Differences in Failure Mode Between Simple and Mattress Suture Configuration in Arthroscopic Bankart Repairs

A Cadaveric Study

Shana N. Miskovsky,[*†‡] MD, Lee M. Sasala,[‡] MD, Christopher N. Talbot,[‡] MD, and Derrick M. Knapik,[*†‡§] MD

Investigation performed at University Hospitals Cleveland Medical Center, Department of Orthopaedic Surgery, Cleveland, Ohio, USA

Background: Traumatic anterior shoulder dislocations disrupt the anteroinferior labrum (Bankart lesion), leading to high rates of instability and functional disability, necessitating stabilization.

Purpose: To investigate modes and locations of repair failure between simple and horizontal mattress suture configurations after arthroscopic Bankart repair using suture anchors in a cadaveric model.

Study Design: Controlled laboratory study.

Methods: A total of 48 fresh-frozen human cadaveric shoulders from 48 specimens underwent creation of Bankart lesions from either the 3:00 to 6:00 o'clock position on the right glenoid or the 6:00 to 9:00 o'clock position on the left glenoid. Shoulder laterality between specimens was alternated and randomized to either simple or mattress suture repair configurations. In each shoulder, anchors were placed on the glenoid at the 3:00, 4:30, and 6:00 o'clock positions on the right or 6:00, 7:30, and 9:00 o'clock positions on the left and were secured via standard arthroscopic knot-tying techniques. Specimens were tested in the supine anterior apprehension position using a servohydraulic testing machine that was loaded to failure, simulating a traumatic anterior dislocation. After dislocation, open inspection of specimens was performed, and failure mode and location were documented. Differences in failure mode and location were compared using nominal multivariate generalized estimating equations.

Results: Simple suture repairs most frequently failed at the labrum, while mattress suture repair failed at the capsule. Regardless of configuration, repairs failed most commonly at the 3:00 o'clock position on the right shoulder and 9:00 o'clock position on the left shoulder. Compared with mattress suture repairs, simple suture repairs failed at a significantly higher rate at the 6:00 o'clock position.

Conclusion: Traumatic anterior shoulder dislocation after arthroscopic Bankart repair in a cadaveric model resulted in simple suture configuration repairs failing most commonly via labral tearing compared with capsular tearing in mattress repairs. Both repair configurations failed predominately at the anterior anchor position, with simple suture repairs failing more commonly at the inferior anchor position.

Clinical Relevance: Horizontal mattress suture configurations create a larger area of repair, decreasing the risk of repair failure at the labrum. The extra time required for mattress suture placement at the inferior anchor position is used effectively, resulting in lower biomechanical failure rates.

Keywords: Bankart; labrum; shoulder; dislocation; suture

Traumatic anterior shoulder dislocations commonly result in separation of the anteroinferior (AI) labral complex from the glenoid rim, classically referred to as a Bankart lesion.[30,32] After dislocation with resultant labral and capsular injury, high rates of recurrent anterior shoulder instability with resultant functional deficits in shoulder function can occur, particularly in younger populations.[7,13,27,29,35] Surgical restoration and tightening of the capsulolabroligamentous complex is often necessary to restore shoulder stability and function,[16,29] leading to improved stability and outcomes when compared with nonsurgical management.[5] Despite early reports of repair

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failure, with repeat dislocation rates approaching 34% after arthroscopic repair,[20,36] refinements in surgical technique and advancements in instrumentation have decreased rates of recurrent instability to between 4% and 17%, with outcomes comparable with open repairs.[1,2,5,7,8,12,19]

Several arthroscopic stabilization techniques and implants are utilized for arthroscopic Bankart repair, with suture anchors representing the most popular method of fixation.[24] Despite multiple investigations quantifying the biomechanical strength of suture anchors compared with other fixation devices, there remains little information with respect to optimal suture configuration and associated modes of repair failure.[10,11,22,23,33] The cadaveric investigation by Nho et al[27] found no difference with respect to ultimate load to failure, load at 2-mm displacement (repair gapping), or gapping after cyclical loading when comparing simple stitch repair, single-loaded anchors tied with horizontal mattress stitches, double-loaded suture anchors tied with simple stitches, and knotless anchors. The most common mode of repair failure involved anchor pullout, followed by failure at the glenolabral junction and capsular rupture. However, no information regarding suture failure location or glenolabral junction failure type was reported. As such, the influence of suture configuration on failure mode remains largely unknown, while failure location has not been previously reported after arthroscopic Bankart repair.[3,6]

The purpose of this investigation was to use a cadaveric shoulder model to perform arthroscopic repair of an iatrogenic Bankart lesion using single-loaded anchors. After repair, a traumatic anterior shoulder dislocation was simulated, and the mechanism and location of repair failures were analyzed. Specifically, we sought to compare (1) primary failure mode (anchor pullout, suture failure, labral tearing, and capsular tearing) and (2) primary failure location (based on glenoid clock face) after arthroscopic Bankart repair using simple versus mattress suture configurations. Based on prior data,[27] we hypothesized that simple suture repairs would more commonly fail at the anchor, while mattress repairs would fail at the capsulolabral junction, predominantly at the anterior-most anchor position.

