Ability to Retension Knotless Suture Anchors

A Biomechanical Analysis of Simulated Bankart Lesions

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Background: Knotless suture anchors are gaining popularity in arthroscopic glenohumeral labral repairs. The ability to retension knotless designs after initial anchor placement has been reported; however, no studies have quantified this claim or investigated the biomechanical consequence of retensioning.

Purpose/Hypothesis: To determine whether knotless and knotted suture anchors have biomechanical or anatomic differences with regard to labral repairs and to determine whether retensioning of knotless suture anchors affects capsular tension, labral height, and capsular shift. We hypothesized that retensioning of knotless anchors would result in improved capsular tension compared with conventional knotted suture anchors.

Study Design: Controlled laboratory study.

Methods: A total of 18 fresh-frozen cadaveric shoulders with a mean age of 56 years were dissected to the capsule and disarticulated at the humeral capsular insertion. The scapula was potted and placed in a custom shoulder simulator to tension the capsule via braided sutures localized to the anteroinferior glenohumeral ligament. Specimens were randomized into 3 groups: (1) Knotted (KT), (2) Knotless with end retensioning (KL_{end}), and (3) Knotless with stepwise retensioning ($KL_{stepwise}$). All repairs were completed using all-suture anchors placed at the 5-, 4-, and 3-o'clock positions. $KL_{stepwise}$ was used to simulate an intraoperative technique. Resultant mean capsular tension under 5 mm of displacement (subfailure loading) was measured for each anchor placement and retensioning step. Labral height and capsular shift were measured using a MicroScribe digitizer.

Results: The intact, defect, 1-anchor, 2-anchor, and 3-anchor tensions were not significantly different between the KT and KL_{end} groups. For the latter, retensioning of all knotless anchors increased capsular tension by 2.1 N compared with its 3-anchor state, although this was not statistically significant ($P = .081$). The $KL_{stepwise}$ group explored an alternative method to retension the capsule using knotless anchors, with similar final capsular tensions compared with the other groups. All repairs had similar improvements in capsulolabral height and superior capsular shift.

Conclusion: Knotted and knotless suture anchors provided similar overall restorations in anteroinferior glenohumeral ligament tension. However, knotless devices were capable of small but statistically insignificant improvements in capsular tension with retensioning.

Clinical Relevance: Retensioning of knotless anchors allows the surgeon to tighten regions of the glenohumeral capsule that remain lax after repair.

Keywords: knotless; labrum; repair; suture anchors; glenoid; Bankart; retension

Knotless implant devices are becoming increasingly popular in orthopaedic surgery, with a variety of clinical applications for specific subspecialties. At the glenohumeral joint, knotless suture anchors can be used in glenohumeral instability procedures, superior capsular reconstructions, and rotator cuff tear repairs.[1,11,17] Advantages of knotless

anchors include ease of use, time efficiency, and reduced risk of knot and suture abrasion to the articular cartilage, the latter because of their low-profile design.[2,10,12,17] Furthermore, repairs using knotless anchors have been shown to have less variability among surgeons, likely because of the difficulties among surgeons in obtaining proficiency in arthroscopic knot tying of conventional anchors.[4] Newer all-suture knotless anchor designs are now capable of tension adjustments after initial fixation.[6] Advocates of knotless anchors for glenohumeral stabilization procedures

have cited the ability of these anchors to retension the capsulolabral tissue after additional suture anchor placement.[6] However, to our knowledge, a systematic biomechanical method to quantify retensioning of knotless anchors has yet to be developed.

The purpose of the study was to determine whether knotless and knotted suture anchors have biomechanical or anatomic differences with regard to labral repairs and to determine whether retensioning of knotless suture anchors affects capsular tension, labral height, and capsular shift. We hypothesized that retensioning of knotless anchors would result in improved capsular tension compared with conventional knotted suture anchors.

