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A MULTI-SCALE COMPUTATIONAL MODELING OF CRANIAL IMPLANTS: A COMPARATIVE STUDY

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Summary: Since the 3D printing expanded to medicine, implantology has undergone a huge progress due to possibility of manufacturing patient-specific implants. Thanks to this modern technology, it is possible to achieve almost any implant shape with a very high accuracy. This is particularly advantageous in cranial surgery where implants should meet not only functional but also aesthetic requirements. Any new technology is associated with new challenges. New possibilities in designing and manufacturing of implants also increase expectations for high-level structural analyses of the implants and for better predictions of corresponding stresses and strains. This is one of new challenges for cranial biomechanics.

A valuable tool in biomechanics is the computational modeling based on numerical methods, especially the finite element method (FEM).

The quality of the analysis directly depends on the quality of computational model and on the availability of reliable input data. In case of stress-strain analyses of cranial implants, the input data include information about the subject geometry, material characteristics, loading and boundary conditions. In present study, models of human skull were created based on computed tomography (CT) dataset. Material properties of bone were simulated using two different approaches:

1) Using homogenized linear-isotropic model;

2) Using non-homogeneous, linear-isotropic model based on experimentally-obtained characteristics from previously published studies.

The material characteristics in the second approach were mapped onto the FE model using a special in-house software from μCT dataset utilizing the established correlation between HU, bone tissue density and Young's modulus. The submodeling strategy is used to significantly shorten the calculation times.

The aim of the present study is to introduce our approach to multi-scale modeling of cranial implants and to perform a comparative analysis of relevant biomechanical variables (such as displacements and von Mises stress in the implant and fixation mini-plates and von Mises strains in skull). The main purpose is, however, to demonstrate the differences of the results when computational models of various levels are used.