METHODS

Specimens

Before study initiation, institutional review board exemption was obtained at the senior author's (S.N.M.) institution, as no identifying patient information was collected during the investigation. An a priori power analysis was performed to determine the optimum number of specimens needed. Assuming an alpha probability of .05 and a target beta value of 0.8, for an estimated small effect size ($d = 0.2$), the necessary sample size was determined to be 67 specimens in each group, while a medium effect size ($d = 0.4$) would require 34 specimens in each group.

A total of 52 fresh-frozen human cadaveric specimens from a university anatomy program, aged between 30 and 50 years at the time of death, were obtained for this study. Per institutional review board stipulations, we were blinded with regard to specimen sex or any additional characteristic information. Specimens were kept frozen and were thawed at room temperature for 24 hours before use. For each specimen, only the right or left shoulder was utilized, with shoulder laterality alternating between specimens. Each individual specimen was coupled to another specimen based on age at the time of death and the degree of glenohumeral joint disease (Outerbridge I or II), creating a total of 26 age-matched specimens. The specimens were examined arthroscopically by the attending surgeon (S.N.M.) and were excluded based on the following criteria: presence of structural abnormalities to the glenohumeral joint, severe (Outerbridge III or IV) degenerative changes of the articular surface of the humeral head or glenoid, major rotator cuff pathology (2 tendon tears and tendon retraction medial to the coracoid), any absent labral tissue, any evidence of glenoid bone loss or glenoid hypoplasia, evidence of labral damage or prior labral repair, limited range of motion secondary to structural or mechanical blockage (defined as $<120^\circ$ of forward flexion, abduction $<120^\circ$, or external rotation $<90^\circ$ with respect to the scapula, as measured using a goniometer), or scapular fracturing during mechanical testing. All soft tissue overlying the glenohumeral joint was preserved, and the integrity of the musculature and shoulder girdle was left intact to simulate an in vivo arthroscopic repair.

Surgical Preparation

All surgical supplies were purchased and provided by the attending surgeon, as no industry funding was obtained. The repair configuration used for each shoulder of age-matched pairs was randomly selected before surgery using a random-number generator. Shoulders were then disarticulated by cutting the proximal humerus at the surgical neck and carefully dissecting out the scapula to remove all medial soft tissue attachments to separate the scapulohumeral complex. The specimens were potted in cement, ensuring no capsular disruption. Specimens were then positioned

[§]Address correspondence to Derrick M. Knapik, MD, Department of Orthopaedic Surgery, University Hospitals Cleveland Medical Center, 11100 Euclid Ave, Cleveland, OH 44106, USA (email: derrick.knapik@gmail.com).

*Department of Orthopaedic Surgery, University Hospitals Cleveland Medical Center, Cleveland, Ohio, USA.

[†]University Hospitals Sports Medicine Institute, Cleveland, Ohio, USA.

[‡]School of Medicine, Case Western Reserve University, Cleveland, Ohio, USA.

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Ethical approval for this study was waived by University Hospitals Cleveland Medical Center Institutional Review Board (study No. EM-17-03).

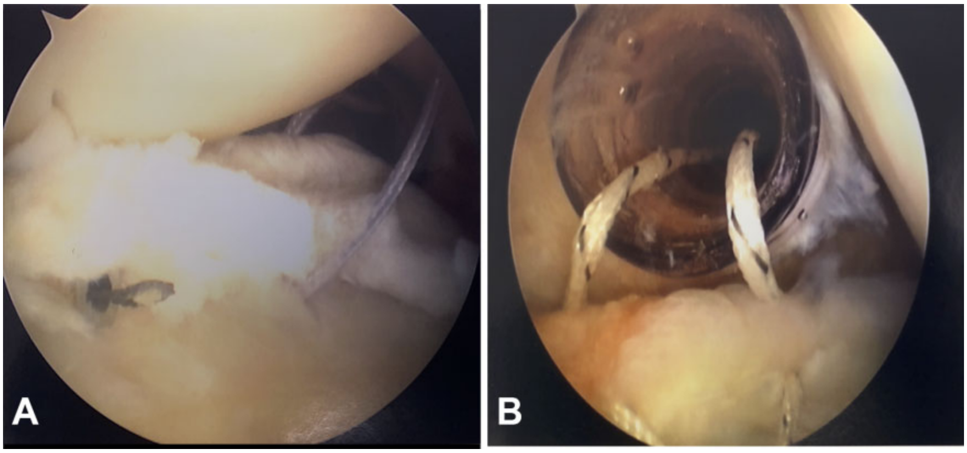

Figure 1. Arthroscopic images during labral repair demonstrating (A) simple suture configuration and (B) mattress suture configuration.

