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A Review of Coronary Stents and Study of Its Interaction with Artery Using Finite Element Analysis *(pp. 134-138)*

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Abstract: This review is based essentially on the development of the stents and their interaction with the artery. Because of our sedentary lifestyle in which mental pressures are increasing day – to – day but physical exercise finds no place, also intake of high caloried fatty food is increasing, which results to deposition of cholesterol in the arteries. This leads to death in certain cases. The stents are coming as instant solution to this problem and give instant relief than other solutions, but interaction of the stents with blood & arteries is a challenging area which needs to consistent attention.
Key words: CAD, FEM, arteries, fatty food

1 INTRODUCTION

In today's world the people are habitual of living high life style where mental challenges are increasing day by day but physical work is decreasing so earlier in western countries but now in eastern countries also coronary heart disease (CAD) is the most common reason for death. Coronary artery disease is specific to arteries of the heart. Coronary artery disease also known as atherosclerosis, occurs when excess cholesterol attaches itself to the walls of blood vessels. Embedded cholesterol also attracts cellular waste products, calcium and fibrin. This leads to a thickening of the vessel wall by complex interaction with constituents of the artery. The resulting pasty build up known as plaque can narrow or even block an artery.

A stent is a device that is used to support arterial walls to alleviate the blockage of arteries due to plaque. Plaque is a fatty substance that is deposited on the artery wall. This plaque accumulates and slowly becomes thicker and influences the mobility of blood flow. If this condition is left untreated, further development of atherosclerosis or build up of fatty substance will reduce the blood flow and may lead to heart attack. Stent implantation is a non-surgical method to treat the coronary artery disease. The procedure figure 1 is that when the stent is properly positioned in the artery at the location of the damaged lining, the stent is expanded by pressurized catheter balloon to a predetermined diameter. The balloon is then deflated and the stent delivery system is removed.

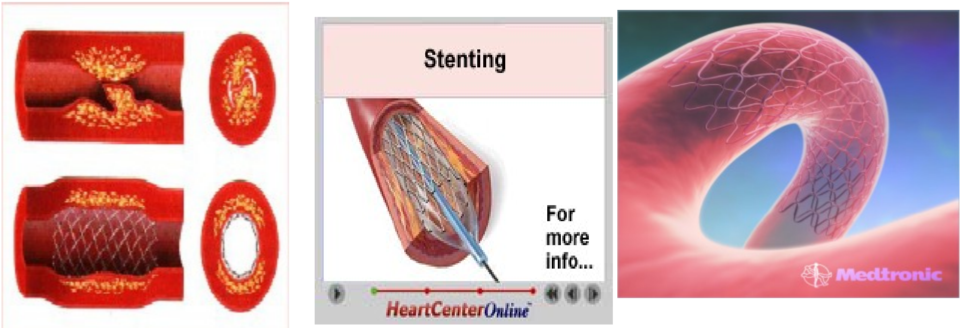

Figure 1: Stents and Stenting Procedure

2 SOME STUDIES RELATED TO PERFORMANCE OF STENTS

Stenting is coming as major upcoming area and solution to coronary artery diseases. A literature survey of such recent work has been carried out and reported below:

Tan (2000) investigated the structural behaviour of two different stent geometries using Freedom *stent geometry* and *Palmaz–Schatz (P-S) stent geometry* to observe the following: Increasing the wire diameter and the arterial elastic modulus by 150% results in the need to increase the balloon pressure to expand the stent by 10-fold. Increasing the number of circumferential convolutions increases the pressure required to initiate radial expansion of mounted stents. Dumoulin (2000) presented shortening percentage on expansion, degrees of radial and longitudinal recoil, and weaknesses of the structure of *the P308 Palmaz stent*. Various methods, differing in their levels of complexity, are then attempted to exhibit the predominant factors responsible for the crushing of a stent under external pressure. we test the stent with regard to fatigue life. Frederique (2001) used finite-element analysis to model two different type of stents: tubular stents (TS) and coil stents (CS). The two stents chosen for this modeling present the most extreme mechanical characteristics of the respective types. Seven mechanical properties were studied by mathematical modeling with determination of:

