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Stress-Strain Relation for Human Trabecular Bone Based on Nanoindentation Measurements

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Abstract : Nanoindentation or depth-sensing indentation (DSI) technique has proven to be very useful to measure mechanical properties of various tissues at a micro-scale. Bone tissue, both trabecular and cortical one, is one of the most commonly tested tissues by means of DSI. Most often such tests on bone samples are carried out to compare the mechanical properties of lamellar and interlamellar bone, osteonal bone as well as compact and cancellous bone. In the paper, a relation between stress and strain for human trabecular bone is presented. The relation is based on the results of nanoindentation tests. The formulation of a constitutive model for human trabecular bone is based on nanoindentation tests. In the study, the approach proposed by Olivier-Pharr is adapted. The tests were carried out on samples of trabecular tissue extracted from human femoral heads. The heads were harvested during surgeries of artificial hip joint implantation. Before samples preparation, the heads were kept in 95% alcohol in temperature 4 Celsius degrees. The cubic samples cut out of the heads were stored in the same conditions. The dimensions of the specimens were 25 mm x 25 mm x 20 mm. The number of 20 samples have been tested. The age range of donors was between 56 and 83 years old. The tests were conducted with the indenter spherical tip of the diameter 0.200 mm. The maximum load was P = 500 mN and the loading rate 500 mN/min. The data obtained from the DSI tests allows one only to determine bone behoviour in terms of nanoindentation force vs. nanoindentation depth. However, it is more interesting and useful to know the characteristics of trabecular bone in the stress-strain domain. This allows one to simulate trabecular bone behaviour in a more realistic way. The stress-strain curves obtained in the study show relation between the age and the mechanical behaviour of trabecular bone. It was also observed that the bone matrix of trabecular tissue indicates an ability of energy absorption.

Keywords : constitutive model, mechanical behaviour, nanoindentation, trabecular bone
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