magnesium stress and pitting corrosion and hydrolytic degradation of polyesters, based on continuum damage mechanics, were implemented as user subroutines to be compatible with the finite element solver Abaqus/Standard (Dassault Systèmes, Providence, USA). Material parameters and degradation constants were obtained by fitting of the degradation dependent stress-strain curves for PLA and magnesium alloy AZ31 (data obtained from literature [Grogan, 2011; Gastaldi, 2011]). We used the pyFormex mesh designer (in-house developed open source software) to create a generic finite element model of both a biocorrodible magnesium and a bioresorbable PLA stent ring which were virtually compressed at different degradation times to obtain their evolving radial strengths.

Results

The initial preservation of the magnesium stent's radial strength (full curve in Figure 1) can be explained by the fact that corrosion is a surface degradation process, which initially does not affect the bulk of the strut. In the second phase, the stent's radial strength is rapidly diminishing because of pitting corrosion and stress corrosion. The PLA stent's hydrolytic degradation is first affecting the amorphous phase of the polymer. The decline of the stents radial strength speeds up when the loadbearing crystalline phase of the polymer starts to degrade (dashed curve in Figure 1).

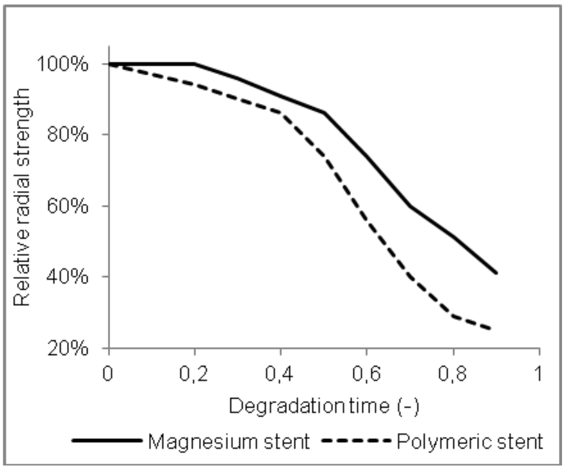

Figure 1: Evolution of the radial strength of a magnesium stent strut and a polylactic acid stent strut.

Discussion

Material models for metal corrosion and polymer degradation were implemented to investigate the evolution of the radial strength of a magnesium stent and a PLA stent within a finite element simulation framework. These models are able to project micro-scale physical phenomena onto the macro-scale stent behaviour. This proof of concept research will however need further experimental validation to lead to clinically relevant information.

References

Ormiston *et al*, Circulation, 2:255-60, 2009.
Grogan *et al*, Acta Biomaterialia, 7:3523-33, 2011.
Gastaldi *et al*, J Mech Behav Biomed, 4:352-65, 2011