THE PROCEDURE FOR GENERATING THE STRUCTURE OF BONE IMPLANT

Jakub Słowiński 1)

1) Institute of Materials Science and Applied Mechanics
Smoluchowskiego 25 str, 50-370 Wrocław, Poland
Corresponding author: jakub.slowinski@pwr.wroc.pl

1. Introduction

The passive part of the human locomotor system - bones, participates in the processes of adaptation to external loads. These processes occur through functional adaptation – called bone remodelling. However, if the value of tensile strength is exceeded, bone tissue is damaged or even destroyed.

Modern orthopedics or bone surgery provides many, often highly complicated ways of treatment. One of them is using bone scaffolds. Bone scaffold is a kind of internal implant used to replace damaged tissue.

There are several ways to prepare structure of these implants, but nowadays we can observe a tendency to prepare customized scaffolds.

In that paper a numerical modelling and optimization procedure will be presented.

2. Materials and methods

In the first step a numerical model of scaffold was developed based on typical structure known from other works [1]. Geometry of that model was generated using beam elements. Every external node (black) of that model was designed as a solid node without possibility of movement. Internal nodes (white) could change position during optimization – Fig. 1. External nodes was the ones which was in contact with bone tissue.

In the next step, during interactive procedure, model of scaffold was virtually implanted in the volume of upper extremity of the tibia bone. After positioning displacements of external nodes was added as input data set to the scaffold. These values was obtained using some other numerical models which was also created during this work [2]. These displacements was added only to external nodes. Internal nodes were free from any loadings. After that step the values of nodal forces was calculated for external nodes. These values were compared to the values which was calculated for appropriate nodes in model of bone without scaffold. The difference between the obtained results was measure of adaptation of scaffold to bone tissue replacement. The lower was the value the better was the adjustment. This value represented the value of adapting the structure to act as a bone substitute.

The last part of calculation was genetic algorithm. In the first step a initial population of 30 models of scaffold were generated with randomly changed positions of internal nodes – Fig. 2.

![Fig. 1: Structure of typical modern beam bone scaffold [1] (left) and numerical model of analysed implant (a cube is the shape of damaged tissue) (right)](image1)

![Fig. 2: Structure of randomly generated bone scaffold](image2)

The calculations described above was performed for each model. Subsequently, all models were segregated (using bubble sort algorithm) according to the calculated value of adaptation – the phenotype value. Then, using the roulette wheel selection of the best-fit...
individuals was carried out [3]. The next step was to create a second generation population in accordance with the process of recombination and mutation. From one pair of selected parents the new one individual was created. The size of new population was the same as the initial population. Each time after the formation of a new generation the calculations were performed again and the process repeated. Change the value of the phenotype shown in the Fig. 3.

![Fig. 3: Plot of phenotype changes during optimization](image)

In the course of the procedure was found the final structure – Fig. 4. Numerical verification confirmed the far better adapted to act as substitute in place of bone loss. The procedure was completed in the thirtieth generation, as further calculations do not lead to a noticeable improvement of certain characteristics of the implant.

The whole procedure of searching for a better matched the structure of the implant takes an average of several hours.

In order to complete it is necessary to know the conditions of biomechanical characteristic of the patient and the place where the implant is implanted.

3. References