in the lateral decubitus position (30°-40° of abduction, 15° forward flexion) using a vise grip on the scapula and drilling a hole in the humeral shaft to create a rope pulley system with 10 pounds of applied traction. A standard posterior arthroscopic portal was established 1 cm medial and 2 cm inferior from the posterolateral corner of the acromion using spinal needle localization. A 4.0-mm 30° arthroscope was then placed in the posterior portal to ensure that the specimen was eligible for inclusion, followed by utilization of an outside-in technique to establish the AI portal just above the superior edge of the subscapularis tendon and the anterosuperior (AS) portal at the anterolateral corner of acromion. Overswitching sticks, see-through, partially threaded, twist-in cannulas (Twist-In 7 × 7 cm; Arthrex) were placed in all 3 portals. The integrity of the biceps tendon and anchor was evaluated using a probe and found to be intact in all specimens. A percutaneous accessory port of Wilmington (1 cm lateral to and anterior to posterolateral acromion) or percutaneous posterolateral portal was utilized as needed for suture anchor placement inferiorly.

An in vivo Bankart lesion was created using an angled periosteal elevator through the AS and AI portals by elevating the AI labrum and capsuloligamentous complex from the glenoid. Visualization with the arthroscope in the AS portal and elevator through AI portal confirmed minimal residual tissue attachment to the glenoid neck and adequate mobilization of the Bankart lesion. The anatomic location of the lesion, running from the 3:00 to 6:00 o'clock positions on the right glenoid and 6:00 to 9:00 o'clock positions on the left glenoid, started just inferior to the origin of the middle glenohumeral ligament. To preserve tissue integrity, shoulders were kept continually moist with saline throughout the procedure. A total of 4 randomized specimens (n = 3 simple repair; n = 1 mattress repair) were excluded and discarded before repair because of the presence of severe glenohumeral osteoarthritis with absence of reparable labral tissue.

Arthroscopic repair was performed using three 3.0-mm Bio-SutureTAK anchors preloaded with No. 2 FiberWire (Arthrex) beginning at the 6:00 (inferior), 4:30 (AI) and then 3:00 (anterior) o'clock positions on the anterior articular edge of the glenoid face in right shoulders and beginning at the 6:00 (inferior), 7:30 (AI), and then 9:00 (anterior) o'clock positions in left shoulders. Capsulolabral tissue was advanced to the glenoid by grasping the tissue distal to the anchor using a curved needle device with a looped wire for suture shuttling (Suture Lasso; Arthrex) to create the simple (Figure 1A) and mattress suture (Figure 1B) configurations. All repairs involved standard arthroscopic knot-tying technique with a knot pusher (Single Hole Knot Pusher; Arthrex), including a slidable lockable knot (Seoul Medical Center knot)[18] followed by 3 reverse half-hitches to secure the suture,[23] performed by the attending surgeon. Sutures were then trimmed a few millimeters from the knot using an arthroscopic knot cutter (4.2-mm Suture Cutter; Arthrex). After final suture placement, the integrity of each repair was confirmed using an arthroscopic probe to ensure appropriate tissue advancement and stability of the AI glenoid.

Biomechanical Testing

To facilitate fixation to the testing apparatus, the soft tissue of the distal 10 cm of the humerus was removed to expose the bone. The overlying soft tissue of the scapula was similarly removed to the level of the glenoid neck. The humerus was potted in a cylindrical container, with the long axis of the shaft centered along the container's diameter. The scapula was potted in a plastic container, with the medial border in the base and the glenoid parallel to the base using polyethylene epoxy (Smooth-On) (Figure 2).

