Mechanical Performance of Bioresorbable Polymeric Stents during Crimping and Expansion in Diseased Artery

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Abstract

This paper compared the mechanical performance of four bioresorbable polymeric stents with different designs, i.e., Absorb, Elixir, Igaki-Tamai and RevaMedical, during crimping and expansion in diseased artery based on finite element simulations. Abaqus CAE was used to create the models for tri-folded balloon, stent and diseased artery (50% stenosis). For the stents, elastic-plastic behaviour was used, with hardening implemented by considering the increase of yield stress with the plastic strain. The balloon was treated as linear elastic, and the plaque was modelled as an isotropic hyperelastic material. The HGO model was used to describe the anisotropic constitutive behaviour of arterial layers. To simulate the crimping of stents, a set of 12 rigid plates were generated around the stent with a radially enforced displacement boundary condition. A pressure of 1.4 MPa was applied on the inner surface of three-folded balloon to simulate the inflation of stents, and then reduced to zero during the deflation process.

Significant levels of stresses were developed at the U-bend regions of the stents during both crimping and expansion processes. The crimping and expansion rates were found different for the four stents due to the variation in radial stiffness and strength for each stent design. Specifically, the Igaki-Tamai stent experienced the fastest crimping/expansion rate and the RevaMedical stent shrunk/expanded at the lowest rate. While the Absorb and Elixir stents behaved similarly, with medium crimping/expansion rate, because of design similarity. Similar trend was also obtained for the spring back (following crimping) and recoiling (following expansion) effects. Particularly, the Igaki-Tamai stent produced the most spring back and recoiling effects, because of its sharper U-bends and larger axial strut spacing when compared to the other three stents. The Reva stent had the least spring back and recoiling effects, attributed to middle-to-middle connection by axial struts which limited the flexibility of stent geometry. The stress state of the stent-artery system was also affected by stent design, depending on the final diameters achieved after crimping and expansion. This work highlighted the importance of design in controlling the mechanical performance of bioresorbable polymeric stents.

Keywords: Bioresorbable polymeric stents; Finite element; Crimping; Expansion; Spring back; Recoiling.

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