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Microstructural Mechanical Properties of Human Trabecular Bone Based on Nanoindentation Test

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Abstract : Depth-sensing indentation (DSI) or nanoindentation is becoming a more and more popular method of measuring mechanical properties of various materials and tissues at a micro-scale. This technique allows measurements without complicated sample preparation procedures which makes this method very useful. As a result of measurement force and displacement of the intender are obtained. It is also possible to determine three measures of hardness i.e. Martens hardness (HM), nanohardness (HIT), Vickers hardness (HV) and Young modulus EIT. In this work trabecular bone mechanical properties were investigated. The bone samples were harvested from human femoral heads during hip replacement surgery. Patients were of different age, sexes and stages of tissue degeneration caused by osteoarthritis. The specimens were divided into three groups. Each group contained samples harvested from patients of different range of age. All samples were investigated with the same measurement conditions. The maximum load was Pmax=500 mN and the loading rate was 500 mN/min. The tests were held without hold at the peak force. The tests were conducted with indenter Vickers tip and spherical tip of the diameter 0.2 mm. Each trabecular bone sample was tested 7 times in a close area of the same trabecula. The measured loading P as a function of indentation depth allowed to obtain hysteresis loop and HM, HIT, HV, EIT. Results for arbitrarily chosen sample are HM=289.95 ± 42.31 MPa, HIT=430.75 ± 45.37 MPa, HV=40.66 ± 4.28 Vickers, EIT=7.37 ± 1.84 GPa for Vickers tip and HM=115.19 ± 15.03 MPa, HIT=165.80 ± 19.30 MPa, HV=16.90 ± 1.97 Vickers, EIT=5.30 ± 1.31 GPa for spherical tip. Results of nanoindentation tests show that this method is very useful and is perfect for obtaining mechanical properties of trabecular bone. Estimated values of elastic modulus are similar. The differences between hardness are significant but it is a result of using two different types of tips. However, it has to be emphasised that the differences in the values of elastic modulus and hardness result from different testing protocols, anisotropy and asymmetry of the micro-samples and the hydration of bone.

Keywords : human bone, mechanical properties, nano hardness nanoindentation, trabecular bone
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