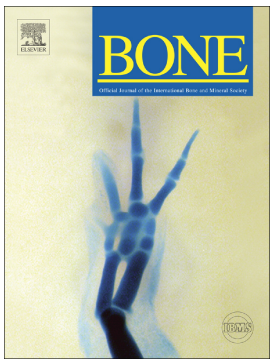

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Ali Hamed Alomari, Marie-Luise Wille, Christian M. Langton

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Bone volume fraction and structural parameters for estimation of mechanical stiffness and failure load of human cancellous bone samples; in-vitro comparison of ultrasound transit time spectroscopy and X-ray μCT

Ali Hamed Alomari[1,2], Marie-Luise Wille[1] and Christian M Langton[1,3]

[1] Science & Engineering Faculty and Institute of Health & Biomedical Innovation, Queensland University of Technology, Brisbane, QLD, Australia

[2] The University College in Al-Qunfudah, Umm Al-Qura University, Saudi Arabia

[3] Laboratory of Ultrasonic Electronics, Doshisha University, Kyotanabe, Japan

Abstract

Conventional mechanical testing is the 'gold standard' for assessing the stiffness (N mm^{-1}) and strength (MPa) of bone, although it is not applicable in-vivo since it is inherently invasive and destructive. The mechanical integrity of a bone is determined by its quantity and quality; being related primarily to bone density and structure respectively. Several non-destructive, non-invasive, in-vivo techniques have been developed and clinically implemented to estimate bone density, both areal (dual-energy X-ray absorptiometry (DXA)) and volumetric (quantitative computed tomography (QCT)). Quantitative ultrasound (QUS) parameters of velocity and attenuation are dependent upon both bone quantity and bone quality, although it has not been possible to date to transpose one particular QUS parameter into separate estimates of quantity and quality. It has recently been shown that ultrasound transit time spectroscopy (UTTS) may provide an accurate estimate of bone density and hence quantity. We hypothesised that UTTS also has the potential to provide an estimate of bone structure and hence quality. In this in-vitro study, 16 human femoral bone samples were tested utilising three techniques; UTTS, micro computed tomography (μCT), and mechanical testing. UTTS was utilised to estimate bone volume fraction (BV/TV) and two novel structural parameters, inter-quartile range of the derived transit time (UTTS-IQR) and the transit time of maximum proportion of sonic-rays (TTMP). μCT was utilised to derive BV/TV along with several bone structure parameters. A destructive mechanical test was utilised to measure the stiffness and strength (failure load) of the bone samples. BV/TV was