Computational Analysis on Commercially Available Stent Designs

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Abstract

INTRODUCTION:

Today coronary artery disease is one of the leading causes of untimely deaths. For single vessel and bi-vessel diseases of atherosclerosis, coronary stents are becoming increasingly popular as a minimally invasive method. The performances of stents are found to be highly dependent on material properties and design. Commercially, one finds various types of stents with varying materials and design modifications. Even after deployment, many patients undergo a re-stenting procedure because of restenosis.

This study aims to computationally analyze the performances of some of these commercially available stents and to identify the effect of various geometric parameters of a stent on the blood flow.

Use of COMSOL Multiphysics®:

COMSOL Multiphysics® has been used for the study and divided into two components:

a. Stress Analysis of Commercially Available Stents: In this study the Structural Mechanics Module was employed. Two designs: PS Stent (Cordis JnJ, USA) and S670 Stent (Medtronic, USA) were reconstructed and a stationary study was performed. Five different commercially used materials were chosen. Boundary conditions employed were clinically-recommended deployment pressures (14-16 atm), used for inflating the stent balloon, and the pressure given by the atherosclerotic plaque (780 KPa). The von Mises stresses developed in the stent were observed (Figure-2) and compared with UTS.

b. Analysis of Blood Flow Post Stenting: A time-dependant analysis using the CFD Module was done. A two-dimensional model of an arterial cross section post stenting was created. At an inlet, a pulsatile flow was given. For the Newtonian model, viscosity was 0.004 PaS. For the non-Newtonian model, a power law was used where m=1.029 and n=0.703. The stent struts

considered were rectangular (0.1mmX0.2mm) and square (0.1mm2) shaped. The wall was assigned a 'no slip' condition. The velocity (Figure-3), pressure, viscous stress and the recirculation lengths post stent deployment were found out.

RESULTS:

The stress analysis showed that at higher deployment pressures the von Mises stress developed sometimes exceeded the UTS of material. In comparison to PS Stents, the design of S670 Stent delivered better performance. Use of Tantalum resulted in failure in both designs. Pt-Cr alloy, Nitinol and Co-Cr alloy showed excellent material properties for stent designs. SS-316L showed optimum results when used for S-670 Stents.

Utilizing streamlines (Figure-4), rectangular struts with filleted edges were found to have better results. The case with square struts was similar. Rectangular struts displayed more recirculation than square shaped struts.

CONCLUSION:

The high von Mises stresses developed exceeding the UTS of material don't necessarily lead to the immediate breakage of the metallic stents. But as a result of this phenomenon, micro cracks are likely to develop in the body of the stents which, due to fatigue loading over time, ultimately contributes to the mechanical failure of the stents.

Strut shapes have a pronounced effect on blood flow behavior Rectangular struts lead to more recirculation than square struts. More recirculation is likely to cause more debris depositions in the stented region, thereby causing restenosis.

The study needs experimental evidence before making any clinical conclusions.

Reference

1. C. Lally, et.al, Stents. Wiley Encyclopedia of Biomedical Engineering. 2006.
2. Metals Handbook, tenth edition, Volume 2: Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, ASM International, Materials Park, Ohio, 1990, 1328 pages.
3. O'Brien B, et.al, A platinum chromium steel for cardiovascular stents. Biomaterials. 2010;31:3755-3761.
4. Foin N, et.al, Importance of knowing stent design threshold diameters and post-dilatation capacities to optimise stent selection and prevent stent overexpansion/incomplete apposition during PCI. Int J Cardiol. 2012 Oct 31. pii: S0167-5273(12)01291-0
5. Linxia Gu, et al, The Relation between Arterial Stress and Restenosis Rate after coronary Stenting. Journal of Medical Devices 4 (2010), no. 031005.

Figures used in the abstract

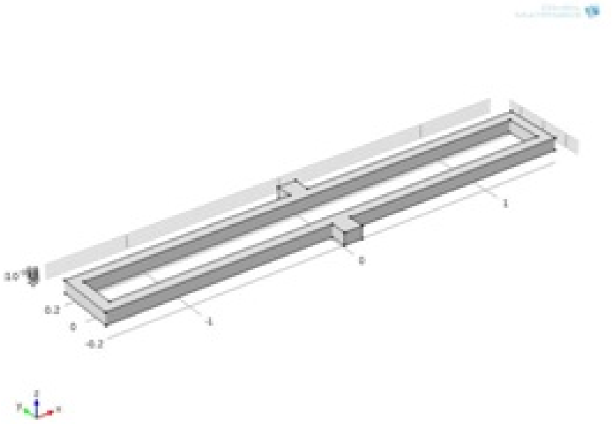

Figure 1: Geometry of a PS Stent(Cordis JnJ, USA)