METHODS

Specimen Preparation

This cadaveric study was deemed exempt from institutional review board approval at our institution. A total of 18 fresh-frozen human cadaveric shoulders were obtained from commercial sources (MedCure Inc and Science Care). The specimens were randomized to 1 of 3 groups: (1) Knotted anchor repair (KT), (2) Knotless anchor repair with end retensioning (KL$_{end}$), and (3) Knotless anchor repair with stepwise retensioning (KL$_{stepwise}$) (Figure 1).

Specimens with knotted anchor repair served as controls. For the KL$_{end}$ group, repair was supplemented with a final retensioning step of all knotless anchors, starting inferiorly and ending superiorly, to quantify the effect of retensioning. The third group, KL$_{stepwise}$, was added to simulate an intraoperative knotless anchor technique used by 2 of the authors (K.J.C., P.E.C.), which we have named the "zipper technique." In this technique, anchors were placed in a standard fashion from interior to superior, but after each additional knotless anchor was secured, the preceding anchor was retensioned. This technique allowed for any laxity in the capsulolabral repair to be corrected before placement of additional anchors. Analogous to a zipper on a jacket, one could not advance until the lower end was fully approximated. Further, to minimize the number of active sutures in the arthroscopic cannulas, the suture could be cut after retensioning, maintaining ≤ 2 repair sutures at all times. KT and KL$_{end}$ groups were compared head-to-head because they had similar testing protocols.
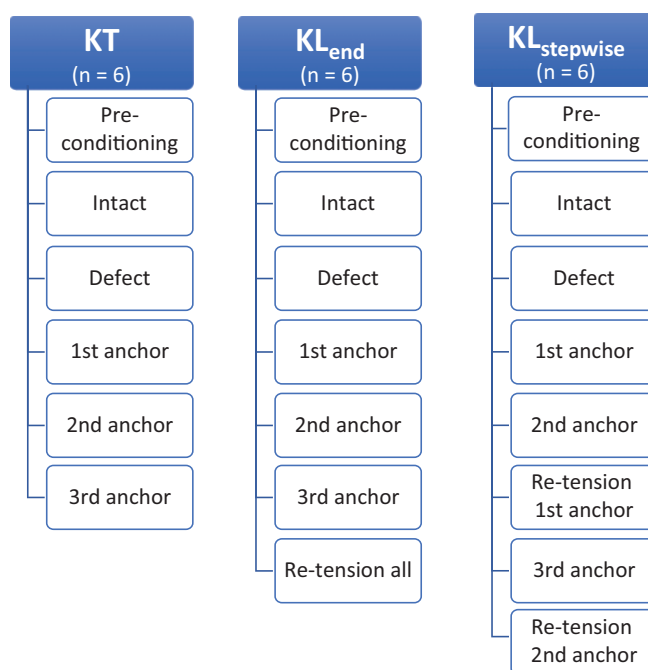
Figure 1. Flow diagram of the testing protocol for knotted (KT) and knotless (KL) anchor groups. Two retensioning sequences were used for the KL anchors. For KL$_{end}$, all anchors were retensioned at the end, starting inferiorly and ending superiorly. For KL$_{stepwise}$, the knotless anchors were retensioned in a stepwise order to simulate an intraoperative technique in which the surgeon could attempt further tightening of the inferior capsule before proceeding to additional anchors superiorly. Each group underwent preconditioning and testing of the intact and anteroinferior defect states. After each anchor placement or retensioning step, the anterior capsule was loaded, and the capsular tension was measured.

Specimens were thawed for 24 hours before dissection. First, the skin and soft tissues were carefully dissected and removed, leaving the labrum and glenohumeral capsule intact. The humerus was disarticulated at the humeral insertions of the capsule to preserve as much capsule as possible. Specimens with labral tears, capsule lesions, significant glenoid bone defects, or severe degenerative