Mechanical testing was performed using a servohydraulic testing machine that allowed for uniaxial loading (8501 M; Instron). As utilized in a prior investigation,[9] a specialized testing apparatus specifically designed and developed for uniaxial loading was used to attach the specimens to the machine. The scapula was positioned in the testing apparatus to simulate the shoulder in supine position such that the costal surface faced the ceiling, while the face of the glenoid was perpendicular to the floor and parallel to the direction of the applied load. The apparatus was designed such that the scapula could be oriented at an angle of 10° relative to the

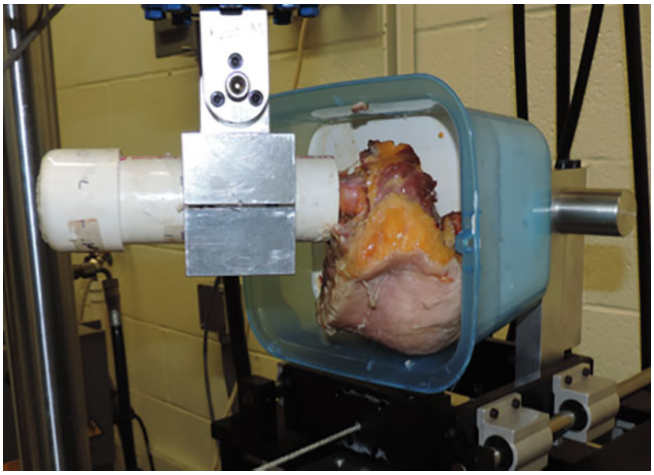

Figure 2. Setup showing potting of humerus in cylindrical container with potting of scapula in polyethylene epoxy.

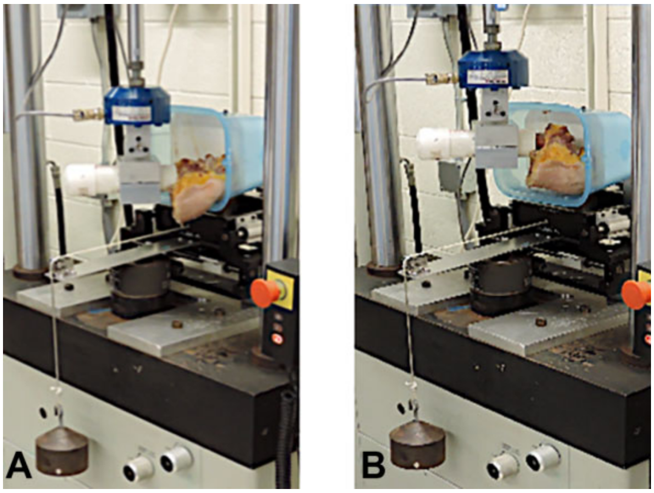

Figure 3. Mechanical testing apparatus setup for servohydraulic machine testing demonstrating cadaveric shoulder (A) before dislocation and (B) after dislocation. Before biomechanical testing began, the humeral head was centered in the glenoid.

horizontal to simulate an approximate anatomic position on the posterior thoracic wall.

The humerus was positioned at neutral forward flexion, with 60° of abduction and 90° of external rotation with respect to the plane of the scapula. This point was set as the zero point. External rotation was measured by palpating the bicipital groove. This is equivalent in vivo to the anterior apprehension position of 90° of abduction and 90° of external rotation. The scapula pot was fixated to a translation table that allowed for free movement along the medial-lateral and superior-inferior axes. A joint compression force of 22 N directed perpendicularly to the glenoid face was applied to the translation table using a weight and pulley system (Figure 3). This technique has been shown in previous studies[9,37] to provide physiologic load to the rotator cuff musculature.

Shoulders were then loaded to failure at 150 mm/s for a total displacement of 40 mm. A speed of 150 mm/s has previously[26] been shown to simulate traumatic dislocation. After multiple test runs, a displacement of 40 mm was determined necessary to sufficiently dislocate shoulders of varying size in the AI direction. After dislocation, each shoulder was disarticulated from the scapulothoracic complex using an open posterior approach. Each specimen was then evaluated using an open approach to determine the failure mode: anchor pullout, suture failure, labral tear, or capsular tear. Failure mode was defined as anchor pullout in the setting of preserved suture and capsulolabral tissue with evidence of anchor displacement out of the bone. Suture failure was determined by the presence of free suture ends without anchor displacement and preserved capsulolabral tissue. Labral tearing was characterized by labral disruption with maintenance of the anchor and suture with no discernable disruption of the peripheral capsular tissue. Capsular tearing was defined by preservation of the anchor and suture with no labral disruption in the setting of capsular pull-through. Primary sites of failure, based on clock-face position on the corresponding glenoid, were inspected visually and recorded.

Data Analysis

Statistical analysis was performed to determine differences in mode of failure and failure location between repairs using the simple versus mattress suture configuration. Values were calculated using nominal multivariate generalized estimating equations, assuming an exchangeable covariance structure. All statistical analyses were performed using SPSS statistical software (Version 25.0; IBM Corporation).

