UNIVERSITÄT ZU LÜBECK

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Program: Biomedical Engineering

Master's Thesis

Title: Validation of an Optical Measurement Procedure for Determination of Anisotropic Shear Parameters in Cancellous and Cortical Human Femoral Bone

Summary: Increasing demand for patient specific bone modeling requires a generation of FE models incorporating the patient's individual mechanical properties. The anisotropic properties of bone therefore necessitate the acquisition of 9 independent mechanical parameters, 3 of which are shear moduli for 3 spatial orientations at different anatomic sites. Cancellous and cortical bone is present in the anatomy of femoral bone. Both types have to be investigated separately due to diverse mechanical tissue properties. Specimen size is dictated by the anatomic boundaries. A new measurement principle and an evaluation method have to be developed and validated for determination of shear modulus in specimens of similar properties and size. For this purpose 36 specimens, 24 from 12.5pcf polyurethane (PU) foam, mimicking trabecular bone and 12 from epoxy fiber composite (EFC), representing cortical bone tissue, have been prepared for torsional testing. To ensure the fulfillment of the applied continuum model assumption, two different sizes of PU foam specimens were prepared and tested. Shear modulus was determined in cyclic testing on a torsion machine using videoextensometry. Ultimate shear strength was measured in quasi static testing on the same test apparatus. For validation of the procedure, results were compared with expected values, calculated from regression of a model describing the structural density dependent properties of PU foam. The expected shear modulus was calculated with 38.3MPa. Experimentally determined shear modulus was significantly equal at 38.9$\pm$2.1MPa. The standard deviation (Std. Dev.) of the small sized PU sample was notably larger than in the large samples. Additionally, significant differences were found for shear properties in specimens of different spatial orientation. No significant findings were detected in the EFC test samples. Measurement quality was found to be lower than in PU samples. A finite element analysis (FEA) was performed to exclude violation of the continuum criteria due to the specimen geometry. The optical measurement procedure and the testing machine were successfully validated for the measurement of shear modulus in general. However, the experiments involving specimen of the required target size for cortical bone, showed lower quality and unacceptable scattering of the results. The experiments showed that trabecular bone specimen of the required size cannot be tested with this measurement technique, due to limitations of the continuum assumption, which could not be overcome in the experiments. The FEA showed that the assumption of continuum is valid for the specimen geometry. The measurement principle and evaluation process as such were validated successfully. Further improvements are necessary regarding the measurement of bone tissue using target size specimens.

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