(1) stent deployment pressure, TS/CS =2.8
(2) the intrinsic elastic recoil of the material used,TS(5.4%)>CS(2.6%) (3) the resistance of the stent to external compressive forces,(TS can be deformed by 10% at compressive pressure between 0.7 & 1.3 atm., CS can be deformed between 0.2 – 0.7 atm.)
(4) the stent foreshortening,(foreshortening observed increases with deployment diameter for TS but CS lengthen during deployment)
(5) the stent coverage area,(2 times greater for TS than CS)
(6) the stent flexibility,(TS/CS = 2060 – 2858) and
(7) the stress maps at stent diameter of 3mm .

This series of finite-element analyses illustrates and quantifies the main mechanical characteristics of two different commonly used stents.

David (2001) studied the extent of expansion, foreshortening of the stent and stress levels at different increments of pressure due to the different speeds of application of pressure. Hui (2002) presented a method to compare the geometric dynamics of the coronary artery before and after stenting using biplane angiography. Two cases are reviewed and a number of parameters are proposed to describe the longitudinal change of the vessel before and after stenting. This analysis technique has the potential to identify some aspects of stent design and procedure that might improve the success rate with this therapeutic approach. Francesco (2002) applied the finite element method, to understand the effects of different geometrical parameters (thickness,metal-to-artery surface ratio, longitudinal and radial cut lengths) of a typical diamond-shaped coronary stent on the device mechanical performance, to compare the response of different actual stent models when loaded by internal pressure and to collect suggestions for optimizing the device shape and performance. The stent expansion and partial recoil under balloon inflation and deflation were simulated. Results showed the influence of the geometry on the stent behavior: a stent with a low metal-to-artery surface ratio has a higher radial and longitudinal recoil, but a lower dogboning. The thickness influences the stent performance in terms of foreshortening, longitudinal recoil and dogboning.

David (2003) investigated; the pressure was applied as a surface load on the inner surface of the balloon. Pressure load provided the force which caused the dilation of the stent. The displacement and stress distributions over the stent were computed and analysed. The deformation characteristics of the stent and localised stress region under application of internal pressure are presented. Lorenza (2003) explored the advantages of the finite element method (FEM) in order to investigate new generation stent performance in terms of flexibility. Two different FEM models, resembling two new generation intravascular stents, were developed as *Cordis BX-Velocity and Carbostent Sirius coronary stent.*

Bending tests under displacement control in the unexpanded and expanded configuration were carried out. Cordis model showed a higher flexibility. Lower flexibility in the expanded configurations for both models was detected. However this flexibility depends on how the contact takes place between the different parts of the struts. Mcgarry (2004) studied the stent material behaviour using Classical phenomenological plasticity theory (J2 flow theory) and crystal plasticity theory. The *crystal plasticity theory models show closer agreement to published performance data.*

