Biomechanical Comparison of Single- Versus Double-Row Capsulolabral Repair for Shoulder Instability

A Review

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Background: The glenohumeral joint is the most commonly dislocated joint in the body. Failure rates of capsulolabral repair have been reported to be approximately 8%. Recent focus has been on restoration of the capsulolabral complex by a double-row capsulolabral repair technique in an effort to decrease redislocation rates after arthroscopic capsulolabral repair.

Purpose: To present a review of the biomechanical literature comparing single- versus double-row capsulolabral repairs and discuss the previous case series of double-row fixation.

Study Design: Narrative review.

Methods: A simple review of the literature was performed by PubMed search. Only biomechanical studies comparing single- versus double-row capsulolabral repair were included for review. Only those case series and descriptive techniques with clinical results for double-row repair were included in the discussion.

Results: Biomechanical comparisons evaluating the native footprint of the labrum demonstrated significantly superior restoration of the footprint through double-row capsulolabral repair compared with single-row repair. Biomechanical comparisons of contact pressure at the repair interface, fracture displacement in bony Bankart lesion, load to failure, and decreased external rotation (suggestive of increased load to failure) were also significantly in favor of double- versus single-row repair. Recent descriptive techniques and case series of double-row fixation have demonstrated good clinical outcomes; however, no comparative clinical studies between single- and double-row repair have assessed functional outcomes.

Conclusion: The superiority of double-row capsulolabral repair versus single-row repair remains uncertain because comparative studies assessing clinical outcomes have yet to be performed.

Keywords: capsulolabral; double-row; single-row; repair

From 2005 to 2013, a total of 800,000 high school shoulder injuries were reported.[23] The glenohumeral joint is the most commonly dislocated large joint in the body,[7] and glenohumeral dislocations occur in 11.2 per 100,000 persons per year.[6] Initial and recurrent dislocations cause injury to the capsulolabral complex, which is well described and is known as a Bankart injury.[4] The glenoid labrum is a static stabilizer and provides increased stability to the glenohumeral joint through 3 main mechanisms: It doubles the depth of the glenoid socket (from 2.5 mm to 5 mm), increases surface area for contact of the humeral head, and serves as a fibrocartilaginous ring to which glenohumeral ligaments can attach.[14,15] The labrum attaches to the rim of the glenoid, where the capsule has attachments along the glenoid neck. Both entities can lose structural integrity with shoulder dislocations.

Good functional results have been reported with open and arthroscopic labral fixation.[5,12,18,20] Reported failure of arthroscopic labral repair for a Bankart injury is approximately 8%.[21] Clinical studies suggest radiographic evidence of premature-onset osteoarthritis in 18% of patients

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without recurrent dislocation. In patients with recurrent dislocation, radiographic evidence of osteoarthritis is found in 26% treated with arthroscopic Bankart repair versus 36% treated nonoperatively. Preventing recurrent dislocation and failure of repair after arthroscopic capsulolabral repair is associated with a lower percentage of patients developing premature osteoarthritis.[8] Patient factors that entail high risk for failure of arthroscopic labral repair include young age at the time of surgery, male sex, bilateral shoulder instability, joint hyperlaxity, participation in collision sports, early return to contact sports, size of Hill-Sachs lesion, and bony deficits associated with instability.[21] Concern regarding failure of fixation resulting in persistent instability and premature arthritis has stimulated attempts to increase the strength of fixation with surgical techniques. Historically, the glenolabral complex has been repaired with and without capsular shift with a single-row fixation. Recent surgical techniques,[16,19] along with biomechanical and clinical studies, have suggested that fixation with a double-row technique increases load to failure and anatomic restoration of the shoulder capsulolabral footprint.[1,13] The purpose of this review was to evaluate the biomechanical literature comparing single-row versus double-row capsulolabral repair and to discuss the results of previous case series of double-row fixation.