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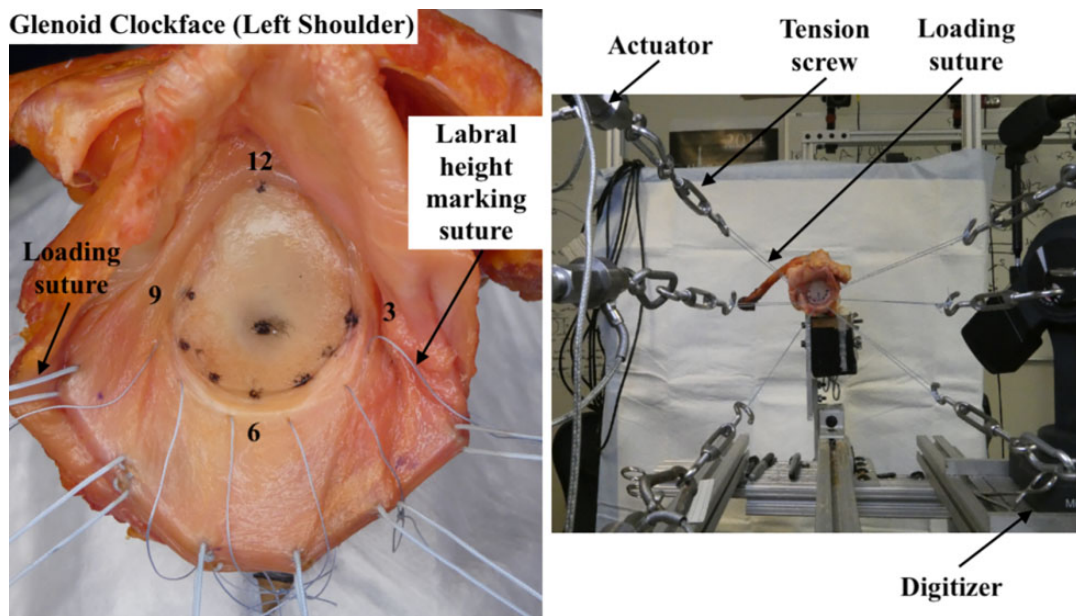
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Figure 2. Six loading sutures were placed at 2 cm from the glenoid rim to define the center and the superior/inferior edges of the anteroinferior and posteroinferior ligaments. Additional sutures were placed at the anterior capsulolabral junction to mark the 3:30, 4:30, and 5:30 clockface positions on a right shoulder (shown) or the 6:30, 7:30, and 8:30 positions for a left shoulder to use as reproducible markers to assist with measuring the labral height. A similar arrangement was placed on the posterior side to serve as a control. A custom shoulder simulator was used to attach the 6 loading sutures to 6 adjustable tension screws in series with linear screw-driven actuators and 444-N load cells (not pictured). The anterior limbs were tensioned at 5 mm of displacement throughout the testing protocol. The posterior limbs were tensioned only during the preconditioning step to reduce creep to the inferior axillary pouch. Anatomic measurements were recorded using a digitizer device.

changes were excluded. For each specimen, the scapular body was potted in a rectangular mold using bone cement, aligning the vertical axis of the glenoid face perpendicular to the floor and the horizontal axis parallel with the edge of the mold. Dual-energy x-ray absorptiometry testing was completed on all specimens to measure any bone mineral density (BMD) biases at a 1-cm^2 area of the anteroinferior glenoid, using a Lunar DPI XQ Dexascan (GE Healthcare).

Next, the borders of anteroinferior and posteroinferior glenohumeral ligaments (AIGHL and PIGHL, respectively)[3,13] were identified, and high-tensile sutures (No. 2 FiberWire; Arthrex) were placed centrally in these structures at 2 cm from the glenoid rim. Using the anatomic clockface descriptions presented by Dekker et al,[3] the surgeon (M.R.L.) placed additional high-tensile sutures 1 hour superior and inferior to those centered at the AIGHL and PIGHL, for a total of 6 loading sutures. The 3 anterior sutures would allow tensioning of the full width of the AIGHL. The posterior sutures were added to more effectively remove creep from the inferior axillary pouch before repair with superior capsular shift. Then, smaller nonabsorbable sutures (No. 4-0 FiberWire; Arthrex) were added at the capsulolabral junction at the 3:30, 4:30, and 5:30 positions for a right shoulder (6:30, 7:30, and 8:30 positions for a left shoulder) to give a precise, reproducible marker to reference when measuring the labral height as described by Slabaugh et al.[15] A similar arrangement was placed on the

posterior side to serve as a control. The placement of loading sutures and labral height marking sutures is shown in Figure 2.