Lally (2004) studied two different types of stent designs as S7 (Medtronic AVE) and the NIR (Boston Scientific) and are tested to study different levels of vascular injury. *S7 stent design causes lower stress to an atherosclerotic vessel with a localized stenotic lesion compared to the slotted tube NIR design. These results correlate with observed clinical restenosis rates, which have found higher restenosis rates in the NIR compared with the S7 stent design.* Wei-Qiang (2004) studied *two types of stents* and *six collocations of stents* and their balloons were modeled. Modelling results showed that the dogboning phenomenon can be eliminated by improving geometry of a stent or/and varying the length of balloon over stent. The above modeled results were further confirmed by following in situ observation. Linxia (2004) investigated the effects of the covering on the mechanical behavior of the covered microstent. Variations in the mechanical properties of the covered microstent such as deployment pressure, elastic recoil, longitudinal shortening due to change in thickness and material properties of the cover have been investigated. Philippe (2005) describe the technology and methodology for the numerical study of nitinol stent through the FEM. Ansys 8.0 software is used. The nitinol is modeled with superelastic law and polyethylene with a yield hardening law. A first simulation determines the final geometry of the laser cut from a small tube. A second simulation examines the behavior of the prosthesis during surgery and over the 4 weeks following the operation. The results demonstrate that a compromise can be reached between limited expansions prior the inflation of the expandable balloon and a significant expansion by creep of the polymer rings. Wei (2006) results show that in the CV model, the vessel was straightened by stenting and a hinge effect can be observed at extremes of the stent. *The maximum tissue prolapse of the CV model was more severe (0.079 mm) than the SV model (0.048 mm); and the minimum lumen area of the CV was decreased (6.10mm2), compared to that of the SV model (6.28mm2)*. Wei (2006) two different stents were considered to show the influence of stent design on the stent–vessel interactions. Results show that the superelastic stents were delivered into the stenotic vessel lumen through the sheath and self-expanded in the internal and common carotid artery. The stent with shorter struts may have better clinical results and the different stent designs can cause different carotid vessel geometry changes. This FEM can provide a convenient way to test and improve biomechanical properties of existing carotid stents and give clues for new nitinol carotid stent designs. Matthieu (2007) in a study determined the unfolding and expansion of the balloon. Different expansion modeling strategies are studied and compared for a new generation balloon expandable coronary stent. The trifolded balloon methodology presented in this paper shows very good qualitative and quantitative agreement with both manufacturer's data and experiments. Therefore, the proposed numerical expansion strategy appears to be a very promising optimization methodology in stent design.

3 CONCLUSIONS

A thorough review of the available literature concerning the stents reveals following conclusions:

- To Study of wall injury using different stents.
- The Phenomenon of Restenosis has to be focused after inserting stents.
- The Interaction between wall of artery and stent has to be studied.

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5 REFERENCES

David Chua, S.N. (2002). “Finite element simulation of stent expansion”, Journal of Material Processing Technology 120, 335-340.

David Chua, S.N. (2003). “Finite element simulation of stent and balloon interaction”, Journal of Materials Processing Technology 143–144, 591–597.

De Beule, Matthieu (2008). “Realistic finite element-based stent design: The impact of balloon folding”, Journal of Biomechanics 41, 383–389.

Dumoulin, C. (2000). “Mechanical behaviour modelling of balloon-expandable stents”, Journal of Biomechanics 33, 1461-1470.

Etave, Frederique (2001). “Mechanical properties of coronary stents determined by using finite element analysis”, Journal of Biomechanics 34, 1065–1075.

Gu, Linxia (2005). “Finite element analysis of covered microstents”, Journal of Biomechanics 38, 1221–1227.

Hui Zhu, (2003). “Comparison of coronary artery dynamics pre- and post-stenting”, Journal of Biomechanics 36, 689–697.

Lally, C. (2005) “Cardiovascular stent design and vessel stresses: a finite element analysis”, Journal of Biomechanics 38, 1574–1581.

Mcgarry, J.P. (2004). “Analysis of the mechanical performance of a cardiovascular stent design based on micromechanical modeling”, Computational Materials Science 31, 421–438.

Migliavacca, Francesco (2002). “Mechanical behavior of coronary stents investigated through the finite element method”, Journal of Biomechanics 35, 803–811.

Petrini, Lorenza (2003). “Numerical Investigation of the intravascular coronary stent flexibility”, Journal of Materials Processing Technology 143–144, 591–597.

Tan, L.B. (2001). “A method for investigating the mechanical properties of intracoronary stents using finite element numerical simulation”, International Journal of Cardiology 78, 51–67.

Theriault, Philippe (2006). “Finite element modeling of a progressively expanding shape memory stent”, Journal of Biomechanics Volume 39, Issue 15, 2837-2844.

Wang, Wei-Qiang (2006). “Analysis of the transient expansion behavior and design optimization of coronary stents by finite element method”, Journal of Biomechanics 39, 21–32.

Wu, Wei (2007). “Delivery and release of nitinol stent in carotid artery and their interactions: A finite element analysis”, Journal of Biomechanics 40, 3034–3040.

Wu, Wei (2007). “Stent expansion in curved vessel and their interactions: A finite element analysis”, Journal of Biomechanics 40, 2580–2585.