Biomechanical Comparison of a Knotless Suture Anchor With Standard Suture Anchor in the Repair of Type II SLAP Tears

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Purpose: To compare the biomechanical strength of knotless suture anchors and standard suture anchors in the repair of type II SLAP tears. **Methods:** Five pairs of cadaveric shoulders (10 shoulders) were dissected free of soft tissue except for the glenoid labrum and long head of the biceps tendon. Type II SLAP tears were created and repaired with 1 of 2 anchors: the Mitek Lupine suture anchor or the Mitek Bioknotless suture anchor (DePuy Mitek, Raynham, MA). All specimens were preloaded to 10 N, and loaded for 25 cycles in 10 N increments to a maximum of 200 N. If specimens were still intact after 200 N, they were loaded to ultimate failure. The load at which 2 mm of gapping occurred, load to ultimate failure, mode of failure, and the number of cycles to failure were compared using the Wilcoxon signed-rank test. **Results:** Load to 2-mm gapping was lower (P = .042) for knotless anchors (70 N) versus knotted anchors (104 N), with similar differences for ultimate failure (74 N *v* 132 N; P = .043), cycles to 2-mm gapping (133 *v* 219 cycles; P = .042), and cycles to failure (143 *v* 297; P = .043). Eight of 10 specimens failed at the soft tissue interface (4 knotless, 4 knotted) and 2 failed by anchor pullout (1 knotted, 1 knotless). **Conclusions:** The results of this study suggest that repair of a type II SLAP with a Mitek knotted suture anchor and mattress suture configuration through the biceps anchor is stronger than repair with a Mitek knotless suture anchor. The most likely method of repair failure was at the suture–soft tissue interface regardless of the type of anchor used. The application of a suture anchor that requires arthroscopic knot tying may be preferable to a knotless anchor for the surgical repair of type II SLAP tears. **Clinical Relevance:** Repair of type II SLAP tears with knotless suture anchors may allow for the avoidance of arthroscopic knot tying but is weaker than repair with standard suture anchors. **Key Words:** Arthroscopy—Knotless—Labrum—SLAP—Suture anchor.

Surgical repair of type II SLAP lesions is currently the standard of care. Many authors have reported favorable results for repair of type II SLAP lesions through the application of suture anchors and bioabsorbable tacks.[1-8] Thal[9,10] first introduced the application of a knotless suture anchor design for the repair of anterior labral lesions, but Yian et al.[11] were the first to describe a technique for the application of these knotless anchors in the repair of SLAP lesions. Leedle and Miller[12] subsequently examined the pullout strength of several suture anchors, and found the knotless anchor was statistically stronger to pullout from the glenoid than the standard suture anchors. However, to our knowledge there have been no studies examining the strength of superior labral repair with knotless suture anchors or the mode of failure of SLAP repairs with these anchors.

The purpose of this biomechanical study was to compare a knotless suture anchor with a standard "knotted" suture anchor for the fixation of type II SLAP tears.

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METHODS

Five pairs of cadaveric shoulders (10 shoulders total) were obtained. Based on previous work it was estimated that 10 specimens per technique would be required to show a 40 N difference in load to 2-mm gapping between techniques at $P < .05$ with 80% power. Therefore, a matched pair design was used to reduce the number of required specimens while maintaining statistical power. Only donors under 50 years of age were used for this study, because SLAP repairs are typically performed in younger patients. After the specimens were thawed to room temperature, all soft tissue was removed from the glenoid except for the long head of the biceps and glenoid labrum. None of the used specimens had any evidence of biceps or labral pathology, or advanced degenerative disease of the articular cartilage. The glenoid and scapula, along with the attached labrum and long head of the biceps tendon, were trimmed down and potted in 2.4-in PVC pipe with polymethylmethacrylate bone cement (Howmedica International, Limerick, Ireland) for subsequent testing. Standardized type II SLAP lesions were then created as described by DiRaimondo et al.,[2] dissecting at least 5 mm medial to the glenoid and extending the labral tear 7 mm anterior and posterior to the anterior and posterior border of the biceps anchor, respectively. Bone density testing was not performed, because all specimens were relatively young and anchor pullout from bone was not expected to be the mode of failure.

