Material Properties of Glenoid Cancellous Bone

G. Poort and F. van Keulen
Structural Optimization and Computational Mechanics Group
Faculty of Mechanical Engineering
Delft University of Technology
Mekelweg 2, 2628 CD Delft, The Netherlands
Phone: +31 (0)15 278 35 22, E-mail: G.Poort@wbmt.tudelft.nl

Introduction

In Total Shoulder Arthroplasty (TSA) both the humeral head and the glenoid are replaced. TSA is applied to shoulders suffering from degenerative joint disease, osteoarthritis, or rheumatoid arthritis. A complication that occurs frequently is loosening of the glenoid prosthesis. Revision of the prosthesis is difficult since not much bone is available. Hence the design and fixation technique of the prosthesis are crucial for the performance of TSA.

Objective

The objective of the current research is to obtain the material properties of the cancellous bone in the glenoid. Cancellous bone (Fig. 1) is a porous material with spatially varying volume fraction and stiffness. Relations between volume fraction and stiffness are sought, to be able to predict the material properties based on the apparent density of the bone. It is assumed that the morphology of cancellous bone in the glenoid is the same for different individuals.

Methods

The 3D cancellous bone structure was obtained from two glenoids by micro CT-scanning. The apparent material properties of the cancellous bone at a certain position were determined by averaging the properties of a 5x5x5mm cube surrounding that position [1]. As cancellous bone has orthotropic symmetries, also the orthotropic directions were obtained. This procedure was repeated at every 1mm in all directions. Relations between volume fraction and stiffness were obtained using nonlinear regression.

Results

The following relations between the components of the stiffness tensor ($C_{ij}$ (MPa)) and the volume fraction ($\phi$ (-)) are found

\[
C_{11} = 4822\phi^{1.27} \quad C_{12} = 1389\phi^{1.43} \quad C_{13} = 1236\phi^{1.49} \\
C_{22} = 6584\phi^{1.75} \quad C_{23} = 1389\phi^{1.52} \quad C_{33} = 5339\phi^{1.80} \\
C_{44} = 2221\phi^{1.94} \quad C_{55} = 1651\phi^{1.62} \quad C_{66} = 1795\phi^{1.49}
\]

The orthotropic directions are shown for a part of one glenoid (Fig. 2).

Discussion

The proposed method provides good insight in the relations between volume fraction and stiffness. The stiffest orthotropic direction is perpendicular to the joint surface. In the center of the glenoid the bone is transverse isotropic, which gives less pronounced 2-2 and 3-3 directions. This study only includes healthy bone. Future work will also include results of diseased bone.

References