Shoulder Simulator

After specimen preparation, the potted scapula was mounted to the frame of a custom shoulder simulator, ensuring that the glenoid face was perpendicular to the floor using a level. The 6 loading sutures were looped and secured to adjustable tension screws in series with linear screw-driven actuators (Bimba). Actuators were positioned in accordance with the humeral attachments of the AIGHL and PIGHL, as described by Dekker et al,[3] to allow tensioning in the directionality of the fibers. Actuators were connected to 444-N load cells (Futek), with load cell accuracy reported at ±0.1 N and laboratory-confirmed accuracy of ±0.08 N. Load cell output was monitored in real time using Sensit Version 2.5.1.0 software (Futek). The shoulder simulator setup is shown in Figure 2. Preliminary testing showed that setting the tension to 2 N in each actuator was sufficient to remove slack from the system while not overstretching the capsule. This was used as a resting state for all tests.

Testing Protocol

Preconditioning was completed by pulling the 6 regions of the capsule at 5 mm of displacement for 25 cycles at 0.1 Hz.

To simulate a Bankart lesion (defect state), the labrum was detached from the glenoid rim from the 3- to 6-o'clock position in a right shoulder using a No. 15 blade.[6,12] For each step in the testing protocol that followed preconditioning (Figure 1), 5 mm of displacement at 2 Hz was applied simultaneously to the 3 loading sutures in the anterior region, and they were held at 5 mm of displacement for 45 seconds to measure the capsular tension. Before each test, the resting tension of 2 N in each actuator was restored using the adjustable tension screws in order to account for displacement changes as the repaired labrum/capsule was brought back to the glenoid. As a consequence, the custom shoulder simulator allowed the anteroinferior capsule to be more uniformly loaded during the next phase of the testing protocol, which would not have been possible with a single nonadjustable soft tissue clamp that has been used in other studies.[5,12] Specimens were kept moist using a normal saline spray throughout the testing protocol.

Repair Technique

Suture anchors were placed at the articular margin of the glenoid, at approximately 45° to the glenoid face,[15] in a standardized order: 5-o'clock (ie, first anchor), 4-o'clock (second anchor), and 3-o'clock (third anchor) positions for a right shoulder.[9] Drill holes were placed and anchors were tapped to the recommended depth according to the manufacturer's guidelines. Anchors were then manually pretensioned. The sutures were carefully passed through the chondrolabral junction, and capsular tissue was punctured using a straight needle with a nitinol loop to shuttle the repair suture through the anterior capsule 10 mm from the capsulolabral junction[6] and at a position located anteroinferior to its respective anchors[12,15]: for example, the 4:30 position for the 4 o'clock anchor in a right shoulder. This would allow the labrum to be pulled superiorly to retension the AIGHL (ie, superior capsular shift).[12,15]

For all knotted repairs, the surgeon used 1.8-mm Fiber-Tak Soft Anchors (Arthrex) in a simple stitch configuration and tied with 2 half-hitches in the same direction, followed by 4 reverse half-hitches on alternating posts using a knot pusher.[12] For all knotless repairs, the surgeon used 1.8-mm Knotless FiberTak Soft Anchors (Arthrex), and the repair sutures were passed using the looped shuttle suture according to the manufacturer's instructions. For both anchor designs, repairs at each anchor position were completed once all conditions for significant loop security were met: (1) visual dimpling or indentation of the tissue, (2) inability to further compress the tissue, (3) inability to advance the suture loop further and (4) inability to position the arthroscopic probe between the labrum and glenoid. Additionally, for the knotless anchors, the force required to achieve said loop security ("securement force") was recorded by looping and tying the free end of the repair suture to a 444-N bidirectional load cell (Omega). Similarly, this load cell was used to measure the force to retension the knotless anchor according to the testing protocol. For retensioning, the repair suture was again looped onto the bidirectional load cell and steadily pulled a second time until the above criteria for loop security were met. These force measurements
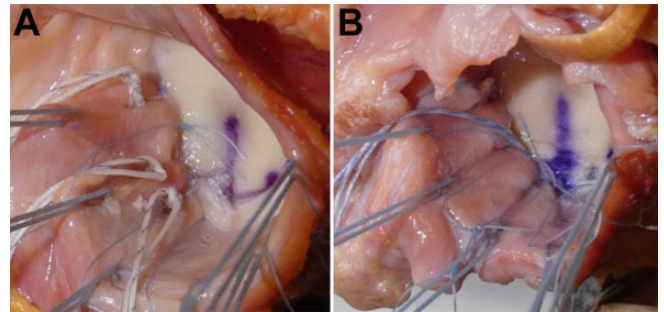
Figure 3. Final repairs of representative specimens from the (A) knotted and (B) knotless groups.

