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Research paper

Respective roles of organic and mineral components of human cortical bone matrix in micromechanical behavior: An instrumented indentation study

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ABSTRACT

Bone is a multiscale composite material made of both a type I collagen matrix and a poorly crystalline apatite mineral phase. Due to remodeling activity, cortical bone is made of Bone Structural Units (BSUs) called osteons. Since osteon represents a fundamental level of structural hierarchy, it is important to investigate the relationship between mechanical behavior and tissue composition at this scale for a better understanding of the mechanisms of bone fragility. The aim of this study is to analyze the links between ultrastructural properties and the mechanical behavior of bone tissue at the scale of osteon.

Iliac bone biopsies were taken from untreated postmenopausal osteoporotic women, embedded, sectioned and microradiographed to assess the degree of mineralization of bone (DMB). On each section, BSUs of known DMB were indented with relatively high load (~500 mN) to determine local elastic modulus (E), contact hardness (H_c) and true hardness (H) of several bone lamellae. Crystallinity and collagen maturity were measured by Fourier Transform InfraRed Microspectroscopy (FTIRM) on the same BSUs. Inter-relationships between mechanical properties and ultrastructural components were analyzed using multiple regression analysis.

This study showed that elastic deformation was only explained by DMB whereas plastic deformation was more correlated with collagen maturity. Contact hardness, reflecting both elastic and plastic behaviors, was correlated with both DMB and collagen maturity. No relationship was found between crystallinity and mechanical properties at the osteon level.

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