METHODS

A search of PubMed for the keywords "capsulolabral, OR Bankart, AND double, AND row, AND repair" was performed, and 15 studies were identified. All papers that directly compared single- versus double-row capsulolabral repair were included. Only 4 biomechanical studies were found that compared single- and double-row capsulolabral repairs. Four case reports describing double-row capsulolabral techniques were identified. Review of references from these articles identified 2 additional articles as descriptive techniques and case series. Only descriptive techniques with reported clinical data were included. Additionally, only articles available with full text in English were reviewed. The comparative biomechanical studies were reviewed, and the case series with case reports are presented in the Discussion.

RESULTS

Biomechanical Studies

In 2009, Ahmad et al[1] compared double- versus single-row capsulolabral repair in the first published biomechanical study to characterize the anatomic footprint of the capsulolabral complex. This study evaluated 8 cadaveric shoulders and attempted to characterize the normal insertional anatomic features of the capsulolabral footprint. Double- versus single-row techniques were then analyzed to determine which technique better restored the anatomic footprint of the capsulolabral complex. All specimens were stripped of the humerus, acromion, and soft tissues, leaving only the glenoid, labrum, and capsule intact. The scapula was mounted on a vise. All measurements were obtained via microscope with 3-dimensional digitizer and Rhino NURBs modeling software (McNeal and Associates) in the same technical fashion as previously described.[2,3] First, each specimen was measured to determine the mean (±SD) footprint of the capsule, which was 256.0 ± 40.4 mm^2, and the labrum, which was 152.3 ± 24.4 mm^2. The capsule was then dissected off of the glenoid from the anterior-inferior labrum at the level of the coracoid to the 6-o'clock position. Specimens were randomly selected to first undergo single- or double-row suture bridge labral repair. Four anchors were placed at the 2:30-, 3:30-, 4:30-, and 5:30-o'clock positions after the digitizer was used to measure the contact area. The initial repair was taken down to allow for evaluation of the second repair in the same manner. Single-row repair had a mean surface area of 108.3 ± 28.2 mm^2, whereas double-row repair had a mean (±SD) surface area of 220.2 ± 39.3 mm^2 ($P < .01$). This cadaveric study demonstrated that the labrum attachment to the glenoid rim represents only 59% of the overall capsulolabral attachment. Double-row fixation resulted in nearly double the mean surface area compared with single-row fixation and more closely resembled the native anatomic capsulolabral footprint. These findings supported the ability of double-row capsulolabral repair to restore its footprint compared with single-row technique.

TABLE 1
Pressure, Force, Contact Area, and Percentage of Contact of a Repaired Capsulolabral Complex Footprint[a]

	Single Row (n = 30)	Double Row (n = 30)	*P* Value
Peak pressure, MPa	0.31 ± 0.08	0.42 ± 0.09	.025
Mean pressure, MPa	0.21 ± 0.03	0.29 ± 0.04	.003
Force, N	27.46 ± 7.5	38.95 ± 11.71	.005
Contact area, mm^2	106.4 ± 16.8	211.8 ± 18.6	.001
Contact area, %	39.4	78.4	

[a]Reprinted with permission from Kim et al.[11] Data reported as mean ± SD.

Kim et al[11] published a biomechanical study comparing the surface area of single- versus double-row labral repair, but unlike Ahmad et al,[1] Kim et al[11] assessed contact pressure and force and used pressure-sensitive films in their method (Fuji Film Prescale Pressure Densitometer) as opposed to a digitizer.[12] Thirty-three cadaveric shoulders were prepared, and labral tears were produced similar to those reported in the Ahmad et al[1] study. Repair sequence (single vs double row) was also randomized. In this case, an Ilizarov external fixator was used to stabilize the scapula. Fuji films were used to assess the contact area and contact pressure between the capsulolabral complex and the insertion site after single- and double-row fixation of labral tears. With respect to peak pressure, mean interface pressure, interface contact force, and mean pressurized contact area, superior results were demonstrated with double-row repair (Table 1).