Each pair of shoulders was then divided into 2 groups. All repairs were done in an open environment by the same surgeon and kept moist with frequent sprays of isotonic saline solution throughout the testing protocol. Shoulders in group 1 were repaired with a standard "knotted" Mitek lupine anchor preloaded with No. 2 Orthocord suture (Mitek, Norwood, MA; Fig 1A). The glenoid was predrilled with a 2.9-mm bit at a 45° angle to the superior glenoid and inserted at the biceps insertion on the superior labrum. Each suture limb was passed through the biceps anchor in a mattress configuration as described by Domb et al.[13] A spinal needle was passed 1 mm anterior to the posterior border of the biceps anchor, and a free No. 3 Prolene suture (Ethicon, Somerville, NJ) was passed through the spinal needle. The spinal needle was withdrawn, and the prolene suture was tied around 1 limb of the orthocord suture in the suture anchor. The Prolene was then pulled back out through the biceps anchor, passing the suture limb inferiorly to superiorly through the biceps anchor. The same

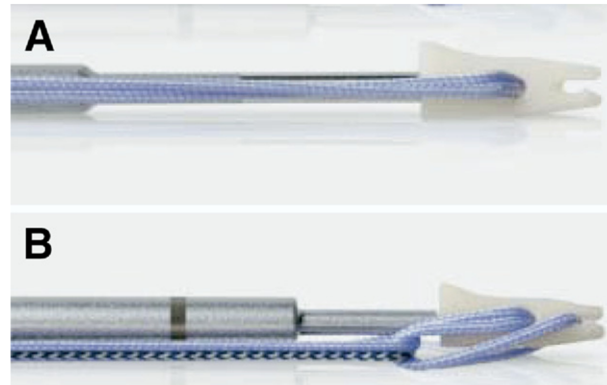

FIGURE 1. (A) Lupine (knotted) anchor and (B) Bioknotless suture anchor (DePuy Mitek, Raynham, MA).

procedure was repeated for the anterior limb, and the sutures were tied using a modified Weston knot and 4 alternating half-hitches, as would be performed arthroscopically.

In group 2, the contralateral shoulder from the same donor was repaired using the Mitek Bioknotless suture anchor (Mitek; Fig 1B). This anchor is also bioabsorbable, preloaded with No. 2 Panacryl suture, and is the same size as the Mitek lupine anchor but does not require the application of arthroscopic knot tying. This repair was performed using the knotless technique described by Yian et al.[11] First, a 2.9-mm hole was predrilled in the superior glenoid at the biceps anchor insertion on the superior labrum as was done for group 1. The utility suture in the knotless anchor was then threaded through a free needle. The free needle was passed inferiorly to superiorly through the center of the biceps anchor. The utility loop was then pulled through the soft tissue until the anchor loop was through the biceps anchor medially. One limb of the anchor loop was then engaged in the end of the knotless anchor, the soft tissue was tensioned, and the anchor was advanced into the previously drilled pilot hole until the repair was secure. A Krackow stitch using No. 2 Fiberwire (Arthrex, Naples, FL) was then run in the substance of the long head of the biceps of both groups of specimens for subsequent fixation during biomechanical testing. Care was taken to place 8 to 10 locking loops along the length of each tendon. Specimens were alternated between pairs (i.e., the right shoulder was repaired with a standard "knotted" anchor in one pair of shoulders, and repaired with the knotless anchor in the next pair of shoulders).

FIGURE 2. All specimens were tested with the biceps tendon loaded at 90° to the face of the glenoid.

Biomechanical Testing

The potted specimens were tested using a Materials Testing System (MTS Systems, Eden Prairie, MN). The specimen was secured to the MTS machine using 3 large bolts that countersunk into the PVC tubing. The tendon was then rolled around a Kocher clamp several times, thereby minimizing the stress on the clamp–tendon interface and eliminating slippage. The specimens were tested in an open environment with the line of pull at 90° to the face of the glenoid (Fig 2). The testing protocol consisted of applying a 10 N preload to the mounted specimens (to eliminate slack in the construct), followed by 25 cycles of loading from 10 N to 20 N. After completely unloading the construct, this cyclic loading procedure was repeated using progressively-larger loads in 10 N increments (i.e., 25 cycles from 10 to 30 N loading, 25 cycles of 10 to 40 N loading, etc.) until either ultimate failure of the construct or the construct survived 25 cycles of loading to 200 N. Loads were applied using a ramp protocol, at a rate of 1 cycle per second. Between cycling, the specimens were sprayed with saline to keep them from drying out.

