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ORIGINAL ARTICLE

Biomechanical comparison of acute Hill-Sachs reduction with remplissage to treat complex anterior instability

Grant H. Garcia, MD[a], Ryan M. Degen, MD[a], Christopher N.H. Bui, MD[b,c], Michelle H. McGarry, MS[b], Thay Q. Lee, PhD[b,c,*], Joshua S. Dines, MD[a]

[a]*Sports Medicine and Shoulder Service, Hospital for Special Surgery, New York, NY, USA*
[b]*Orthopaedic Biomechanics Laboratory, Long Beach Veterans Affairs Healthcare System, Long Beach, CA, USA*
[c]*Department of Orthopaedic Surgery, University of California, Irvine, Orange, CA, USA*

Background:: Acute Hill-Sachs reduction represents a potential alternative method to remplissage for the treatment of an engaging Hill-Sachs lesion. This study biomechanically compared the stabilizing effects of an acute Hill-Sachs reduction technique and remplissage.
Methods: Six cadaveric shoulders were tested. For the acute Hill-Sachs lesion, a unique model was used to create a 30% defect, compressing the subchondral bone while preserving the articular surface. Five scenarios were tested: intact specimen, bipolar lesion, Bankart repair, remplissage with Bankart repair, and Hill-Sachs reduction technique with Bankart repair. The Hill-Sachs lesion was reduced through a lateral cortical window with a bone tamp, and the subchondral void was filled with bone cement.
Results: At 90° of abduction and external rotation (ER), total translation was 11.6 ± 0.9 mm for the bipolar lesion. This was significantly reduced after remplissage (5.9 ± 1.1 mm; $P < .001$) and after Hill-Sachs reduction (4.7 ± 0.4 mm; $P < .001$). Compared with an isolated Bankart repair, the average ER loss after remplissage was 4° ± 4° ($P = .65$), and the average ER loss after Hill-Sachs reduction was 1° ± 3° ($P = .99$). Similar joint stability was conferred after both procedures, with minimal change in range of motion.
Conclusions: Remplissage may still be the best way to address chronic Hill-Sachs lesions; however, the reduction technique is a more anatomic alternative and may be a potential option for treating an acutely engaging Hill-Sachs lesion.
Level of evidence: Basic Science Study; Biomechanics
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Keywords: Hill-Sachs; bipolar lesion; bone loss; instability; remplissage; anatomic reduction; cadaveric study

Determining the ideal treatment for anterior shoulder instability is a complex, multifactorial problem. One of the more difficult scenarios involves the acute treatment of patients with "engaging" Hill-Sachs lesions. Hill-Sachs lesions have been estimated to be present in 45% to 80% of primary anterior dislocations and in up to 90% of recurrent dislocators.[42,46,49] These lesions have also been shown to contribute to failure rates of an anterior stabilization if not addressed at the time of surgery.[9,29,43] As a result, many surgical techniques have

*Reprint requests: Thay Q. Lee, PhD, Orthopaedic Biomechanics Laboratory, VA Long Beach Healthcare System, 5901 E 7th St (09/151), Long Beach, CA 90822, USA.
E-mail addresses: tqlee@med.va.gov, tqlee@uci.edu (T.Q Lee).

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been developed to treat these lesions and reduce the risk of recurrent dislocations.

During the past decade, these methods have included Latarjet, rotational osteotomy, and iliac crest autograft or osteochondral allograft reconstruction.[7,8,23,29,41] Successful results have been reported, but all of these procedures are technically demanding and have numerous potential complications.[2,19] The remplissage procedure has recently come into favor because it represents a minimally invasive way to treat engaging Hill-Sachs lesions.[13,16,38,40] Despite its success, remplissage is not an anatomic reconstruction and relies on tenodesing the infraspinatus tendon into the Hill-Sachs defect.[39] Some studies have reported this postoperative stability comes at the expense of decreased external rotation (ER).[12,30,35]

When the same patient group that would benefit from remplissage is treated with surgery acutely, reducing the Hill-Sachs lesion without altering the shoulder's normal soft tissues constraints becomes a potentially viable option, which would theoretically provide the most anatomic surgical option. This has been previously described by Re et al,[41] referred to as humeroplasty, where the engaging Hill-Sachs defect was reduced in 4 patients with a bone tamp and an anterior cruciate ligament guide. Despite biomechanical success, there are potential disadvantages such as stress risers from the cortical window, potential heat necrosis, dislodging the fragment, and over-reduction. Further cases series are needed to elaborate on these potential risks. More recently, Stachowicz et al[45] used kyphoplasty instrumentation to perform a humeroplasty in a cadaveric model, with complete reduction of the lesions. These previous case series and limited cadaveric work provide proof of concept for further study. Consequently, biomechanical evaluations are needed before widespread clinical use can occur.