RESULTS

A total of 48 unique shoulders underwent repair. Three scapulae were fractured during mechanical testing after repair (n = 3 simple suture repair) but before dislocation and were excluded, resulting in a total of 45 shoulders included in the final analysis (n = 20 simple suture repair; n = 25 mattress repair). No suture repair failures were present before testing.

After traumatic dislocation, the major mode of failure for simple suture repair configurations was labral tearing (50%; n = 10/20), while mattress suture repairs primarily failed because of capsular tearing at the glenoid, which occurred at the entrance and exit points of the suture (68%; n = 17/25) (Table 1; Figure 4, A and B). Labral tears were significantly more likely to occur with simple suture repairs compared with mattress suture repairs ($P < .005$), whereas capsular tearing was significantly more common with mattress suture repairs ($P = .01$).

The most common failure location was at the 3:00 o'clock position in right shoulders and at the 9:00 o'clock position in left shoulders in both simple suture (45%; n = 9/20) and mattress suture (68%; n = 17/25) repairs (Table 2). Simple suture repairs were significantly more likely to fail at the

TABLE 1
Mechanisms of Repair Failure Based on Suture Configuration

		Suture Configuration, n (%)		
		Simple (n = 20)	Mattress (n = 25)	*P*
Mechanism of failure	Anchor pullout	1 (5)	3 (12)	.73
	Suture failure	3 (15)	4 (16)	.63
	Labral tearing	10 (50)	1 (4)	<.005
	Capsular tear	6 (30)	17 (68)	.01

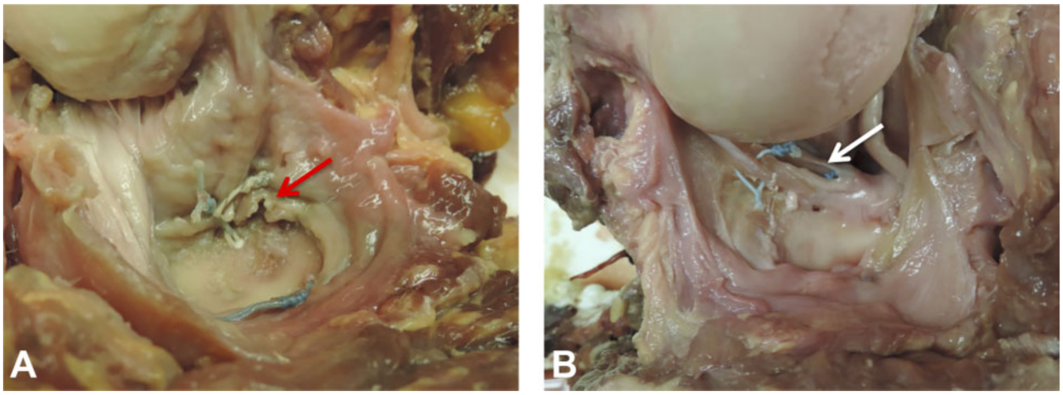

Figure 4. Cadaveric specimens after dislocation and disarticulation allowing visualization of major repair failure and location, demonstrating (A) labral repair failure (red arrow) at the anterior labrum after simple suture repair and (B) capsular failure (white arrow) at the anterior position after mattress suture configuration.

TABLE 2
Location of Repair Failure Based on Suture Configuration[a]

		Suture Configuration, n (%)		
		Simple (n = 20)	Mattress (n = 25)	*P*
Location of failure	R 3:00 L 9:00 (anterior)	9 (45)	17 (68)	.12
	R 4:30 L 7:30 (anteroinferior)	5 (25)	7 (28)	.82
	R 6:00 L 6:00 (inferior)	6 (30)	1 (4)	.02

[a]L, left shoulder; R, right shoulder.

6:00 o'clock position when compared with mattress repairs (*P* = .02).

DISCUSSION

In this investigation, after simulation of a traumatic anterior shoulder dislocation in cadaveric shoulders after arthroscopic Bankart repair we found that simple suture repairs failed most commonly by labral tearing, compared with capsular tearing after mattress repair. The most common site of failure in both suture configurations occurred at the anterior-most anchor position (3:00 o'clock in right shoulders, 9:00 o'clock in left shoulders). Moreover, simple suture repairs failed at a significantly higher rate at the inferior-most position (6:00 o'clock in right and left shoulders) when compared with mattress repairs.

