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TOPOLOGY MULTISCALE OPTIMIZATION OF BONE SCAFFOLDS

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Injuries and diseases of the human skeletal system are an important issue from both medical, biomechanical and economical point of view. Modern medicine and engineering helps significantly reduce the time of treatment and in the case of very advanced degeneration of the tissues and joints of the skeleton, allows for implantation of artificial structures supporting or realizing their natural functions. In order to design more better implants we need to know the state of strain at the micro scale of the bone. Human hip joint is an area of growing number of surgical interventions. The head of the femur, which is a part of the hip joint is built primarily of trabecular bone (spongy bone). On the base of models and results of analyzes the structure of human trabecular bone the methodology for implantation of bone scaffolds adapted to the specific patient is considered in the paper. The optimization of bone scaffold is performed and the structure of bone scaffold that will provide a similar level of strains as in the case of natural bone is searched. Multiscale modelling methods applied to the analysis of human bones can better determine the relationship between the structure, functions and the parameters of tissues and implants at different scales of observation.

The paper is devoted to the geometry optimization of bone scaffolds. The multiscale approach with use of computational homogenization method is used [1,2]. The paper presents a method for scaffolds geometry optimization. The scaffolds material properties needs to be similar to the material properties of the surrounding bone tissue. Comparison of the materials is performed using a computational homogenization method. The averaged orthotropic material properties for bone tissue are determined in the first stage [3]. The cubical specimen of trabecular bone, extracted from the proximal femur bone is used as an example. Basing on the experimental and simulation data, and by using the artificial intelligence methods, bone trabeculas material parameters were determined. The average material parameters for bone specimen are then obtained with use of numerical homogenization method. The objective function of the optimization process is formulated as a norm of the difference between homogenized material parameters of scaffold and bone. The design variables describes the topology of the scaffold. The evolutionary algorithm is used in optimization process. The fitness function of the evolutionary algorithm is equal to the objective function of optimization problem. The evaluation of the objective function value leads to the analysis of multiscale problem. The geometry of representative volume element (RVE) for scaffold [4] is created on the basis of genes values. Then the boundary value problems are solved six times to obtain stress-strain relation with use of the computational homogenization method. The averaged material properties are used in the fitness function value computation. The analyses of scaffolds RVEs and reference bone RVE are performed with use of the finite element method. The one of the obtained result - the microstructure of the bone scaffold is shown in Fig. 1.

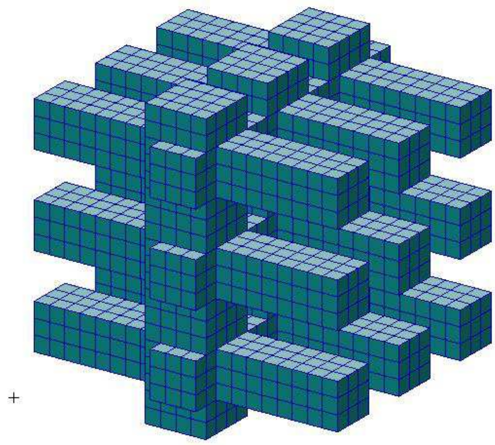

Fig. 1 . The sample of optimized microstructure of bones scaffold

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