were blinded to the investigator completing the repairs and served as a control measure to quantify the force to retension the anchors compared with initial placement (M.R.L.). Representative knotted and knotless repairs are shown in Figure 3.

Anatomic Measurements

To ensure similar repair techniques and soft tissue handling between the repair groups, the labral height and capsular shift were measured using a MicroScribe G2X 3D digitizer device (Revware) and Rhino 5 software (Robert McNeel & Associates). The digitizer has a reported average error of 0.239 mm[16] with laboratory-confirmed accuracy of ±0.3 mm. The digitizer was securely fastened to the simulator frame, and a standardized local coordinate system was used (x-axis, anteroposterior; y-axis, superoinferior; z-axis, mediolateral). The center of the glenoid was recorded. For each iteration of the testing protocol, the locations of the capsulolabral junction or repair "bumper" at the 3:30, 4:40, and 5:30 positions in a right shoulder were recorded using the labral height marking sutures as a reference. The labral height was calculated by finding the difference in the z-coordinates between the glenoid center and the capsulolabral junction.[15] The superior capsular shift was determined by following the change in y-coordinate of the central AIGHL tensioning suture throughout the testing protocol.

Statistical Analysis

Descriptive statistics including means and standard deviations were used to characterize the 2 groups. A power analysis was performed to determine the number of specimens required to observe differences in capsular tension between the KT and KL_{end} constructs. Assuming a common standard deviation of ±1.25 N, a sample size of 6 specimens per group would provide 80% power to detect a 2.5-N difference in capsular tension at an alpha level of .05. Capsular tension was recorded as the mean force among all 3 anterior loading sutures. Pairwise comparisons of mean capsular tension, labral height, and superior capsular shift between the groups were carried out for the intact, defect, 1-anchor, 2-anchor, and 3-anchor construct conditions for KT and

TABLE 1
Donor Characteristics (N = 18 Shoulders)[a]

	KT Group (n = 6)	KL_{end} Group (n = 6)	$KL_{stepwise}$ Group (n = 6)	P
Age, y	55.3 ± 7.1	56.8 ± 3.3	55.7 ± 7.2	.454
Bone mineral density, g/cm^2	0.598 ± 0.150	0.605 ± 0.079	0.581 ± 0.105	.932
Laterality, n				
Left	2	3	4	
Right	4	3	2	
Sex, n				
Male	5	5	5	
Female	1	1	1	

[a]Data are presented as mean ± SD unless otherwise indicated. KL, knotless; KL_{end}, knotless with end retensioning; $KL_{stepwise}$, knotless with stepwise retensioning; KT, knotted.

TABLE 2
Comparison of Capsular Tension Between KT and KL_{end} Repairs[a]

	Capsular Tension, N, Mean ± SD			
State	KT	KL_{end}	Δ (95% CI)[b]	P
Intact	20.0 ± 4.1	20.9 ± 4.3	0.8 (−3.8 to 5.5)	.730
Defect	9.7 ± 3.7	10.3 ± 5.9	0.6 (−4.1 to 5.3)	.798
1 anchor	18.2 ± 5.3	17.4 ± 6.5	−0.9 (−5.5 to 3.8)	.717
2 anchors	20.8 ± 5.4	19.8 ± 5.8	−1.0 (−5.7 to 3.7)	.675
3 anchors	20.6 ± 5.4	21.6 ± 4.1	0.9 (−3.7 to 5.6)	.690
Retensioning[c]	NA	23.6 ± 4.8	2.1 (−0.3 to 4.4)	.081

[a]KL, knotless; KL_{end}, knotless with end retensioning; KT, knotted; NA, not applicable.
[b]Δ compared with KT.
[c]Unique comparison with the 3-anchor state of the KL_{end} group.

