POLITECHNIKA ŚLĄSKA

WYDZIAŁ MECHANICZNY TECHNOLOGICZNY

Instytut Mechaniki i Inżynierii Obliczeniowej

Praca doktorska

Wyznaczanie własności mechanicznych tkanki kostnej gąbczastej na podstawie obrazowania mikrotomograficznego

mgr inż. Łukasz Cyganik

Promotor: dr hab. inż. Grzegorz Kokot, prof. nzw. w Pol. Śl.

GLIWICE 2018

Determination of the mechanical properties of trabecular bone tissue based on microcomputed tomography imaging

Summary

The work presents a research on the development of a non-invasive method for the assessment of mechanical properties of trabecular bone based on microtomographic imaging. The method uses a quantitative computer microtomography for determination of the trabecular bone structure and for estimation of the bone mineral density distribution. Then, the distribution of the Young's modulus within the trabecular bone structure is determined by applying an appropriate relationship between the Young's modulus and the bone mineral density. The mechanical properties of trabecular bone obtained in this way can be used to determine the mechanical characteristics of trabecular bone structures using, for example, the finite element method. Despite the many relationships correlating the Young's modulus with bone mineral density available in the literature, no unambiguous tests have been made to indicate the relationship, that is characterized by the highest accuracy in the prediction of mechanical properties of trabecular bone tissue. Therefore, the main problem in the development of a non-invasive method for the assessment of mechanical properties of trabecular bone was the selection of an appropriate relationship between Young's modulus and bone mineral density characterized by high accuracy of mechanical properties prediction.

As part of the research, a new relationship correlating the Young's modulus with bone mineral density was developed. In addition, the accuracy of the mechanical properties prediction of several other relationships between Young’s modulus and bone mineral density available in the literature have been verified. The research included an experimental mechanical tests carried out on 11 cubic trabecular bone specimens with displacement and strain full field measurements using digital image correlation method. In addition, the use of quantitative computer microtomography and the finite element method allowed to carry out the simulations of compression tests on the numerical models of trabecular bone specimens. The mechanical properties of trabecular bone tissue in numerical models were determined using different relationships between the Young's modulus and bone mineral density selected for the study. Comparison of the results obtained from experimental measurements and numerical simulations allowed to determine the accuracy of mechanical properties prediction of trabecular bone tissue for each examined relationship. The highest accuracy was achieved for the new relationship between Young's modulus and bone mineral density proposed by the

author. The use of this relationship in combination with quantitative computer microtomography establishes a new non-invasive method for the assessment of mechanical properties of trabecular bone.