Causes behind Bankart repair failure after primary stabilization are multifactorial, with male sex, younger patient age, and open repair being identified as risk factors.[38] However, repeat traumatic shoulder dislocation events after repair represent the most common methods of failure, accounting for 34% to 96% of failures.[4,21,25,31] Voos et al[35] identified patients aged <25 years, the presence of ligamentous laxity, and the presence of large (>250 mm^3) Hills-Sachs lesions as significant risk factors for recurrent instability after repair. While previous investigations[10,11,22,23,33] have evaluated the biomechanical strength and performance characteristics of different arthroscopic knot-tying configurations during repair, little is known regarding the method and location in which these repairs fail on the glenoid.

Based on the perpendicular orientation of the simple suture configuration on the labrum, there is less area of contact between the tissue and suture, resulting in fixation being applied over a smaller repair area. This appears to create a "cheese cutter" effect on the labral tissue, resulting in failure within the labrum with a subsequent radial tearing of the labrum. Clinically, in setting of a repeat labral injury, information extrapolated from our model could create concern for recurrence or progression of a repaired tear using a simple stitch configuration. Moreover, radial labral tears present more of a reconstruction challenge, particularly in revision surgery. In contrast, the horizontal mattress configuration creates a larger area of repair, resulting in a lower risk of failure at the labrum. As such, based on the findings of this study, horizontal mattress sutures may represent a superior repair configuration in the setting of labral tearing, especially in the setting of poor labral tissue quality; however, determination of the clinical validity of this finding warrants further in vivo investigation.[28]

The observed modes of failure based on suture configuration in our investigation are in slight contrast to the modes of failure reported by Nho et al,[27] where anchor pullout was observed in 100% of specimens using the suture anchor–simple stitch configuration. In contrast, they found that specimens with suture anchor–mattress suture configuration failed 80% of time at the glenolabral junction and 20% at the capsule. However, there are several important methodological differences when comparing the Nho et al investigation with the current study. Repairs performed by Nho et al utilized only 2 suture anchors at the 4:00 and 5:00 o'clock positions, with all repairs performed in an open manner after disarticulation of the humeral head with excision of capsular tissue along its most lateral humeral insertion. All repairs in our investigation were performed using 3 sutures placed arthroscopically in a preserved glenohumeral joint, allowing for maintenance of soft tissue integrity. Furthermore, the cadaveric shoulders utilized by Nho et al were loaded to failure by cyclic loading, while we utilized a single applied load to failure (ie, dislocation). Thus, these testing model factors may account for the dissimilar failure modes noted between the 2 studies and warrant further investigation.

In the current study, both simple and mattress suture repair configurations failed most frequently at the anterior-most anchor position (3:00 o'clock position in right shoulders and 9:00 o'clock position in left shoulders). Failures most commonly occurred at this position because of the presence of less robust soft tissue, composed of the middle glenohumeral ligament, thin capsule, and superior aspect of the anterior band of the inferior glenohumeral ligament, which has been shown to stretch significantly after acute Bankart lesions.[34] Moreover, simple suture repairs failed at a significantly higher rate at the thicker capsuloligamentous tissue at the inferior-most position (6:00 o'clock position in right and left shoulders) on the glenoid when compared with mattress repairs. Coupled with the difficulty of obtaining an optimal anchor placement angle and a tight working space, the increased repair area created using a horizontal mattress configuration may account for the lower incidence of inferior repair failures when compared with the simple suture repairs.[15,17] This suggests that despite less time being required for placement of a simple suture, the extra surgical time required for mattress suture placement at the inferior glenoid is effective in restoring the high and stable bumper after capsular shift, resulting in lower biomechanical failure rates at this position.

Limitations

This investigation was not without limitations. Arthroscopic Bankart repair and subsequent testing were performed at time zero, so the effect of natural physiologic healing of the capsuloligamentous complex and other tissues before testing is unknown. Moreover, our biomechanical model can only partially imitate physiologic motion. As such, while our model of creating a dislocation episode was performed using an accepted biomechanical model, dislocation events in real life possess more complex patterns of shoulder motion that we were not capable of re-creating. Moreover, cadaveric tissues are less pliable, resulting in higher rates of capsular or labral tearing around the sutures and potentially accounting for the high rates of failures seen in these tissues during this investigation. In vitro creation of the lesions may not have created the falling-off phenomenon of the labrum that occurs clinically in a Bankart lesion.[14] Unlike prior investigations,[27] there was no comparison between knotted versus knotless suture anchors and no determination of ultimate load to failure, repair elongation, or stiffness. While labral height has been shown to correlate with shoulder stability and better re-created using mattress sutures,[3,14] measurement of labral height was not performed.

