CALCULATION OF FEMORAL CORTICAL BONE ELASTICITY MODULUS FROM COMPUTED TOMOGRAPHY SCANS

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Abstract
The results obtained from the finite element analysis, apart from precise geometry, depend on the applied boundary conditions and material properties. The use of patient specific geometries and patient's material properties leads to more accurate results. The aim of this paper was to determine elasticity modulus of a human femoral bone when the bone is considered as an isotropic material. Elasticity modulus for the femoral bone was calculated from a computed tomography images and obtained values showed how the modulus changes along the femoral bone. The images were additionally used to create a patient specific 3D model of the femoral bone. Additionally, the effect of a change in elasticity modulus values was demonstrated by comparison of maximum displacement and von Mises stress obtained from the finite element analyses of the femoral bone model. The numerical simulations showed the influence of the elastic modulus on the displacement and stress values and importance of the appropriate elasticity modulus.

Key words: Computed tomography, Elasticity modulus, Femoral bone, Finite Element Analysis

1. Introduction

The bone tissue elasticity modulus depends on a number of parameters such as age, gender, diseases, etc [1]. The most realistic results of a finite element analysis (FEA) will be obtained, if the applied material properties belong to the person whose model was created for the analysis. Considering that the measurements of elasticity modulus are mostly invasive, it is not possible to easily obtain needed values. A potential solution is to use computed tomography (CT) images in order to determine Young's modulus of elasticity.

2. Materials and Methods

The calculation of Young's modulus of elasticity was based on the correlation of the Hounsfield unit with bone density that was later used to calculate elasticity modulus. After a CT image was imported, the values of each pixel were transformed into Hounsfield units. The transformed values were then used to segment a bone and calculate bone density. The obtained density values were transformed into the modulus of elasticity, based on the empirical relations of tissue density - modulus of elasticity available in the literature [2].

3. Results and Conclusions

Figure 1 shows calculated values of elasticity modules from CT scans. The distribution of calculated values corresponds to the known fact that elasticity modulus is higher in femoral bone shaft and lower in femoral head, neck and distal condyles

Figure 1. Calculated elasticity modulus along femoral bone.

Table 1 shows the comparison of the FEA obtained maximum stress and displacement values using calculated elasticity modulus (13079 MPa) and modulus obtained from literature (16700 MPa) [3]. Percentage difference between these two cases was higher for displacement (17.4 %) compared to stress (1.42 %).

	Calculated modulus	Literature modulus
Maximum stress value [MPa]	41.7	42.3
Maximum displacement value [mm]	0.987	0.841

Table 1. Comparison of obtained results

Although the development of tool for non-invasive assessment of elasticity modulus can be useful for numerical simulations, it is necessary to validate obtained values. The best confirmation of this tool would be to compare values from computational tool and measured values in the same place.

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