ALL THREE REGIONS OF THE INFERIOR GLENOHUMERAL LIGAMENT CONTRIBUTE TO ANTERIOR STABLITY

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INTRODUCTION

The anterior-inferior region of the inferior glenohumeral ligament (IGHL), termed the anterior band (AB), is the primary static stabilizer to anterior translation of the humeral head with the arm abducted.[1] Clinical exams evaluate the integrity of this capsular region. However, recent studies have indicated that the capsule functions as a continuous entity.[2,3] Therefore, other regions of the IGHL (axillary pouch and posterior band (PB)) may contribute to stability. The objective of this study was to quantify strain and force distributions in all three regions of the IGHL during a simulated clinical exam. These analyses were performed using a finite element (FE) model and reaction forces were used to validate the FE model. It was hypothesized that all three IGHL regions are subjected to substantial strains and forces during the simulated clinical exam.

METHODS

Experimental kinematics were obtained for a shoulder specimen (F, 64 yrs.) during a simulated clinical exam. Sensors for a 6 DOF magnetic tracking system were attached to the scapula and humerus while 13.4 N was applied to each rotator cuff tendon. Registration blocks were affixed to the scapula and humerus to allow co-registration of kinematic and CT datasets. A third sensor, attached to a stylus, was used to establish coordinate systems for the humerus, scapula and registration blocks to determine the relative motion of the registration blocks. A clinician oriented the humerus at 60º of glenohumeral abduction, 0º of flexion/extension, and applied an anterior load at 0º and 60° of external rotation to simulate a simple translation test.

A subject-specific FE model was constructed and analyzed using our published methods [4]. Plastic markers (6x6 grid, 1.6 mm diameter) were affixed to the regions of the IGHL and the joint position corresponding to the least marker movement between 0.7 KPa and 3.8 KPa was determined. [3] A reference configuration was established in this joint position by inflating the capsule to 1 KPa while the CT data was acquired. The surfaces of the scapula, humerus, IGHL regions, articular cartilage, and registration block were extracted from the CT data. The bone surfaces were represented using rigid shell elements, while shell and hexahedral elements were used to represent the IGHL regions and cartilage, respectively. The kinematics of the registration blocks were used to prescribe the motion of the bones in the FE model. Rigid node sets were used to attach the IGHL regions to the scapula and humerus. Contact and load transfer between the IGHL regions and articular surface of the humeral head was enforced using the penalty method. The IGHL regions were represented as isotropic hypoelastic and material coefficients for the constitutive model were obtained based on our previous experimental studies. [5] The NIKED FE code was used for all analyses. Each capsular region was divided equally into thirds: proximal; mid; and distal with respect to the glenoid and average 1st principal strains were calculated for each region (Figure 1). Insertion site forces were determined at the glenoid for each structure. The effects of region (AB-IGHL, pouch, PB-IGHL) and anatomical location (proximal mid, distal) on 1st principal strain were assessed at each external rotation angle using a 2-way ANOVA with significance set at $p<0.05$.

RESULTS

A significant effect of region and anatomical location on the 1st principal strain was found at both 0° and 60° ($p<0.001$ in all cases). At both 0° and 60° of external rotation and maximum anterior translation, the PB-IGHL (5.3±4.9% and 9.5±7.0%, respectively) and proximal third of the axillary pouch (5.8±5.7% and 10.0±6.7%, respectively) experienced their greatest average strain near the glenoid. (Figure 2) In contrast, strains in the AB-IGHL near the glenoid were relatively low. Instead, the largest average strains for the AB-IGHL were located at the humeral insertion. The mid third of the axillary pouch, AB-IGHL, and PB-IGHL underwent small strains during the simulated clinical exam with the greatest being in the PB-IGHL (6.8±1.9%).

The highest reaction forces occurred in the axillary pouch at both 0° and 60°. The reaction forces for the axillary pouch, AB-IGHL, and PB-IGHL at the glenoid for 60° of external rotation (25N, 4N, and 11N, respectively) and maximum anterior translation were predominantly greater than that at 0° of external rotation (16N, 5N, and 9N, respectively) and maximum anterior translation. The reaction force for the three regions combined was 14N and 23N, respectively.

DISCUSSION

The predicted strains in the regions of the IGHL support the hypothesis that all three regions of the IGHL experience substantial strain and load during a simulated clinical exam. This was true at both 0° and 60° of external rotation; however, the predicted strains at 60° were larger than those predicted for 0° of external rotation. Our results are consistent with the physical arrangement of the IGHL with respect to the direction of applied load – the IGHL is primarily in a plane that is parallel to the applied load, resulting in a shear deformation with highest strains at the corners (proximal PB-IGHL and distal AB-IGHL). However, the largest force contributions were from the axillary pouch.

Based on vector addition of reaction forces, the clinician applied a minimum of 14N at 0° of external rotation. A previous study [2] determined that the in-situ force in the AB-IGHL was approximately 18N at 0° of external rotation under an 89N anterior load. The predicted reaction force at the glenoid (14 N) is in good agreement with the experimental value. The magnitude of the predicted strains compare well to a previous experimental study that quantified strain in the antero-inferior capsule (mean principal strain: 14%) during constrained joint motion.[3] However, locations of maximum strain were different, which may be due to the interactions between the capsular regions that were not modeled. Therefore, future studies should model the entire glenohumeral capsule to accommodate interactions between the IGHL and the rest of the capsule.

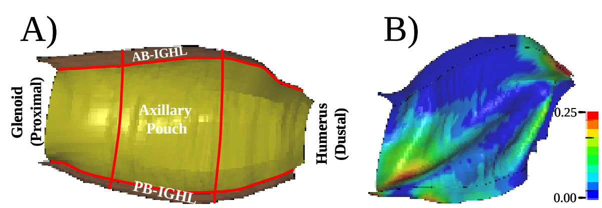

Figure 1: A) Regions of IGHL B) Fringe plot of 1st principal strain distribution at 60° of external rotation and max anterior translation.

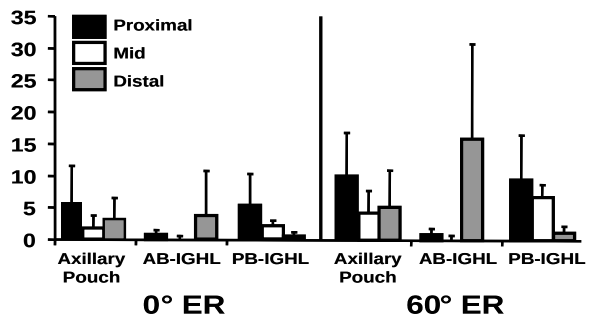

Figure 2: Regional strains in the axillary pouch, AB-IGHL, and PB-IGHL in their proximal, mid, and distal sections. (mean±SD)

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