MECHANICS OF IMPLANTS WITH TISSUE INTERACTIONS

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Introduction

Three steps analysis of implant alignment to surrounding tissues were carried out. Basic parameters of bone – implant interaction were estimated (macro: stiffness characteristics, shear strains distribution, bone tissue density distribution; micro: trabecular structures development, trabecular microcracks distribution, bone cells strain distribution). Estimation of each parameter was carried out using by development of numerical tools which allow to control bone tissue changes coming from changes in implant design.

The cognition of the processes on the implant – biosystem border is significant for the proper activity of an implant in tissue environment and for the appropriate selection of surface preparation technology.

The implant – tissue contact surface is a place of interaction between live cells and the surface layer of biomaterial introduced to the organism. On the implant – biosystem border there is an implant surface layer and a thin para-surface layer which plays a key role biomaterial wear out processes.

Biomechanical alignment of implant might be controlled by the proper selection of implant shape and dimensions but also by selection of implant material. Among new generation of metal alloys there are exists those ones, which are characterized by lower stiffness and higher biocompability (Fig. 1).

Taking into consideration new materials, biomechanical characteristics of implant, which comes from implant design should be investigated on the macro level as well as on micro level. That leads into ascertainment that in process of implant design should be considered parameters such major stiffness characteristics but also influence of implant shape and dimension on tissue structures growth and remodeling or even influence of implant on the bone cells activity.

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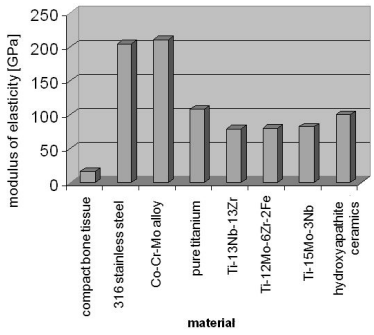

Figure 1: Modulus of elasticity values for typical and new generation metallic alloys used for implant manufacturing.

Numerical and experimental analysis

Proposed analysis consists three steps. First step is analysis of implant mechanical characteristics on the macro level. Investigations of implant stiffness characteristics were carried out using FE models of implant and implant-bone complex. Fig. 2)

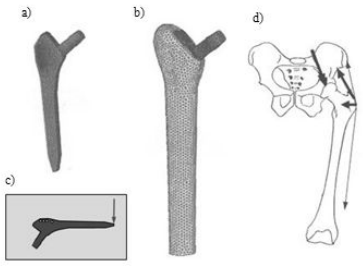

Figure 2: Model of implant (a), model of implant – bone complex (b), model of load used in stiffness characteristic calculations (c) and model of loading used in shear strain distribution analysis (d) .

Second step of analysis consists numerical simulations of bone adaptation processes. It were carried out analysis of changes in bone

density after implantation using Carter model [2] of bone remodeling to estimate tissue behavior on the macro level.

Third step of analysis was analysis of bone cells strain distribution in order to estimate influence of external loading on the bone cells activity. It was assumed that strains on the osteocyte surface is proportional to the mechanical stimulus signal, which controls bone tissue growth and remodeling.

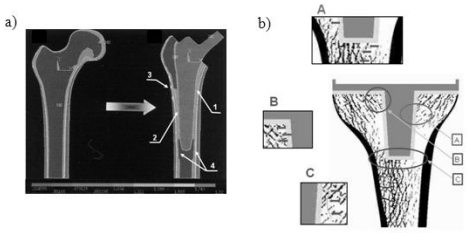

Figure 3: Exemplary results of bone remodeling simulations on macro (a) and (micro (b) level

A condition to be met to obtain osteointegration with an implant is the development of haematoma and its transformation into fibrous tissue. For osteointegration to take place, particular must be maintained, among others these are: appropriate relations of deformation including the avoidance of stresshielding in bone tissue surrounding an implant as well as bioacceptability.

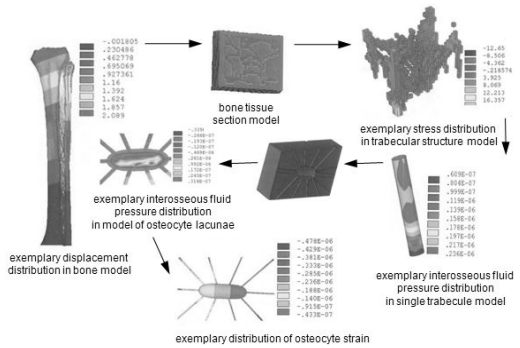

Figure 3: Exemplary results of bone cells strain analysis

The research was conducted on samples of titanium alloy Ti-6Al-4V, paddle and implants of C-shaped bone combinations which were coated with an external layer by zol-gel method.

On the basis of our research a conclusion can be made that the tested layers were characterized with high level of adhesion to the base. Attempts of growing bacterial culture were conducted on the samples.

Conclusion

The purpose of the research was an analysis and assessment of biomechanical and biochemical conditions for proper shaping of an external level and structure of an implant in order to obtain the required osteointegration process.

The main goal of contemporary research is to obtain a proper implant-bone interaction, so that the process of osteointegration is achieved. It has been proved that osteoconduction of the bone cells is surface-dependent and that is why implants' coatings seem to be simply necessary. But to obtain osteointegration some more special conditions, such as avoiding of stress-shielding or the adequate implant-bone strain relations, are needed.

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