ARE ISO-ELASTIC FEMORAL STEMS BENEFICIAL FOR SECONDARY IMPLANT STABILITY IN CEMENTLESS THA?

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Introduction

The use of cementless iso-elastic stems in total hip replacement (THA), for the purpose of reducing stress shielding, has briefly been investigated in the literature in the past, but such stems are generally not used in the clinical practice. This may be due to several reasons such as complication in manufacturing of such devices. However, the advancing of 3D printer technology and laser sintering processes may open up new possibilities for producing stems with highly variable material properties. This could be done by controlling the variation in the porosity of the bulk material in the stem during production. The aim of the present study was to optimize the property distribution of an iso-elastic femoral stem and compare the strain stimulation in the host bone to that of a host bone implanted with a stiff stem.

Materials and Methods

I CT dataset of an "average" femur was created based on statistical model of appearance generated from a database consisting of 130 femurs. The femoral stem geometry was taken from a CAD model database (GrabCAD). The creation of the FE models was carried out in several steps; 1) segmentation in Amira; 2) solid CAD models of stem and bone assembly created in SolidWorks and 3) FE mesh generated in ANSYS Workbench. Loads on the proximal femur were derived from [Heller, 2005] assuming a bodyweight of 800 N. The model was fixed at the distal end. Material properties were assigned to each node of the bone FE model using $E=6.85\rho_{app}^{1.49}$ (GPa) [Morgan, 2003]. The stem was assumed to have the material properties of TiNbZr with varying degrees of porosity [Wang, 2009]. The implant was divided into 6 different parts which were assigned different material properties. Optimization of the property distribution was carried out in Matlab running ANSYS in batch mode. The objective of the optimization was to maximize the volume fraction of bone with equivalent Von Mises strains (ε_{vm}) in the interval 0.1-0.8%, subjected to the constraints $\varepsilon_{vm} < 0.8$ and $\sigma_{vm} < \sigma(PVF)_{fatigue}$ for the stem. σ_{vm} is the Von Mises stress in the stem according to FE simulations and $\sigma(PVF)_{fatigue}$ is the estimated fatigue strength of the stem material as a function of pore volume fraction (PVF) of the bulk material.

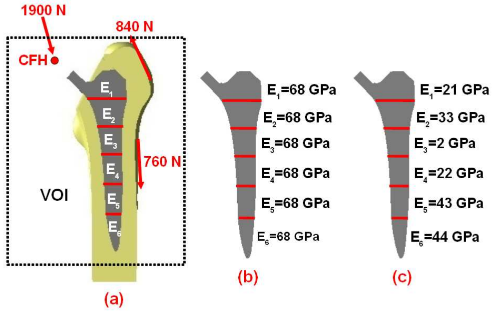

Figure 1: (a) FE model concept. CFH: centre of femoral head. (b) Stem with constant material properties. (c) Stem with best material property distribution according to results of optimum search.

Results and Discussion

Multiple solutions for material property distributions were found in the optimum search that provided improved strain stimulation of the bone, compared to strain stimulus using constant stem properties. The increase in stimulated bone volume, within the volume of interest (VOI), was 51% for the optimum solution compared to the solution with solid TiNbZr.

Conclusions

Our simulation results indicate that iso-elastic stems may provide improved secondary stability of femoral stems in THA.

References

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