J Shoulder Elbow Surg (2014) 23, 888-894

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Effect of Bankart repair on the loss of range of motion and the instability of the shoulder joint for recurrent anterior shoulder dislocation

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Background: Bankart repair postoperative complications include loss of shoulder motion and shoulder instability. The primary reason that postoperative complications develop may be excessive imbrication of the anterior band of the inferior glenohumeral ligament (AIGHL) or inadequate repair position. The purpose of this study was to quantitatively evaluate the influence of inadequate repair by computer simulation for a normal shoulder joint.
Methods: Magnetic resonance images of 10 normal shoulder joints were acquired for 7 positions every 30° from the maximum internal rotation to the maximum external rotation with the arm abducted at 90°. The shortest 3-dimensional path of the AIGHL in each rotational orientation was calculated. We used computer simulations to anticipate the loss of motion and instability by changing the AIGHL length and insertion sites on the glenoid.
Results: The AIGHL length measured 50 ± 5 mm at the maximum external shoulder rotation. AIGHL shortening by 3, 6, and 9 mm made the angle of maximum external rotation 80°, 68°, and 54°, respectively. A superior deviation of 3, 6, and 9 mm on the glenoid insertion resulted in a maximum external rotation angle of 85°, 79°, and 77°. An inferior deviation of 3, 6, and 9 mm produced humeral head translation of 1.7, 2.9, and 3.6 mm.
Conclusion: Simulation of both excessive imbrication and deviation of the insertion position led to quantitative prediction of the resulting loss of motion and instability. These findings will be useful for anticipating complications after Bankart repair.
Level of evidence: Basic Science Study, Computer Modeling, Imaging.

Keywords: Shoulder; in vivo; 3-dimensional kinematics; Bankart repair; anterior band of the inferior glenohumeral ligament; simulation

This study was conducted as an institutional committee–approved study (No. 09157-2).

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Traumatic recurrent anterior shoulder dislocation is thought to be due to the Bankart lesion, in which the anterior and anteroinferior glenoid labrum is detached from the glenoid.[1,2] Speer et al[22] reported that the simulated Bankart lesion resulted in selected increases in humeral

1058-2746/$ - see front matter © 2014 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2013.09.004

head anterior translation from the glenoid at 0°, 45°, and 90° of shoulder elevation. Turkel et al[23] described the dislocation of all shoulders at 45° and 90° of elevation when the anterior band of the inferior glenohumeral ligament (AIGHL) was cut. They concluded that glenoid labrum detachment from the glenoid resulted in subsequent anterior humerus dislocation. Mizuno et al[19] reported that an isolated Bankart lesion was present in 84.5% of 303 recurrent shoulder dislocations and that the labral detachment from the glenoid was also present in a majority of recurrent shoulder dislocations.

Bankart repair is often performed to repair labral injury after shoulder dislocation. It is important that the Bankart lesion be repaired adequately. Excessive surgical imbrication of the anteroinferior capsule including the AIGHL results in loss of shoulder motion.[20] Instability and loss of motion may also occur when the repair is performed in an inadequate position.[4] Little has been reported on objective evaluation of motion loss due to excessive imbrication as well as instability due to a Bankart repair glenoid insertion site deviation.

There are many published reports of in vivo 3-dimensional kinematics analysis using systems developed at our institution.[6,10-12,18,21,24] We are able to evaluate 3-dimensional joint kinematics with magnetic resonance imaging (MRI) in multiple positions. The advantage to this approach is the analysis of joint kinematics in the living under physiologic conditions, unlike cadaver studies. We studied the effects of the amount of imbrication and the deviation of the Bankart repair position. The purpose of this study was to investigate shoulder joint loss of motion and instability by changing the amount of AIGHL imbrication or insertion position with computer simulation for a normal shoulder joint.

Materials and methods

This is a study designed to quantify Bankart repair postoperative complications. We evaluated the loss of external rotation and shoulder translation by changing the ligament length and the ligament insertion site with computer simulation.

Subjects

The right shoulders of 10 healthy volunteers (1 man and 9 women; age range, 22-32 years; mean age, 27.8 years) were examined. All shoulders were asymptomatic and had no history of injury and no clinical sign of disease, such as laxity or impingement sign.

Image acquisition for 3-dimensional MRI

Three-dimensional magnetic resonance images were acquired by use of a wide-gantry open MRI scanner (1.5 T MAGNETOM Espree, Siemens, Erlangen, Germany) with an open-bore system (internal bore, 70 cm; length, 125 cm). MRI scanning was performed with the 3-dimensional FLASH method (repetition time, 12 ms; echo time, 5.8 ms; flip angle, 20°; thickness, 0.8 mm; field

Figure 1 Images were acquired by 3-dimensional magnetic resonance imaging. We created a special device designed to allow free movement of the scapula while maintaining a comfortable posture. We scanned at 30° external rotation with the arm abducted to 90°.

of view, 240 × 240 mm^2; 452 × 512 matrix; scan time of 5 m 25 s). Each subject was examined in the supine position with the same equipment as was used in our previous study[12] (Fig. 1). MRI was performed in 7 isometric positions: maximum internal rotation (IR), IR 60°, IR 30°, neutral rotation, external rotation (ER) 30°, ER 60° and maximum ER with the arm abducted at 90°.

Segmentation and creation of a 3-dimensional bone surface model

All images were digitized by a computer with 3-dimensional images of the shoulder reconstructed with use of the Virtual Place M software (AZE, Tokyo, Japan), developed at our institution. Contours of the humerus and scapula were automatically segmented from the magnetic resonance volume images in the neutral rotational position, and the contours were then manually modified, including the cortical bones. An individual 3-dimensional surface bone model was reconstructed from the magnetic resonance image segmented area by use of the marching cubes algorithm for each subject.[13] The surface bone model was visualized with original software based on the Visualization Toolkit (Kitware, Clifton Park, NY, USA). There were variations in bone size among individuals. We scaled the bone models up or down with a computer to normalize all subjects to the same bone size.[24] The accuracy of this method has been determined to be 0.04 mm in translation and 0.82° in rotation.[6]

Image matching (voxel-based registration)

The voxel-based registration technique is a method for superimposing images by minimizing the sum of squared intensity differences for segmented voxels.[8] Segmented humerus and scapula at the neutral rotational position were superimposed on the same bones in images of other positions by this method. Transformation matrices from the neutral rotational position to other positions were calculated for each bone in the global coordinate system of the MRI scanner. Six degrees of freedom of in vivo bone kinematics at the shoulder joint could be respectively analyzed by this method. In our previous validation study, mean