EFFECTS OF LABRUM THICKNESS AND MODULUS ON GLENOHUMERAL CAPSULE AND LABRUM STRAINS

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INTRODUCTION

The shoulder is the most often dislocated joint in the body, and 80% of the dislocations occur in the anterior direction. The primary regions of the glenohumeral capsule that provide anterior stability in abduction and external rotation are the Anterior (AB-IGHL) and Posterior (PB-IGHL) Bands of the Inferior Glenohumeral Ligament, and the Axillary Pouch (AP). Previously, we developed and validated a subject-specific finite element model of the glenohumeral capsule (Moore, 2006). The model did not explicitly represent the labrum, which serves as an insertion site for the capsule (Eberly, 2002) and deepens the glenoid socket. The model predicted an area of high strain concentration near the insertion of the AP to the glenoid during a simulated diagnostic exam (Fig. 1, left). However, labrum strains were not validated experimentally and the effects of the labrum on capsule mid-tissue strains are unknown. The objective of this study was to investigate the effects of labrum thickness and modulus on mid-tissue and labrum strains using a finite element model of the glenohumeral capsule.

METHODS

Our previously validated finite element model of the glenohumeral capsule was modified to explicitly include the labrum. The labrum utilized similar shell elements and constitutive model as the capsule. A baseline model was created with labrum moduli equal to the corresponding capsule region (i.e. 2.05, 2.73, 4.92, 2.12, and 2.12 MPa for the AB-IGHL, PB-IGHL, AP, antero-superior, and posterior regions, respectively), and a thickness set to the capsule thickness of 2.0 mm (Fig 1, left). A previous study (Howell, 1989) was used to assign the labrum of the baseline model a depth of ~3.0 mm (dimension from glenoid to capsule). As per our validation studies, the models were driven by kinematics that simulate a simple translation test for anterior instability: a 25 N anterior load was applied to the joint at 60° of glenohumeral abduction and 60° of external rotation.

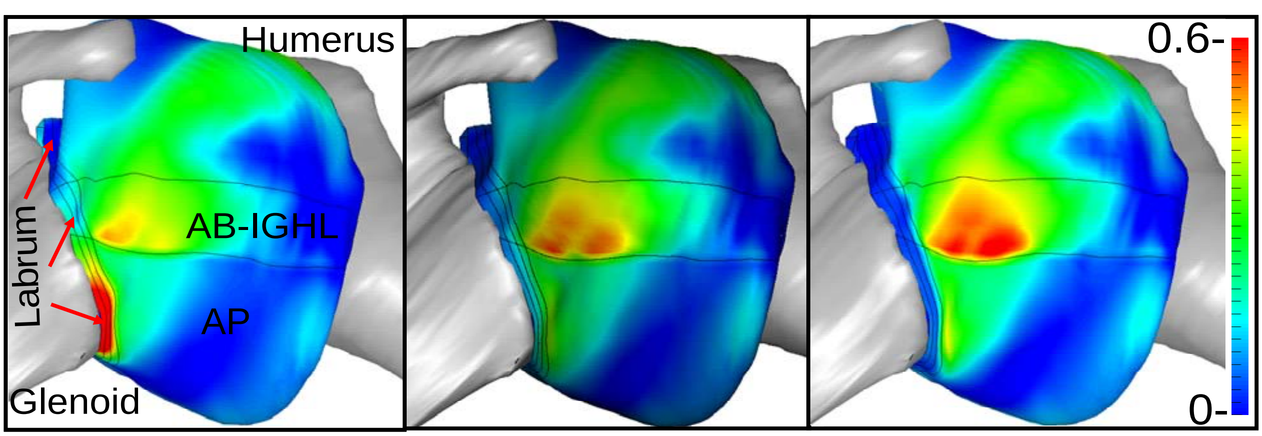

Figure 1. Left) Nominal model. Middle) Model with 6 mm thick labrum. Right) 5X modulus model.

Four models were created for a labrum thickness sensitivity study. Inspection of cadaveric samples demonstrated that the labrum tapers from glenoid to capsule, so the thickness was tapered from 3.0, 4.0, 5.0, and 6.0 mm, respectively, down to 2.0 mm. These thickness values were based on published data (Carey, 2000).

Based on an animal study (Ferguson, 2001), the labrum modulus was varied with respect to its corresponding capsule region modulus. Three models were created for the labrum modulus sensitivity study, with labrum moduli 50%, 2X, and 5X higher than the respective capsule region moduli (with nominal model thickness).

Average regional Green-Lagrange 1st principal strains from the described models were calculated for the mid-tissue regions that were previously used to validate the capsule model. Qualitative assessment of labrum strains was also conducted for each model.

RESULTS

Stiffening the labrum by increasing the thickness or the modulus slightly increased mid-tissue strains, but substantially decreased labrum strains (Fig. 1). The models that had labrum thicknesses of 3.0, 4.0, 5.0, and 6.0 mm had average capsule mid-tissue strain increases of 2, 3, 3, and 4%, respectively. Increasing the labrum modulus by 50%, twice, and five times increased capsule mid-tissue strains an average of 3, 4, and 5%, respectively. Except for the model with a 6 mm thick labrum, all of the average mid-tissue strain increases due to thickening the labrum were within the repeatability of our experimental strain measurements (±3.5%). Increasing the labrum modulus had a slightly greater effect with the 2X and 5X moduli models causing increases in average mid-tissue strains larger than the experimental repeatability. The mid-tissue strain increases were largest near the labrum for both methods of increasing the labrum stiffness.

DISCUSSION

The results of this study demonstrate that increased labrum stiffness, either through increased thickness or modulus, has a larger effect on labrum strains than on capsule mid-tissue strains. Tapering the labrum from its thickest point at the glenoid to its thinnest point where it connects to the capsule, was supported by the cadaver's anatomy and seems more realistic than the large stiffness gradient caused by increasing the entire labrum modulus. Since the labrum acts as an interface between the relatively soft capsule and bone, the labrum could stiffen from capsule to glenoid to decrease stress risers at the interface. This construct stiffening probably occurs through both an increase in modulus and thickness and further research is needed to ascertain exactly how these parameters change throughout the labrum.

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