Computational modeling of coated biodegradable stents

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ABSTRACT

Aims

Biodegradable stents are a promising technological development, 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 of conventional drug eluting stents. Moreover, the biodegradable stent material forms an ideal vehicle for local drug delivery [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]. Because of their complex material behavior, biodegradable stents have created new challenges in the study of stents via computer simulations. 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. We have developed the base for such a computational environment in which the mechanical behavior of coated biodegradable stents can be investigated.

Methods & results

Recently, several material models have been proposed to model degradation of bioresorbable stents, based on continuum damage theory [3,4]. We combined these material constitutive equations to study the radial strength of biodegradable stents as a function of material mass loss. As the latest generation of bioabsorbable magnesium stents will have a bioresorbable coating (acting as a drug carrier and controller of stent erosion), the effect of this coating upon stent degradation has also been taken into account. 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 behavior was fit to the available experimental data. The different material models were implemented in fortran user subroutines to be compatible with the accurate Abaqus/Standard (Simulia, Providence, USA) finite element solver. The left side of Figure 1 depicts the finite element model of a coated bioabsorbable magnesium stent in a stenotic artery. Represented in detail is a cross-cut of the stent mesh, showing coating elements and magnesium stent elements. 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 result of this simulation is illustrated on the right side of Figure 1. The first half of this graph shows the change in stent radius during stent deployment, including stent crimping, recoil after crimping, stent expansion and recoil after expansion. The second half of the graph shows the change in stent radius as the stent is compressed by the blood vessel because of degradation. During coating degradation, the stent radial strength is maintained. Once the coating has disappeared, the magnesium stent starts to corrode, causing a decline in stent radial stiffness.

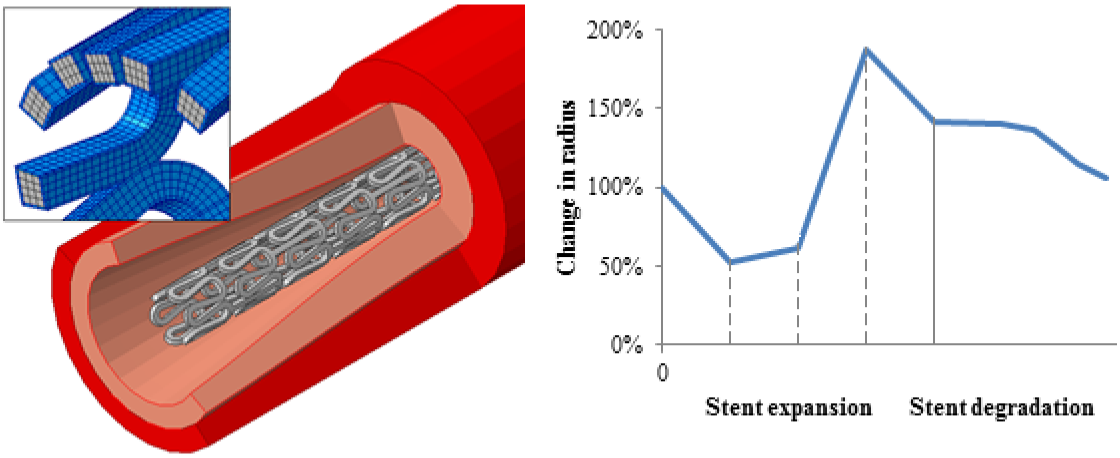

Figure 1: Finite element model of a coated magnesium stent in a stenotic artery, and the evolution of the stent's radius during stent expansion and degradation.

Conclusion

We were able to develop a computational framework to simulate the mechanical behavior of polymeric and metallic biodegradable stents. This virtual environment allows to assess the time-varying radial strength and vessel scaffolding potential. Good agreement with available experimental data could be obtained. In order to obtain clinically relevant information future work will include further experimental validation to quantitatively calibrate the degradation model.

References

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