KL_{end}. To examine the effect of retensioning in the KL_{end} group, the final tension of the construct was compared with its own 3-anchor state tension. Similarly, the effects of the first and second retensioning steps in the $KL_{stepwise}$ group were investigated by comparing them with the 2-anchor and 3-anchor states, respectively. Results are reported as mean differences with corresponding 95% CIs. A P value of <.05 was considered significant for all comparisons. All analyses were performed using Stata 15 Software (StataCorp).

RESULTS

The mean age of the specimens was 55.9 ± 5.8 years. The mean BMD of the anteroinferior glenoid was 0.594 ± 0.109 g/cm^2. Donor characteristics are shown in Table 1. No statistical differences with respect to age or BMD were found among the 3 groups.

Capsular Tension

We found no significant differences in mean capsular tension at 5 mm of displacement between KT and KL_{end} anchor specimens for the intact, defect, 1-anchor, 2-anchor, and 3-anchor states (Table 2), indicating that repair techniques were comparable. The final retensioning step of all knotless anchors trended toward an increase in capsular tension compared with its 3-anchor state, but this was not statistically significant (Δ = 2.1 N; 95% CI, −0.3 to 4.2 N; P = .081). The stepwise improvements in capsular tension during retensioning of the knotless zipper technique group (ie, $KL_{stepwise}$) are shown in Figure 4; these changes were not statistically significant. Importantly, for both knotless groups, small but measurable increases in capsular tension were shown with retensioning steps. The average securement forces for both initial placement and retensioning of all knotless anchors are shown in Table 3.

Labral Height and Capsular Shift

We found no significant difference between changes in labral height via capsulolabral augmentation when averaging the 3:30, 4:30, and 5:30 positions and no significant difference in superior capsular shift between the KT group and both KL groups (Table 4).

DISCUSSION

The results of this study did not support our hypothesis that retensioning of knotless anchors would result in improved capsular tension compared with conventional knotted suture anchors. However, we observed that the retensioning of knotless suture anchors trended toward improvements in capsular tension via 2 different repair techniques. The final capsular tension in the KT anchor group was 20.6 N, compared with 21.6 N for the KL_{end} before retensioning (P = .690). After all anchors were tightened, the tension improved to 23.6 N in the KL_{end} group, although this was not statistically significant. Furthermore, the final tension in the capsule for the stepwise knotless repair was 22.7 N, with the first retensioning step contributing a larger degree to the final tension (Δ = 2.6 N). Perhaps more important, our study suggests that knotless anchors do not have to be retensioned in order to achieve adequate capsular tension compared with conventional knotted devices.
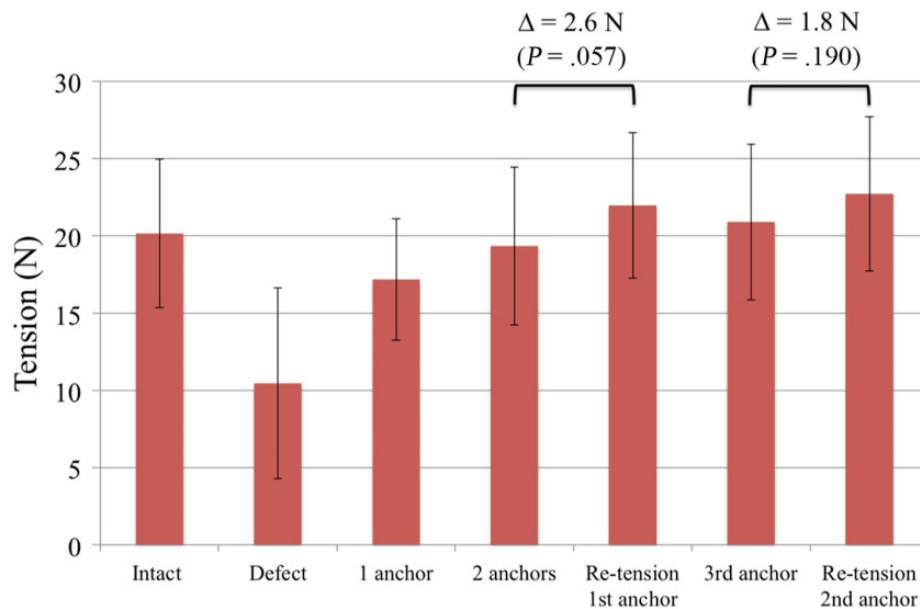
Figure 4. Graph showing stepwise improvement in capsular tension during retensioning of knotless anchors (KL$_{stepwise}$).