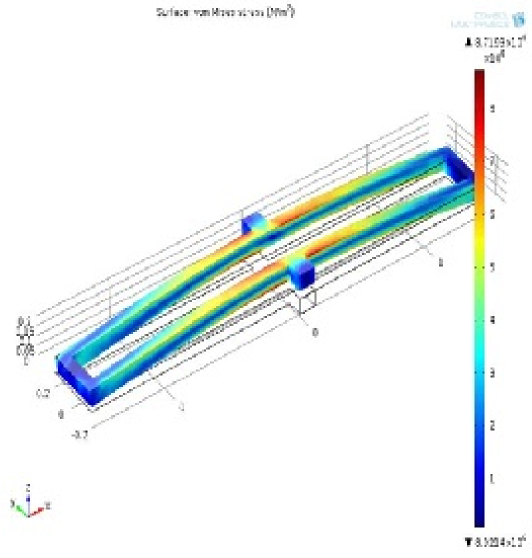

Figure 2: Von Mises Stress at 14 atm in a Nitinol PS Stent (Cordis JnJ, USA)

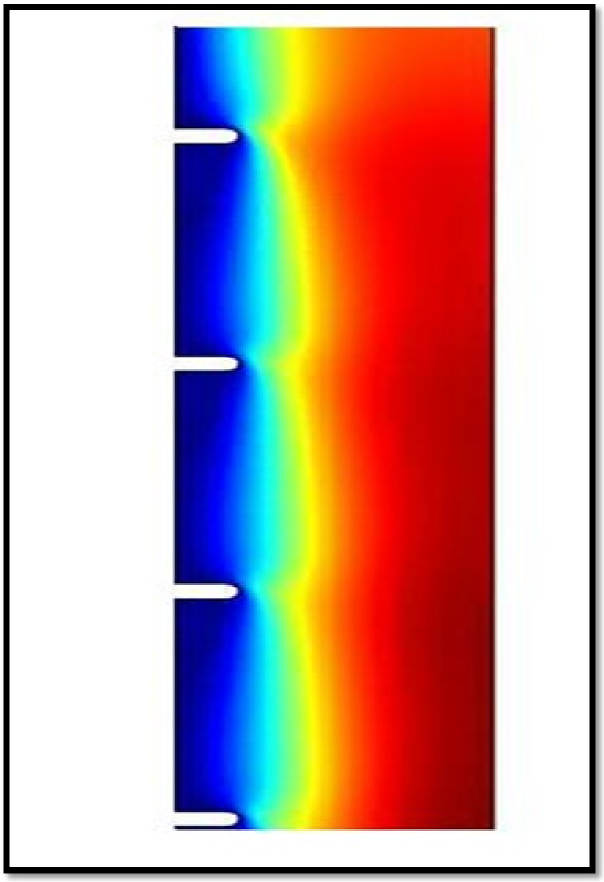

Figure 3: Velocity Plot of blood flow after deployment of fully filleted rectangular struts

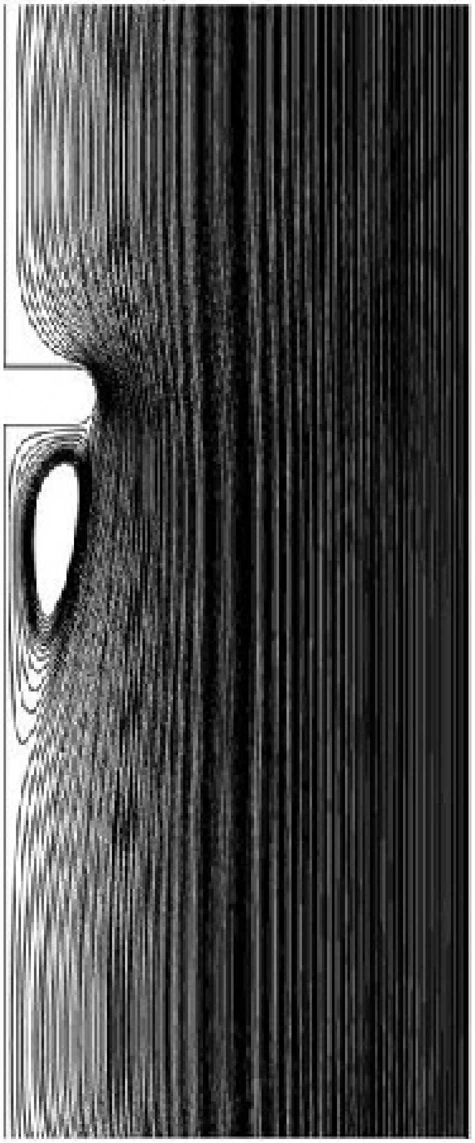

Figure 4: Streamline Plot of blood flow after deployment of fully filleted rectangular struts