Outcomes Measures

Repair failure was defined as permanent displacement of the repaired labral tissue from the glenoid of 2 mm at any point during the testing as measured by digital calipers (model H13415-0000; Scienceware, Pequannock, NJ). Ultimate failure was defined as rupture of the entire SLAP repair complex. The force and the number of cycles at which repair failure and ultimate failure occurred were recorded. The mode of failure was also recorded for all specimens (i.e., suture breakage, soft tissue tearing, and anchor pullout).

Statistical Analysis

Based on preliminary studies and previous work, it was estimated that 10 specimens per technique would be required to show a 40 N difference in load to 2-mm gapping between techniques at $P < .05$ with 80% power. Given the scarcity of fresh anatomic specimens that met the age criteria previously outlined, a matched pair design using the Wilcoxon signed-rank test (with a median of 0) was used to reduce the number of required specimens while maintaining statistical power. All statistics were computed using SPSS (version 10.0; SPSS, Chicago, IL).

RESULTS

Results are summarized in Table 1. The mean age of the specimens was 40.8 years (range, 31 to 47 years). The mean load repair failure, defined as permanent gapping of 2 mm, was lower ($P < .05$) for knotless anchors (70 N ± 22.3 N) versus knotted anchors (104 N ± 33.6 N). Mean ultimate failure was also lower for the knotless anchors compared to the knotted anchors (74 N ± 30.9 N *v* 132 N ± 58.9 N; $P < .05$; Fig 3). In addition, the knotless anchors showed fewer cycles to 2-mm gapping (mean, 133 cycles ± 57 *v* 219 cycles ± 80; $P < .05$), and cycles to failure (mean, 143 cycles ± 75 *v* 297 cycles ± 150; $P < .05$) than the knotted anchors.

Specimen Failure Mode

Eight of 10 specimens failed at the suture–soft tissue interface (4 knotless, 4 knotted). In all of these specimens, the intact suture pulled through the repaired labral tissue. Two specimens failed as a result of anchor pullout from the bone (1 knotted, 1 knotless). Both specimens that failed as a result of anchor pullout were in the same 42-year-old woman who died as a result of a motor vehicle accident.

Failure Outliers

A single specimen in the knotted mattress repair group withstood the entire testing protocol to 200 N of force without undergoing ultimate failure. This specimen was loaded to ultimate failure, and failed at an ultimate load of 307 N.

TABLE 1. *Study Results*

Specimen No.	Age/Sex	Side	Mode of Failure	Force 2-mm Gap (N)	Force to Ultimate Failure (N)	Notes
Knotless						
1	40 F	R	SST	40	40	
4	42 F	L	AP	70	70	AP
5	47 M	R	SST	60	60	
7	31 M	R	SST	80	90	
10	44 M	L	SST	100	120	
				Mean = 70	Mean = 74	
Knotted						
2	40 F	L	SST	80	80	
3	42 F	R	AP	80	80	AP
6	47 M	L	SST	90	200	Failed at 307 N
8	31 M	L	SST	110	110	
9	44 M	R	SST	160	190	
				Mean = 104	Mean = 132	

Abbreviations: AP, anchor pullout; F, female; L, left; M, male; R, right; SST, suture–soft tissue interface.

DISCUSSION

Arthroscopic repair of type II SLAP tears produces good clinical results and has become accepted as the standard of care for these injuries. While a variety of surgical techniques have been described for the surgical repair of SLAP tears, suture anchors are most commonly used in arthroscopic repair of these lesions. Suture anchors require arthroscopic knot tying techniques and advanced suture management that generally requires a learning period. Knotless suture anchors have been examined for the repair of Bankart lesions, but have not been biomechanically studied in the repair of SLAP lesions. The application of these devices could allow for the stable fixation of superior labral tears without the need for arthroscopic knot tying. This would potentially obviate clinical failure as a result of improper knot tying, knot failure, or recurrent pain as a result of the knots themselves. This study aimed to determine if repair of type II SLAP tears with knotless suture anchors provides fixation as strong as a standard "knotted" suture anchor with a mattress suture configuration.