TABLE 3
Knotless Anchor Securement Force[a]

	Securement Force, N	
	KL$_{end}$	KL$_{stepwise}$
Initial	38.3 ± 8.8	37.1 ± 5.3
Retension	37.7 ± 9.0	31.8 ± 4.2

[a]Data are presented as mean ± SD. KL, knotless; KL$_{end}$, knotless with end retensioning; KL$_{stepwise}$, knotless with stepwise retensioning.

Knotless anchors have garnered increased popularity for a variety of shoulder surgeries over the past few decades.[6,10] Knotless designs have been shown to accelerate operative times.[2,10] At the same time, they avoid arthroscopic knot tying, for which proficiency can be difficult to obtain.[2,10] Furthermore, knotless anchors are believed to evade the risks of conventional tied anchors, specifically articular abrasion, knot migration, and knot loosening, aided in part by their low-profile design.[2,10,17] In addition, knotless constructs have been shown to have less variability among surgeons.[4] As reported by Lacheta et al,[6] early generations of knotless anchors could not be retensioned after initial fixation, limiting the strength of the repair.[15] However, newer all-suture knotless anchors are capable of tension adjustments after initial fixation of the anchor to bone.[6] Nonetheless, this has not been biomechanically demonstrated, which was the motivation for this study.

The ability to retension knotless anchors has several clinical advantages. First, the tension in soft tissue repairs can be easily modifiable. In particular, retensioning is helpful in patients with multidirectional instability and hyperlaxity because it allows the surgeon to tighten regions of the joint capsule that remain loose at the end of the repair or plication to centralize the humeral head. Considering our results, we would expect a cumulative effect of retensioning on the final strength of the repair. Second, capsular tightening afforded by retensioning may allow the surgeon to forgo additional supplemental fixation in regions of the repair that remain lax from either inadequate repair technique or loosely tied arthroscopic knots. Consequently, this technique would help minimize cost and operative time. Third, retensioning would help ensure complete approximation of the labrum back to the glenoid rim. Akin to plate fixation of fractures, initial cortical screws can be tightened later as additional screws are placed in the plate and the plate is brought closer to bone. It is possible that a similar phenomenon is experienced with soft tissue repairs. This would explain why all 4 conditions for loop security needed to be reestablished (ie, retensioned) for preceding anchors after the placement of additional anchors. In contrast, knotted suture anchors are incapable of these adjustments.

Previous investigations comparing conventional knotted and knotless suture anchor repairs for glenoid labral injuries have explored load to failure, ultimate load, and stiffness, with overall conflicting results. Lacheta et al[6] and Ranawat et al[14] identified no differences in ultimate load to failure and stiffness; the former used all-suture anchors. Leedle and Miller[8] identified higher ultimate load to failure with knotless anchors. In contrast, Nho et al[12] identified lower ultimate load to failure after cyclic loading with knotless anchors, which is concerning for loosening or suture slippage with repeated loads. Studies have also investigated the forces required to displace the fixation 2 mm, which has been accepted as a biomechanical equivalent of clinical failure.[9,12] In particular, contrary to their ultimate load findings, Nho et al found no statistically significant differences between the groups in terms of 2-mm