In 2014, Spiegl et al[22] published a cadaveric study assessing single- versus double-row capsulolabral repair for a bony Bankart lesion of 25% of the articular surface. This study compared the time zero reduction distance and stability of the fracture in double- versus single-row repairs. Time zero fracture reduction distance was assessed by a coordinate measuring machine (MicroScribe-MX), and a dynamic tensile testing machine (ElectroPuls E10000) was used to assess fracture stability. Fourteen matched pairs of human cadaveric shoulders were randomized between the 2 groups. All soft tissue was stripped, except the labrum and the medial portion of the capsule. A bony Bankart lesion affecting 25% of the width of the articular surface was created in each specimen. Half of the shoulders underwent single-row fixation of the fracture and the other half underwent double-row fixation. After surgical reconstruction of the glenoid was performed, fracture reduction was assessed by measuring displacement of the superior, middle, and inferior thirds of the fracture. The displacement was measured in an unloaded condition, with a 10-N load applied directly anterior and in parallel with the glenoid face. In the unloaded state, 1.1 and 1.6 mm of displacement was observed in the double- and single-row techniques, respectively. Under a 10-N anteriorly directed load, 1.6 and 2.1 mm of displacement was observed in the 2 groups, respectively. The double-row technique resulted in significantly reduced displacement. Specimens were then fixed to the dynamic tensile testing machine. The load vector was 30° medial to the anterior-posterior plane. Specimens were preconditioned and loaded to failure at a displacement rate of 5 mm/min. Loads (N) were recorded at 1.0 and 2.0 mm of fracture displacement. Significantly higher forces were required to achieve fracture displacements in the double- versus single-row repairs, indicated by a mean of 60.6 N at 1 mm and 94.4 N at 2 mm for the double-row technique and 30.2 N at 1 mm and 63.7 N at 2 mm for the single-row technique. Results of this cadaveric biomechanical study imply that double-row fixation increases stability versus single-row repair.

Most recently, McDonald et al[17] published a cadaveric study using load-testing devices to assess load to failure and decreases in excessive motion in single- versus double-row capsulolabral repairs. Six matched pairs of cadaveric shoulders were studied. All muscles surrounding the glenohumeral capsule were sectioned. The humerus was sectioned 2 cm distal to the deltoid tuberosity, then suspended in a polyvinyl pipe with plaster of paris, and the scapula was secured in a scapular box with plaster of paris within the shoulder testing system. Compressive force of 22 N was applied to the glenohumeral joint. Internal and external range of motion with 2.2 N·m of torque was performed, and maximal values were recorded. Humeral head translation kinematic values were measured by digitizing the position of the humeral head on the glenoid throughout rotational range of motion, with measurements performed between maximal external and internal rotation in 30° increments. Labral tears were created in an open fashion from the 2- to 7-o'clock positions in the right shoulder and corresponding clock face positions in the left shoulder. One shoulder from each pair was randomly selected to undergo single- or double-row fixation, and the other matched shoulder underwent the opposite technique. Single- and double-row anchors were placed in the same position on each shoulder (at 3-, 4-, and 5-o'clock positions on the right shoulder and in a matched clock face position on the left). Results are shown in Table 2 and Figure 1. Double-row repair resulted in favorable results compared with single-row repair with external rotation, total range of motion, yield load to failure, ultimate load to failure, and energy absorbed at ultimate load to failure. In accordance with previous biomechanical studies, these findings show that double-row repair demonstrates increased load to failure compared with single-row repair.

TABLE 2
Load-to-Failure Characteristics of Single- Versus Double-Row Capsulolabral Repair[a]

	Single-Row Repair	Double-Row Repair	*P* Value
Stiffness, N/mm	27.1 (8.8)	33.4 (17.0)	.22
Yield load, N	171.3 (110.1)	216.1 (83.1)	.02
Deformation at yield load, mm	8.6 (4.1)	8.9 (1.8)	.85
Energy absorbed to yield load, N-mm	697.7 (585.0)	778.9 (350.6)	.60
Ultimate load, N	224.5 (121.0)	373.9 (172.0)	.05
Deformation at ultimate load, mm	13.5 (6.5)	22.1 (4.7)	.08
Energy absorbed to ultimate load, N-mm	1745.5 (1462.9)	4649.8 (1930.8)	.02

[a]Data reported as mean (SD). Reprinted with permission from McDonald et al.[17]

DISCUSSION

Is There a Mechanical Advantage to Double-Row Versus Single-Row Repair?