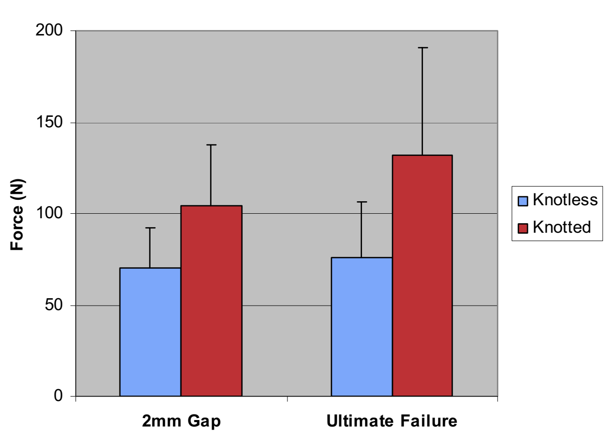

FIGURE 3. Load to repair failure and ultimate failure were higher for the knotted anchor when compared with the knotless anchor.

While application of knotless suture anchors is well documented in the arthroscopic treatment of Bankart lesions,[9,10,14,15] Yian et al.[11] was the first to describe the application of these same anchors in the arthroscopic treatment of SLAP lesions. The proposed advantages of such fixation included low profile repair, avoidance of arthroscopic knot tying, reapproximation of the repaired tissue directly to bone, and potentially more efficient surgery. Leedle and Miller[12] subsequently examined the pullout strength of the Mitek Bioknotless suture anchor in cadaveric glenoids. They found that the pullout strength of the Bioknotless anchor averaged 650 N, which was significantly stronger when compared with 2 other commercially available "knotted" anchors in their study.[12] Other authors have found no difference in pullout strength between knotless and standard knotted anchors.[16] However, as previous research examining both labral and rotator cuff repair has shown, arthroscopic repair with suture anchors is most likely to fail at the suture–soft tissue interface. While data regarding the pullout strength of various suture anchors are certainly useful, they may not accurately represent the strength of soft tissue repair using these anchors.

There is a relative paucity of biomechanical literature regarding the optimal method of repair of type II

SLAP tears. DiRaimondo et al.[2] examined the strength of 3 repair techniques of type II SLAP tears: 1 group with a simple suture technique, 1 with a mattress suture technique, and the last group using a bioabsorbable tack.[2] In their study, the repairs done with the suture anchor were stronger than the tack, but this difference was not statistically significant. The results of their study suggested that labral repairs underwent ultimate failure at labral–implant interface.

Domb et al.[13] subsequently compared the biomechanical strength of 3 different suture configurations for the repair of type II SLAP tears in cadaveric glenoids. Group 1 had a simple suture anterior to the biceps insertion. Group 2 had a loop of suture both anterior and posterior to the biceps instertion. Group 3 had a mattress suture configuration through the biceps anchor. Their work revealed that a mattress suture configuration through the base of the long head of the biceps anchor in the superior labrum underwent repair failure at 106 N and ultimate failure at 194 N. This technique was stronger than a single suture loop anterior to the biceps anchor or a loop both anterior and posterior to the biceps anchor. These authors suggest that a mattress suture configuration through the biceps anchor may allow for more stability after repair and better potential for healing. It was for this reason we performed all "knotted" repairs with a mattress suture configuration. The results of our study found comparable strength values for a mattress suture configuration through the biceps anchor for repair failure (104 N) and ultimate failure (132 N), even though the average age of our donors was significantly younger than in their study (40.8 *v* 57.4 years). Additionally, in Domb et al.'s study,[13] all specimens failed at the glenoid–labrum interface. Their findings were similar to the results of our study, in which both knotted and knotless anchors were most likely to fail at the suture–soft tissue interface.

Zumstein et al.[17] examined gap formation using the Mitek Bioknotless suture anchor and Mitek GII "knotted" suture anchor. Their work showed that ultimate strength to failure was similar between the anchors, but gap formation was greater for the Bioknotless anchor when compared to the GII anchor. Although their study did not include actual soft tissue repair as was done in our study, the results of our work seem to support their finding that knotless anchors are more likely to undergo gap formation at lower loads than knotted anchors. Zumstein et al.[17] expressed reservation for the application of knotless anchors, and encouraged clinicians to keep in mind postoperative loading when considering using knotless suture anchors.