TABLE 4
Labral Height and Superior Capsular Shift Comparing Knotted and Knotless Repairs[a]

	KT	KL_{end}	$KL_{stepwise}$	P^b
Labral height				
Intact, mm	4.4 ± 1.6	6.7 ± 2.0	5.5 ± 1.6	
Final, mm	7.9 ± 2.1	10.1 ± 2.2	8.9 ± 1.9	
Δ, mm	3.5	3.4	3.4	.933, .643, .687
% increase	181	150	163	
Superior capsular shift, mm	4.2 ± 2.1	3.7 ± 0.6	3.9 ± 1.3	.413, .641, .873

[a]Data are presented as mean $\pm$ SD unless otherwise noted. KL, knotless; KL_{end}, knotless with end retensioning; $KL_{stepwise}$, knotless with stepwise retensioning; KT, knotted.
[b]Presented as KT vs KL_{end}, KT vs $KL_{stepwise}$, KL_{end} vs $KL_{stepwise}$.

displacement after cyclic loading, which the authors suggested was more clinically relevant than was ultimate load to failure.[12] The current study was the first to investigate the role that retensioning of knotless anchors has on capsular tension at subfailure loading, using a custom shoulder simulator setup. No repair or anchor failures occurred in either group, including knot slippage, secondary to subfailure loads selected in the study design.

Capsular augmentation of the labrum during repair, particularly with shifting the labrum superiorly and laterally, not only increases the labral height compared with the native state but also helps to restore the AIGHL to normal tension, improving stability by increasing the depth of the glenoid socket concavity and decreasing vulnerability of pathological humeral head translation.[15] As such, restoration of the labrum and labral height is critical in glenohumeral stability.[7] Slabaugh et al[15] showed that labral height restoration was similar between knotted and knotless anchors. Those authors identified a mean labral height improvement from 5.35 mm (native) to 8.05 mm (repaired), corresponding to a 159% improvement. Similarly, in the current study, we identified no statistical differences in labral height among knotted and knotless repairs, with mean improvements of 181%, 150%, and 163% compared with the native state for the KT, KL_{end}, and $KL_{stepwise}$ groups, respectively. Furthermore, superior capsular shift for the knotted and knotless groups was similar (4.2 mm, 3.7 mm, and 3.9 mm for KT, KL_{end}, and $KL_{stepwise}$, respectively). Similarities in labral height and capsular shift suggest that the repair techniques and soft tissue handling were similar among the groups.

The strengths of this study included a custom testing setup and protocol, which allowed us to determine the biomechanical consequence that retensioning of knotless anchors had on restoring capsular tension to the AIGHL. The knotless and knotted groups did not differ with regard to age, BMD, or sex. Further, all specimens were repaired and digitized by the same orthopaedic surgeon (M.R.L.) to ensure consistency, but calculations were blinded to this investigator to limit any bias. The surgeon was also blinded to the force requirement to tension the knotless anchors. Moreover, all repairs used the same instruments, suture material, and knot-tying techniques.

This study had several limitations. First, this is a biomechanical study that reflects only the measured capsular

tension at $t = 0$. As such, translation of these results to an in vivo environment should be made with caution, as natural biological healing cannot occur. Second, subfailure loads were selected to test for incremental changes in tension with subsequent anchor placement and retensioning to prevent anchor failure or loosening during the testing protocol. Consequently, these differences were small in magnitude, and it was difficult to determine statistical significance because of the measured standard error. It is possible that larger loads, such as loading to failure, may have accentuated the effects of retensioning to a greater degree. Future studies should explore the effect of retensioning on the load to failure of knotless suture anchors compared to those without retensioning. Third, these repairs were completed using an open technique with soft tissues removed, which may not account for any unforeseen difficulties in the arthroscopic setting. Fourth, we did not measure the reproducibility of our anatomic measurements in order to hasten procedural time.

CONCLUSION

Knotted and knotless suture anchors had similar overall restorations in anteroinferior glenohumeral ligament tension. However, knotless devices were capable of small but statistically insignificant improvements in capsular tension with retensioning.

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