Ahmad et al,[2] Kim et al,[11] Spiegl et al,[22] and McDonald et al[17] all suggested statistically significant, greater biomechanical advantages with double-row repair. Ahmad et al demonstrated that a double-row capsulolabral repair better resembled the native capsulolabral footprint compared with single-row capsulolabral repair, and the investigators showed an 85% restoration of capsulolabral footprint with double-row repair compared with a 42% restoration of capsulolabral footprint with single-row repair. Kim et al demonstrated that interface pressure is greater with double-row repair and that the capsulolabral footprint was nearly double in double-row repair versus single-row repair. In the Kim et al study, the use of Fuji film led to many limitations, including artifact. In the Spiegl et al[22] study, superior results were observed with double-row fixation, demonstrated by a decrease in fracture displacement and greater load to failure. A limitation of the Spiegl et al[22] study was that a single tensile force was applied to the bony fragment, which is a simplified approximation of the complex physiologic loading that occurs on a bony Bankart repair. In the McDonald et al[17] study, the load to failure was higher with double-row repair, and glenohumeral external rotation was decreased (both results being statistically significant).

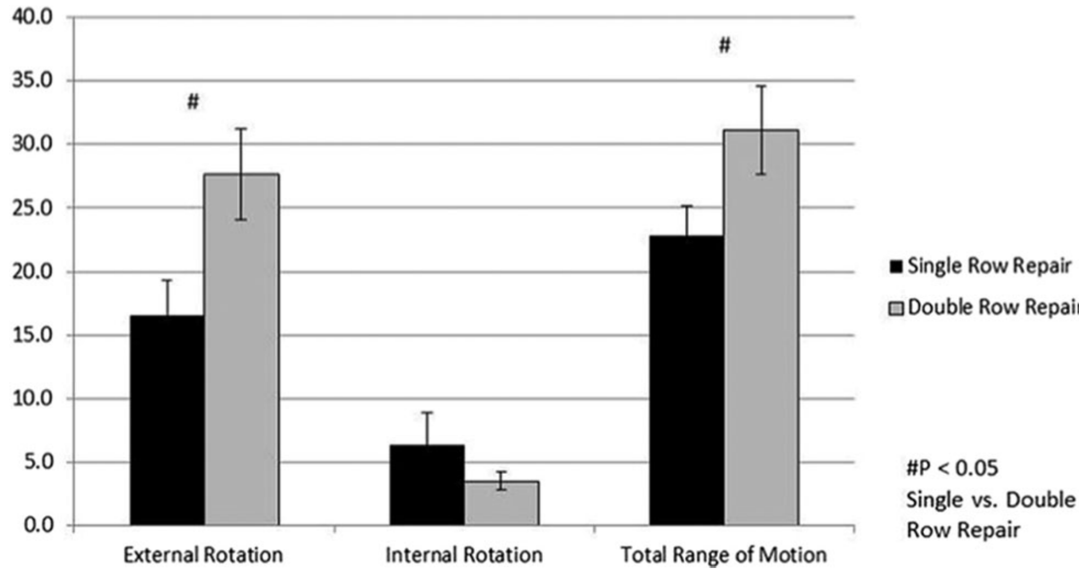

Figure 1. Decrease in range of motion after repair when compared with motion after creation of a Bankart lesion, as reported by McDonald et al.[17] Double-row repair significantly decreased external rotation and total range of motion when compared with single-row repair. Reprinted with permission from McDonald et al.[17]

Therefore, all biomechanical studies reviewed suggest a statistically significant biomechanical advantage with double-row versus single-row repair. However, no studies have been performed to evaluate the vascularized disruption, or strain on repair, that can occur with increased biomechanical fixation. Furthermore, biomechanical studies are open and cannot mimic injury to soft tissue that occurs with in vivo shoulder dislocation and instability. None of these biomechanical studies can account for the body's ability to heal, and the average age of cadaveric specimens is much older than what is seen in clinical practice.

Which Clinical Comparative Studies Support the Biomechanical Studies?

