15th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering
and
3rd Conference on Imaging and Visualization
CMBBE 2018
P. R. Fernandes and J. M. Tavares (Editors)

Abstract ID-43

DEVELOPMENT OF A VALIDATED GLENOID TRABECULAR DENSITY-MODULUS RELATIONSHIP

Nikolas Knowles, G Daniel G Langohr, Mohammadreza Faieghi, Andrew Nelson, Louis Ferreira

UWO, Canada
nknowle@uwo.ca, dan.langohr@gmail.com, mfaieghi@westerneng.ca, anelson@uwo.ca, Louis.Ferreira@sjhc.london.on.ca

Keywords: Glenoid, Trabecular Bone, Mechanical Properties, Density-Modulus

Summary: INTRODUCTION: Subject-specific finite element (FE) models are an valuable tool in biomechanics research. Highly correlated relationships exist between CT intensity and bones mechanical properties. These relationships depend on bone architecture and mineralization, and are therefore site-specific. A validated density-modulus relationship does not exist for the glenoid, potentially limiting the accuracy of these FE studies. As such, the objective of this study was to develop a validated density-modulus relationship specific to the glenoid.
METHODS: Fourteen cadaveric scapulae (7 male, 7 female) were QCT scanned (0.625 mm isotropic voxels), and micro-CT scanned (0.032 mm isotropic voxels). Direct conversion to eight-node brick elements created micro-FE models from 98 virtual 'cores.' Apparent modulus (Eapp) was determined by compressively loading each core to 0.5% strain. Co-registered QCT-FE models were applied one of three density-modulus equations to map heterogeneous material properties to the QCT-FE models. Equation 1 used ordinary least squares regression power fit. Equation 2 was identical, but passed through minimum and maximum values of 0 and 20 GPa, respectively. Equation 3 was a power fit with coefficients derived from log-transformed data. Apparent strain energy density (SEDapp) between micro-FE and QCT-FE models were used as validation. To account for more samples than donors, restricted maximum likelihood estimation (REML) linear fits compared micro-FE SEDapp and QCT-FE SEDapp for each equation.
RESULTS: The REML linear fits showed high correlations for all three equations: equation 1 (R2 = 0.940; QCT-FE SEDapp = 0.862Micro-FE SEDapp + 0.0026), equation 2 (R2 = 0.945; QCT-FE SEDapp = 0.753Micro-FE SEDapp + 0.0048), equation 3 (R2 = 0.945; QCT-FE SEDapp = 0.748Micro-FE SEDapp + 0.0045). Although equations 2 and 3 had slightly higher R2 values, less variation of the residuals occurred with equation 1, and the linear fit equation had a slope which was closer to the ideal value of 1.
CONCLUSION: This study presented a validated density-modulus relationship of the glenoid, with the potential to greatly improve accuracy in biomechanical studies of the shoulder derived from clinical-CT images. A glenoid-specific density-modulus relationship accounting for trabecular bone architecture is essential to properly model the load transfer.