EFFECTS OF STENT OVERSIZING ON ARTERIAL STRESSES BASED ON FINITE ELEMENT ANALYSES

In-stent restenosis remains a significant problem in peripheral arteries. One of the main reasons for restenosis is suggested to be arterial wall damage during and post stenting. With self-expanding Nitinol stents being used for the treatment, clinicians tend to select large stents to ensure optimal wall contact and prevent stent migration. However, this oversizing can cause trauma in arteries and may be the cause for neointimal proliferation and restenosis. Therefore, the aim of this study was to quantify the effects of stent oversizing on arterial stresses with numerical analyses.

Finite element models of two commercially available, self-expanding stents having different stiffness were used in this study. The stents were deployed first in a straight arterial model and then within 5 geometrically patient-specific arteries. All arterial models had inner diameters of 5 mm and 3 layers (intima, media and adventitia) (Fig. 1). The anatomical shapes of the patient-specific arteries corresponded to the popliteal segment of the superficial femoral artery (SFA) of 5 patients, who underwent 3D rotational angiography.

The stents were modelled with the same super-elastic Nitinol, thereby having only geometrical design differences between them. The material model adopted for the arteries was an anisotropic, hyper-elastic model that represented 2 families of collagen fibres. The strain energy density function was based on the constitutive laws proposed by Holzapfel et al., which allows not only the specification of fibre orientations, but also the inclusion of fibre dispersion within each layer. The parameters were taken from the literature to represent healthy arterial tissues. Stent oversizing was simulated by initially constraining the stents to 5.5, 6, 7 and 9 mm diameters. Full stent deployment including crimping was performed for each case. Following stenting, a cyclic pressure (from 80mmHg to 160mmHg) was applied to the intimal surface of the artery to simulate blood flow for fatigue analysis of the stents.

For both straight and curved arteries, stress values were in range of values reported in literature. In all analyses, adventitia supported the bulk of the stresses to prevent large deformations and possible fractures in other layers. The arterial stress as well as the lumen gain increased with increasing oversizing. However, these relationships were not linear; the additional lumen gain between a 7 and a 9 mm stent was minimal. Results of the calculations also showed that the stresses in the curved arteries were significantly higher than in the straight ones. Moreover, the stress increase due to oversizing is amplified by the arterial curvature, suggesting that the curved artery may be more susceptible to restenosis if oversized. The comparison of these numerical results with clinical observations could be used to define a threshold for restenosis in terms of stresses and help clinicians when selecting stents for endovascular procedures.

Keywords: Arterial Biomechanics, Superficial Femoral Artery, Stent Oversizing, Patient-Specific Arterial Geometry, Finite Element Analysis

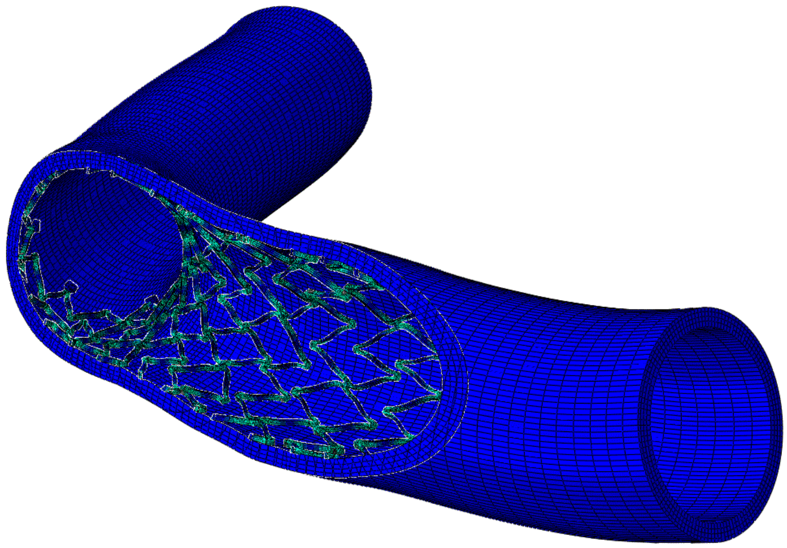

Figure 1- Cut-view of a stent expansion in the patient-specific artery