The purpose of this study was to assess shoulder biomechanics and stability after Hill-Sachs reduction. In addition, the resultant stabilizing effects and shoulder kinematics of the Hill-Sachs reduction was compared with those of the remplissage procedure. Our primary hypothesis was that this new reduction technique would have similar biomechanical stability with a bipolar lesion to remplissage. Our secondary hypothesis was that the anatomic reduction technique would retain greater motion, specifically ER, compared with the remplissage procedure, by preserving and restoring local anatomy.

Materials and methods

Specimen preparation

Biomechanical testing was performed on 6 fresh frozen cadaveric shoulders (5 men and 1 woman, 2 right and 4 left shoulders) using a custom, validated shoulder-testing apparatus.[1,5,22,34] Average donor age was 66.5 ± 5.2 years (range, 57-72 years). The specimens were thawed overnight before testing. The skin and soft tissues were removed except for the coracoacromial ligament, long head of the biceps, and rotator cuff muscles. The humeral shaft was transected 2 cm distal to the deltoid tuberosity. Sutures of #2 FiberWire (Arthrex, Naples, FL, USA) were placed in Krakow fashion through subdivisions of the rotator cuff tendons (supraspinatus, 2; subscapularis, 3; infraspinatus, 2; and teres minor, 1). A fellowship-trained orthopedic surgeon assessed the specimens, and separate staff members performed the biomechanical testing.

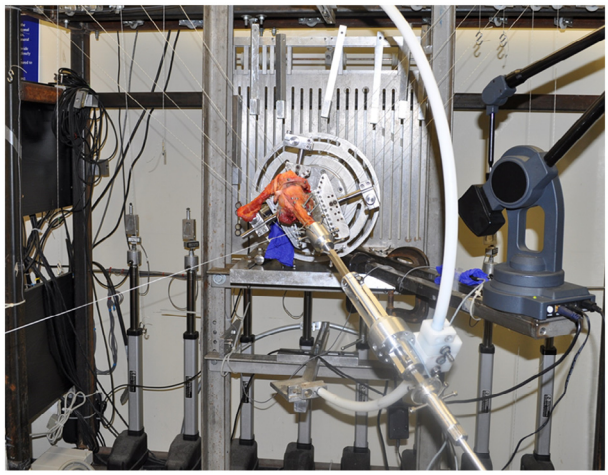

Figure 1 A left shoulder is shown mounted on the custom testing system in 60° of glenohumeral abduction in the coronal plane.

The scapula was bolted to a custom plate with the medial border of the scapula parallel to the mounting bracket and rigidly positioned in the shoulder jig with 20° anterior tilt and 30° abduction (Fig. 1). A custom intramedullary rod was rigidly fixed to the humerus and secured to the arc of the testing jig, which allowed for the humerus to be placed in various positions. The intramedullary rod was also connected to a hollow shaft potentiometer angle sensor (Novotechnik U.S. Inc., Southborough, MA, USA), which allowed for accurate measurement of humeral axial rotation. With the humerus positioned in the scapular plane and 60° of glenohumeral abduction measured using a digital level relative to the scapula position, 90° ER was defined as the position of the humerus when the bicipital groove was aligned with the anterior-lateral acromion.[27,47]

Muscle loading was simulated by attaching braided low-stretch Dacron (DuPont, Wilmington, DE, USA) fishing line (Izorline, Paramount, CA, USA) to the #2 FiberWire sutures in each tendon. The lines were fed through customized muscle plates that were positioned to allow for physiologic lines of pull and then hung over adjustable pulleys. Then, 5 N was applied to each rotator cuff subdivision, which provided a total of 40 N of compressive glenohumeral joint force.[22]

Small screws were fixed into the scapula (coracoid, anterior acromion, and posterior acromion) and humerus (proximal bicipital groove, distal bicipital groove, and posterior humeral shaft). A Microscribe 3DLX instrument (Revware Inc., Raleigh, NC, USA) was used to record the static 3-dimensional (3-D) location of the screws in space for each experiment, and local coordinate systems of the glenoid and humerus and calculations to determine humeral head kinematics and translations were performed from this raw data.

Experimental conditions

Five conditions of the shoulder were tested in order: (1) intact specimen, (2) followed by bipolar bone loss lesions (15% bony Bankart