A further bias exists in that differing amounts of capsulolabral tissue were grasped with each pass during repair. In addition, the mechanical parameters utilized were sufficient to dislocate all shoulders anteroinferiorly; however, glenoid width was not measured before dislocation, and as such the distance at which each shoulder was required to translate before dislocation was not standardized. While cadaveric specimens with time of death between 30 and 50 years of age were used, cadaveric sex was unknown; as such, the effects of this variable on tissue quality of failure mode and locations were unable to be analyzed. Owing to specimen availability and costs, the necessary number of specimens required to detect a small or medium effect size was not attained, resulting in an underpowered investigation. Last, while specimens with obvious pathology to the shoulder were excluded, it is unknown if any specimens had a history of shoulder trauma or dislocation that was not appreciated on gross and arthroscopic examination.

CONCLUSION

Traumatic anterior shoulder dislocation after arthroscopic Bankart repair in a cadaveric model resulted in simple suture repairs failing most commonly via labral tearing, compared with capsular tearing in mattress repairs. Both suture repair configurations failed predominately at the anterior anchor position, with simple suture repairs failing more commonly at the most inferior anchor position.

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REFERENCES

1. Archetti Netto N, Tamaoki MJ, Lenza M, et al. Treatment of Bankart lesions in traumatic anterior instability of the shoulder: a randomized controlled trial comparing arthroscopy and open techniques. *Arthroscopy*. 2012;28(7):900-908.
2. Barber FA, Snyder SJ, Abrams JS, et al. Arthroscopic Bankart reconstruction with a bioabsorbable anchor. *J Shoulder Elbow Surg*. 2003; 12(6):535-538.
3. Boddula MR, Adamson GJ, Gupta A, et al. Restoration of labral anatomy and biomechanics after superior labral anterior-posterior repair: comparison of mattress versus simple technique. *Am J Sports Med*. 2012;40(4):875-881.
4. Boileau P, Villalba M, Hery JY, et al. Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. *J Bone Joint Surg Am*. 2006;88(8):1755-1763.
5. Bottoni CR, Wilckens JH, DeBerardino TM, et al. A prospective, randomized evaluation of arthroscopic stabilization versus nonoperative treatment in patients with acute, traumatic, first-time shoulder dislocations. *Am J Sports Med*. 2002;30(4):576-580.
6. Burks RT, Presson AP, Weng HY. An analysis of technical aspects of the arthroscopic Bankart procedure as performed in the United States. *Arthroscopy*. 2014;30(10):1246-1253.
7. Carreira DS, Mazzocca AD, Oryhon J, et al. A prospective outcome evaluation of arthroscopic Bankart repairs: minimum 2-year follow-up. *Am J Sports Med*. 2006;34(5):771-777.
8. Cole BJ, L'Insalata J, Irrgang J, et al. Comparison of arthroscopic and open anterior shoulder stabilization. A two to six-year follow-up study. *J Bone Joint Surg Am*. 2000;82(8):1108-1114.
9. Deutsch A, Barber JE, Davy DT, et al. Anterior-inferior capsular shift of the shoulder: a biomechanical comparison of glenoid-based versus humeral-based shift strategies. *J Shoulder Elbow Surg*. 2001;10(4): 340-352.
10. Elkousy H, Hammerman SM, Edwards TB, et al. The arthroscopic square knot: a biomechanical comparison with open and arthroscopic knots. *Arthroscopy*. 2006;22(7):736-741.
11. Elkousy HA, Sekiya JK, Stabile KJ, et al. A biomechanical comparison of arthroscopic sliding and sliding-locking knots. *Arthroscopy*. 2005; 21(2):204-210.
12. Fabbriciani C, Milano G, Demontis A, et al. Arthroscopic versus open treatment of Bankart lesion of the shoulder: a prospective randomized study. *Arthroscopy*. 2004;20(5):456-462.
13. Grumet RC, Bach BR Jr, Provencher MT. Arthroscopic stabilization for first-time versus recurrent shoulder instability. *Arthroscopy*. 2010; 26(2):239-248.
14. Hagstrom LS, Marzo JM. Simple versus horizontal suture anchor repair of Bankart lesions: which better restores labral anatomy? *Arthroscopy*. 2013;29(2):325-329.