Yoo et al.[18] recently compared 3 different suture anchor configurations for the repair of posterior type II SLAP tears. This study found that single-anchor mattress repair of a posterior type II SLAP tear was weaker than repair with a single anchor with a loop around the labram and 2 anchors each with a loop around the labrum when the biceps was loaded posteriorly and superiorly. Morgan et al.[19] subsequently compared the biomechanical strength of 2 suture configurations for the repair of type II SLAP tears subjected to a "peel back" mechanism of failure. Group 1 had a suture anchor and simple suture both anterior and posterior to the biceps anchor. Group 2 had 2 suture anchors posterior to the biceps anchor. In this study, the biceps was pulled in a posterior direction, attempting to re-create the peel back mechanism during the late cocking phase of throwing in overhead athletes. In their study, the force to repair failure (2 mm of displacement) was 43 N for 1 suture anterior and 1 posterior to the biceps anchor and 40 N for both sutures posterior to the biceps insertion. These forces are noticeably lower than that achieved in our study and the work of previous authors. However, because the biceps was loaded in a posterior direction in both of these studies (as opposed to 90° to the face of the glenoid), direct comparison of these studies remains difficult.

There are several limitations inherent to this study. The knotless anchors used in this study allow for 2 suture limbs to be passed through labral tissue. However, the knotless anchor design does not allow for the limbs to be passed in a true mattress configuration, as was performed with our knotted anchors. Although the total amount of suture passed through labral tissue was equivalent between groups, this simple design difference could account for the difference in repair strength seen in our study. In addition, the use of cadaveric shoulders provides an ideal testing scenario, but fails to take into account those factors that may come into play in vivo. The testing protocol we applied followed the model originally described by DiRaimondo et al.[2] and subsequently used by Domb et al.[13] By pulling the biceps tendon at 90° to the surface of the glenoid face, a simple and reproducible model is employed. However, the dynamic forces the superior labrum experiences in vivo are not truly re-created with this model. There is certainly biomechanical evidence that the superior labrum may be more prone to a type II SLAP tear with a more posteriorly directed force as may be seen in overhead throwing athletes.[20,21] However, given the fact that nonoverhead throwing athletes also commonly sustain superior labral injuries, it is certainly reasonable to suggest that more than one mechanism results in the formation of type II SLAP tears. While the complex and dynamic forces are quite difficult to accurately re-create in a cadaveric model, we attempt to put our work in context with the current literature by applying the force to the long head of the biceps in a similar manner as previous authors.

It is also worth noting that the open nature of the repairs performed in this study provides optimal conditions for anchor placement, suture passage, and knot tying. Arthroscopic repairs performed in vivo frequently are not performed under optimal conditions, and this certainly can have an impact on the quality of repair. This factor is not taken into account with our study design. SLAP repairs are commonly performed on young patients with more dense bone and stronger tissue quality. A relative strength of our study is that we did limit the age of the donors to under 50 years of age (average, 40.8 years) and tested the shoulders in matched pairs (i.e., left and right shoulder of the same donor). Nonetheless, 2 specimens in our study did fail by anchor pullout. One knotted and 1 knotless anchor failed by anchor pullout, both in the same 42-year-old female donor who died in a motor vehicle accident. While anchor pullout was not expected to be the mode of failure of any of our specimens, bone densitometry would have provided useful information given the nature of these results. Another weakness is the definition and measurement of repair failure as 2 mm of gapping. All of our measurements of repair gapping were made using digital calipers, which is inherently less precise than the use of digital markers like those used by DiRaimondo et al.[2] and subsequently by Domb et al.[13] Mileski and Snyder[5] suggested that arching of the superior labrum at the biceps anchor of greater than 3 to 4 mm with traction on the long head of the biceps was in need of repair. While admittedly it is an arbitrary definition of repair failure, it is certainly within reason to suggest that a gap of this magnitude may impede labral healing to the glenoid.

Finally, our model fails to take into account the vascularity and healing potential of the superior labrum. This study only examines the initial fixation strength of the studied repair techniques. Strangulation and disruption of the vascular supply after repair also cannot be examined, and the impact tissue viability may have on repair was also not examined.

CONCLUSIONS

The results of this study suggest that repair of a type II SLAP with a Mitek knotted suture anchor and mattress suture configuration through the biceps anchor is stronger than repair with a Mitek knotless suture anchor. The most likely method of repair failure was at the suture–soft tissue interface, regardless of the type of anchor used. The application of a suture anchor that requires arthroscopic knot tying may be preferable to a knotless anchor for the surgical repair of type II SLAP tears.

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