THIGHBONE-IMPLANT INTERACTION - TOPOLOGY OPTIMIZATION ANALYSIS

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1. Introduction

In this paper the interaction between the implant and the bone, i.e. the distribution of material when an endoprosthesis modelling construction is introduced into the design domain were numerically analyzed. From the practical point of view, research on the implant/bone interaction is highly important as it aims to minimize the adverse effect of the implant on the bone structure. The topic is discussed in, e.g., [1] where it is proposed to use functionally gradient materials (FGM) for producing implants to avoid problems arising at the contact between the two materials (bone/implant) characterized by different physical properties and the bone resorption problems. In [2] last achievements in bone-implant interactions are discussed, among others porous coated implant bone interfaces. Since generally there is a biomechanical mismatch between the implant and the surrounding tissues, mainly due to the different Young moduli of the two**,** intensive research on the potential use of materials with a gradient structure in bioengineering is underway. This study is similar to [3] where the degradation of the bone in the vicinity of the implant is demonstrated numerically. This is confirmed here.

Minimum compliance approach was adopted to solve considered problem. Earlier tested authors program was used for numerical analysis.

2. Bone-implant modelling

The changes in the structure of the thighbone after the introduction of an implant made of a uniformly dense material were studied in order to determine the effect of the hip joint implant on the structure of the thighbone. Figure 1a shows an exemplary endoprosthesis of the hip joint. The finite elements making up the hip joint endoprosthesis in computations are shown in Fig. 1b.

(a) (b)

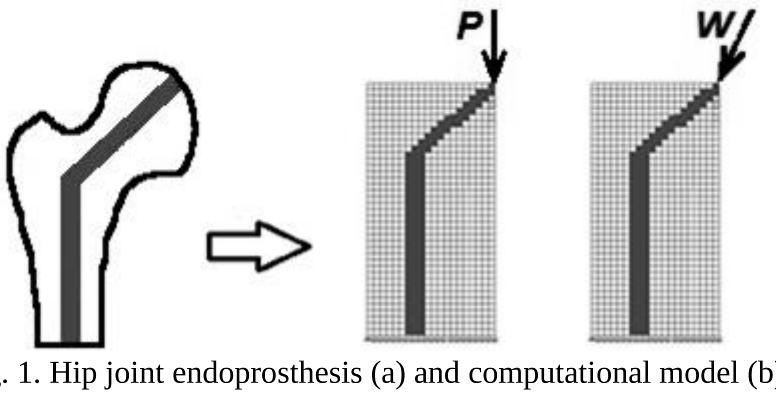

Fig. 1. Hip joint endoprosthesis (a) and computational model (b).

Unit value of W was adopted for computations as a representative loading of the bone. In addition, computations for loading with force P – a concentrated unit force applied vertically to the thighbone's head was performed.

3. Numerical examples

The problem was solved for various values of mass reduction coefficient (α). Figure 2 shows material/voids optimal topologies without implant obtained for P and W forces for various α.

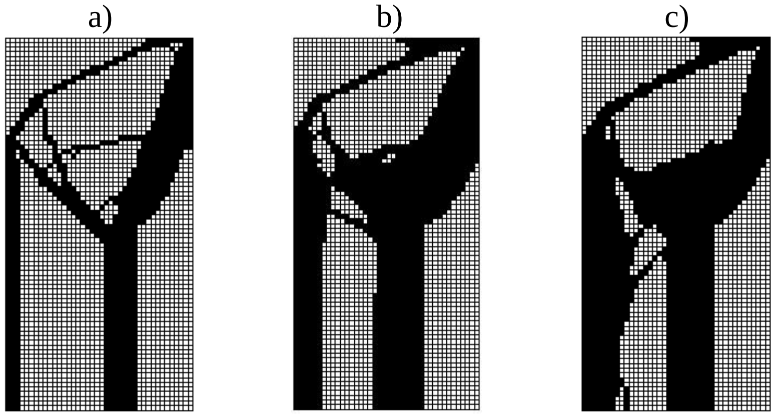

Fig.2. 0/1 topologies for P loading – for $\alpha = 0{,}3$ a) $\alpha = 0{,}5$ b) and for W loading - for $\alpha = 0{,}5$ c)

In Fig. 3 the optimal topologies with implant are shown. The red colour in Fig. 3a was used to highlight the implant shape, in Fig3b and 3c the implant is black and it is the same as in Fig. 3a. The changes in bone structure remodelling after implantation are visible for all cases. As a result of implantation, the areas above the slanting part of the prosthesis (the thighbone head) undergo weakening. Also the cortical bone on the left side is considerably weakened. More material is located on the right side, closer to the force application point. After implantation the structure of the bone changes. Additional horizontal connections, in the form of single bars originating from the implant and extending to the right and to the left towards the cortical bone

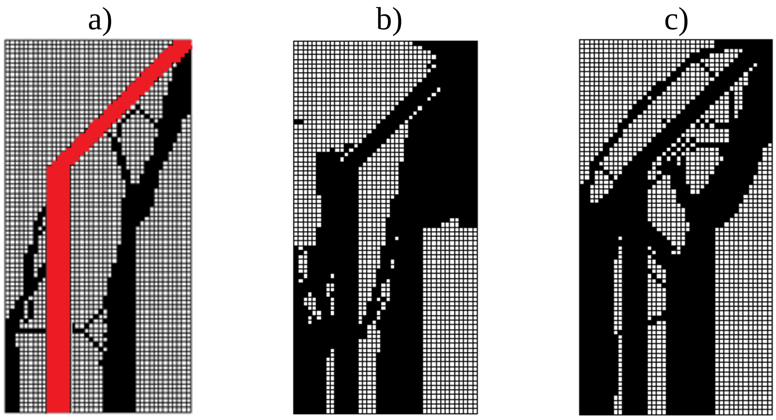

Fig.3. 0/1 topologies with implant for P loading – for $\alpha = 0{,}3$ a) $\alpha = 0{,}5$ b) and for W loading - for $\alpha = 0{,}5$ c).

As a result of the numerical analysis of the model of the thighbone with and without an implant the fact, known from clinical studies, that the bone in the vicinity of the implant undergoes degradation has been numerically confirmed.

4. References

[1] D. Pasini and S.A. Khanoki (2012). Multiscale design and multiobjective optimization of orthopedic hip implants with functionally graded cellular material. *J. Biomech. Eng.* **134**, Issue 3, 031004 (10 pages), http://dx.doi.org/10.1115/1.4006115.

[2] T. Karachalio (ed.), (2014). *Bone-Implant Interface in Orphopedic Surgery, Basic Science to Clinical Applications*, Springer Verlag London.

[3] J. Kerner, R. Huiskes, G.H. van Lenthe, H. Weinans, B. van Rietbergen, C.A. Engh, and A.A. Amis (1999). Correlation between pre-operative periprosthetic bone density and post-operative bone loss in THA can be explained by strain-adaptive remodeling. *Journal of Biomechanics*, **32**, 695-703.