15. Irion V, Cheah M, Jones GL, Bishop JY. The isolated inferior glenohumeral labrum injury, anterior to posterior (the ILAP): a case series. *Int J Shoulder Surg*. 2015;9:13-19.
16. Kamath GV, Hoover S, Creighton RA, et al. Biomechanical analysis of a double-loaded glenoid anchor configuration: can fewer anchors provide equivalent fixation? *Am J Sports Med*. 2013;41(1):163-168.
17. Kim SH, Crater RB, Hargens AR. Movement-induced knot migration after anterior stabilization in the shoulder. *Arthroscopy*. 2013;29: 485-490.
18. Kim SH, Ha KI. The SMC knot—a new slip knot with locking mechanism. *Arthroscopy*. 2000;16(5):563-565.
19. Kim SH, Ha KI, Cho YB, et al. Arthroscopic anterior stabilization of the shoulder: two to six-year follow-up. *J Bone Joint Surg Am*. 2003;85(8): 1511-1518.
20. Lenters TR, Franta AK, Wolf FM, et al. Arthroscopic compared with open repairs for recurrent anterior shoulder instability. A systematic review and meta-analysis of the literature. *J Bone Joint Surg Am*. 2007;89(2):244-254.
21. Levine WN, Arroyo JS, Pollock RG, et al. Open revision stabilization surgery for recurrent anterior glenohumeral instability. *Am J Sports Med*. 2000;28(2):156-160.
22. Lo IK, Burkhart SS, Chan KC, et al. Arthroscopic knots: determining the optimal balance of loop security and knot security. *Arthroscopy*. 2004;20(5):489-502.
23. Mahar AT, Moezzi DM, Serra-Hsu F, et al. Comparison and performance characteristics of 3 different knots when tied with 2 suture materials used for shoulder arthroscopy. *Arthroscopy*. 2006;22(6): 614.
24. Martetschlager F, Michalski MP, Jansson KS, et al. Biomechanical evaluation of knotless anterior and posterior Bankart repairs. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(9):2228-2236.
25. Meehan RE, Petersen SA. Results and factors affecting outcome of revision surgery for shoulder instability. *J Shoulder Elbow Surg*. 2005; 14(1):31-37.
26. Mohammed KD, Sonnabend DH, Goldberg JA, et al. Biomechanical performance of Bankart repairs in a human cadaveric shoulder model. *Am J Sports Med*. 1998;26(6):831-835.
27. Nho SJ, Frank RM, Van Thiel GS, et al. A biomechanical analysis of anterior Bankart repair using suture anchors. *Am J Sports Med*. 2010; 38(7):1405-1412.
28. Park JY, Lee SJ, Lhee SH, et al. Change in labrum height after arthroscopic Bankart repair: correlation with preoperative tissue quality and clinical outcome. *J Shoulder Elbow Surg*. 2012;21(12):1712-1720.
29. Robinson CM, Howes J, Murdoch H, et al. Functional outcome and risk of recurrent instability after primary traumatic anterior shoulder dislocation in young patients. *J Bone Joint Surg Am*. 2006;88(11):2326-2336.
30. Rowe CR, Patel D, Southmayd WW. The Bankart procedure: a long-term end-result study. *J Bone Joint Surg Am*. 1978;60(1):1-16.
31. Rowe CR, Zarins B, Ciullo JV. Recurrent anterior dislocation of the shoulder after surgical repair. Apparent causes of failure and treatment. *J Bone Joint Surg Am*. 1984;66(2):159-168.
32. Sachs RA, Lin D, Stone ML, et al. Can the need for future surgery for acute traumatic anterior shoulder dislocation be predicted? *J Bone Joint Surg Am*. 2007;89(8):1665-1674.
33. Shah MR, Strauss EJ, Kaplan K, et al. Initial loop and knot security of arthroscopic knots using high-strength sutures. *Arthroscopy*. 2007; 23(8):884-888.
34. Stefko JM, Tibone JE, Cawley PW, et al. Strain of the anterior band of the inferior glenohumeral ligament during capsule failure. *J Shoulder Elbow Surg*. 1997;6(5):473-479.
35. Voos JE, Livermore RW, Feeley BT, et al. Prospective evaluation of arthroscopic Bankart repairs for anterior instability. *Am J Sports Med*. 2010;38(2):302-307.
36. Walch G, Boileau P, Levigne C, et al. Arthroscopic stabilization for recurrent anterior shoulder dislocation: results of 59 cases. *Arthroscopy*. 1995;11(2):173-179.
37. Warner JJ, Deng XH, Warren RF, et al. Static capsuloligamentous restraints to superior-inferior translation of the glenohumeral joint. *Am J Sports Med*. 1992;20(6):675-685.
38. Waterman BR, Burns TC, McCriskin B, et al. Outcomes after Bankart repair in a military population: predictors for surgical revision and long-term disability. *Arthroscopy*. 2014;30(2):172-177.