Currently, no comparative clinical study exists; however, clinical studies and descriptive techniques have been published. The first descriptive double-row capsulolabral repair was performed by Lafosse et al.[13] The study described a double-row technique requiring the use of 2 medial anchors and 3 lateral row anchors. This anchor fixation resulted in a *W* shape, so it was termed a *Cassiopeia technique*. The Cassiopeia technique was performed on 12 patients with an average age of 28 years. The study did not address any functional outcome results or define length of follow-up. However, no patients had any reported intraoperative or postoperative complications. Consideration must be given to an excessive medial anterior-inferior portal for placement of medial suture anchors, as neurovascular injury becomes a greater risk when this descriptive technique is used.[13]

Iwaso et al[10] described a similar technique in patients with anterior dislocation sustained during athletic activity. A *V* configuration was used, with 1 medial anchor along the glenoid neck and 2 anchors along the glenoid rim. The technique was performed on 19 joints in 18 patients, and patients were observed for 24 months. The majority of patients studied were male, and the mean age was 24.9 years. At 24-month follow-up, all patients returned to sport without any recurrent dislocation.

Jiang et al[9] described an arthroscopic knotless suture bridge technique to create a stable and low-profile double-row repair. Six patients were included, with an average age of 30 years and follow-up ranging from 4 to 9 months. None of the patients experienced recurrent dislocation or complication.

Two clinical case reports have been published, by Moran et al[19] and Ly et al[16] (2014 and 2016, respectively). Moran et al[19] described a double-row capsulolabral technique performed in a 30-year-old male with recurrent instability and a 20% bony Bankart lesion. Three months postoperatively, the patient was pain-free with negative apprehension and a painless full arc with active range of motion. Ly et al[16] described double-row repair in a patient with a posterior bony Bankart lesion. This study used a technique that included 2 medial anchors, with sutures passed and tied into a lateral row PushLock for a *V* configuration (this *V* configuration was opposite to that used by Iwaso et al,[10] which had 1 medial and 2 lateral row anchors). Treatment was found to be successful at 4 months, with full return to activity at that time.

Iwaso et al,[10] Jiang et al,[9] Moran et al,[19] and Ly et al[16] (unlike Lafosse et al[13]) described medial row anchor placement performed either percutaneously or through an anterior-inferior portal, which minimized the risk of compromising neurovascular structures as with a medial anterior-inferior portal, such as the Lafosse et al[13] descriptive technique suggests.

The above clinical series and case reports demonstrate successful cases of patients treated with double-row labral repair; however, no comparative clinical studies are available. Additionally, a common weakness in many of the case series and reports is the short-term follow-up time (<1 year). Furthermore, no comparative studies assessing functional outcomes of single- versus double-row repair exist. Studies have not reported differences in cost, and the available studies have low power. Most clinical studies demonstrate that the reported rate of dislocation with single-row repair ranges from 4% to 19%.[21] Thus, in high-risk patients (eg, contact athletes; patients with anterior labrocapsular periosteal avulsion lesion, Hill-Sachs lesion, bony glenoid lesions, recurrent dislocation, and revisions), double-row fixation should be considered.[19] Finally, double-row fixation theoretically has a biomechanical advantage; thus, some rehabilitative postoperative protocols are started sooner, leading to a quicker return to sport and recovery.

CONCLUSION

In an effort to improve recurrent instability after arthroscopic repair, recent studies have compared single- versus double-row capsulolabral repair. Biomechanical studies have demonstrated favorable results with double-row capsulolabral repair, suggesting that restoration was closer to the native capsulolabral footprint and that it increased interface pressure, decreased fracture displacement in bony Bankart lesions, increased load to failure, and decreased glenohumeral rotation. Clinical studies and case reports of double-row repair have been described with multiple techniques of fixation and good preliminary results. However, cadaveric studies have limitations, and no comparative clinical studies to assess functional outcome have been conducted. At this time, double-row capsulolabral repair provides a theoretical advantage compared with single-row repair, especially in high-risk patients; however, further comparative clinical studies to assess functional outcomes are needed.

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