Biomechanical Comparison of 3 Suture Anchor Configurations for Repair of Type II SLAP Lesions

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Purpose: Our purpose was to compare 3 commonly used suture anchor configurations for repair of type II SLAP lesions. **Methods:** Biomechanical testing was performed on 3 groups of 7 cadaveric shoulders by use of an optical linear strain measurement system. Standardized type II SLAP lesions were created and repaired via 3 suture anchor configurations: (1) a single simple suture anterior to the biceps; (2) two simple sutures, one anterior and one posterior to the biceps; and (3) a single mattress suture through the biceps anchor. Cyclic traction was applied to the biceps tendon, and strain failure (defined as 2 mm of permanent displacement), yield, and pullout loads were measured. **Results:** The mean load to strain failure was 63 N in group 1, 70 N in group 2, and 106 N in group 3. The mean load to ultimate failure was 140 N in group 1, 194 N in group 2, and 194 N in group 3. Strain failure load was significantly higher in the mattress suture group than in either of the other two groups ($P < .05$). Groups 2 and 3 both had a significantly higher load to ultimate failure than group 1. **Conclusions:** When type II SLAP lesions were subjected to cyclic traction, the load to strain failure was greater with a single anchor and mattress suture than with one or two anchors with simple sutures around the labrum. Fixation with two simple sutures appears to provide intermediate load to strain failure. **Clinical Relevance:** The results of this study suggest that a single anchor with a mattress suture may be a biomechanically advantageous construct for the repair of type II SLAP lesions. **Key Words:** SLAP—Labrum—Repair—Biomechanics—Shoulder—Arthroscopy.

Injuries to the superior aspect of the glenoid labrum near the insertion of the long head of the biceps are the source of significant disability to patients, specifically the overhead-throwing athlete.[1-3] Andrews et al.[4] first described this lesion in 1985 and hypothesized that the biceps tendon acted to "pull off" of the labrum during the deceleration phase of throwing. In 1990 Snyder et al.[3] named these injuries SLAP lesions and classified them into 4 types. The most commonly reported was a type II lesion, in which the superior labrum and the biceps anchor were avulsed off of the glenoid.

Surgical repair of symptomatic type II SLAP lesions has become the standard of care. Many authors have reported favorable results using suture anchors or bioabsorbable tissue tacks as a means to fix the labrum to the glenoid.[1-3,5-12] Although a variety of techniques and suture configurations have been described, biomechanical data comparing the initial strength of the various repairs are sparse. DiRaimondo et al.[8] compared the initial strength of repair of type II lesions with 2 suture anchor configurations (2 simple sutures *v* 2 mattress sutures, both through the labrum) and 1 tissue tack. They found that the 2 suture anchor configurations were equivalent and both provided better fixation as compared with the tissue tack, although this difference did not reach statistical significance. Panossian et al.[13] showed that glenohumeral translation is increased by creation of a SLAP lesion and is

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decreased by repair of the lesion, but they used only 1 repair technique. Although this study provides useful information, there is no conclusive evidence to support any one repair technique.

The purpose of this biomechanical study is to compare the initial fixation strengths for 3 suture anchor configurations in the repair of type II SLAP lesions.

METHODS

Cadaver Preparation

Twenty-one fresh-frozen cadaveric shoulders were obtained. All donors were men aged under 65 years (mean age, 57.4 years) with no history of shoulder injury or surgery. After thawing of the specimens at room temperature, soft tissues were dissected off of the shoulders, sparing the biceps tendon and glenoid labrum. The humerus was disarticulated from the glenoid. The biceps tendon and anchor, as well as the glenoid labrum, were inspected to ensure that all were intact. The scapula was potted in resin and rigidly mounted to a metal frame with 4 bolts. Standardized type II SLAP lesions were created according to the protocol used by DiRaimondo et al.[8] The lesions were created by sharp dissection 5 mm medial to the glenoid rim and extended 7 mm from the anterior and posterior borders of the biceps tendon. The bone density of the specimens was not tested because pullout of the anchor from the bone was not expected to be the mode of failure.

Repair Techniques

The cadaveric shoulders were divided into 3 groups by random assignment. All repairs were performed with Arthrex 3-mm Bio-SutureTak absorbable suture anchors, loaded with No. 2 FiberWire (Arthrex, Naples, FL). Holes were predrilled in the glenoid rim at a 45° angle to the glenoid face by use of the notched drill guide, and the anchors were impacted to the recommended depth. This technique simulated the technique of anchor insertion through an anterior portal. All sutures were tied with 6 sliding half-hitches by use of a knot pusher and standard arthroscopic knot-tying technique.

In group 1 a single suture anchor was placed at the anterior border of the biceps tendon. A simple knot was tied by passing one limb of the suture over the labrum and tying the knot over the top of the labrum (Fig 1).

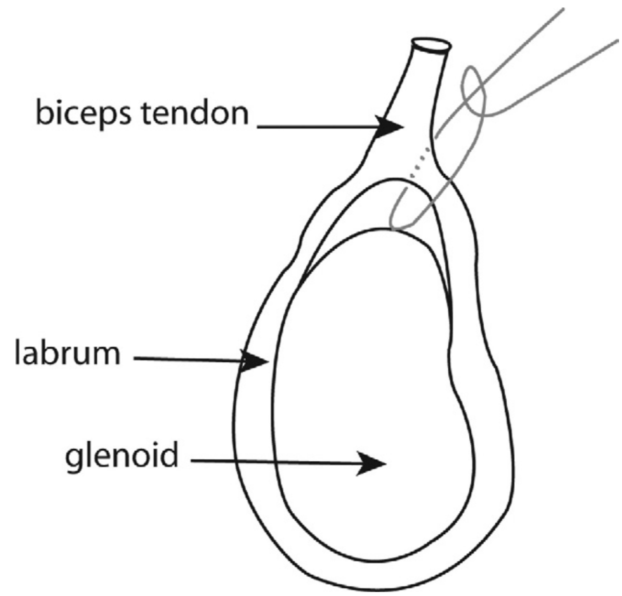

FIGURE 1. Single simple suture (group 1).

In group 2 two suture anchors were placed, one at the anterior border and one at the posterior border of the biceps tendon. A simple suture was tied around the labrum from each anchor (Fig 2).

In group 3 a single suture anchor was placed directly medial to the biceps tendon, and a horizontal mattress stitch was tied over the top of the biceps anchor in the following manner. A spinal needle was used to penetrate the biceps anchor 1 mm anterior to the posterior border of the tendon. A No. 3 Prolene suture (Ethicon, Somerville, NJ) was passed through the spinal needle, and the needle was withdrawn. The Prolene suture was tied to one limb of suture from the suture anchor and was used to pull the limb through the biceps anchor from inferior to superior. The same procedure was repeated for the second suture limb, passing it through the biceps anchor 1 mm posterior to the anterior border of the tendon. The two sutures were then tied over the top of the biceps anchor, completing the horizontal mattress suture (Fig 3). This simulated our arthroscopic technique in which the spinal needle is placed through the site of the portal of Neviaser and directed through the biceps anchor. The spinal needle is used to pass the shuttle suture through the labrum, which is then retrieved through the anterior portal and used to pass the suture from the anchor.

Biomechanical Testing

The scapula was potted in resin and mounted on a custom-made linear displacement platform (Parker

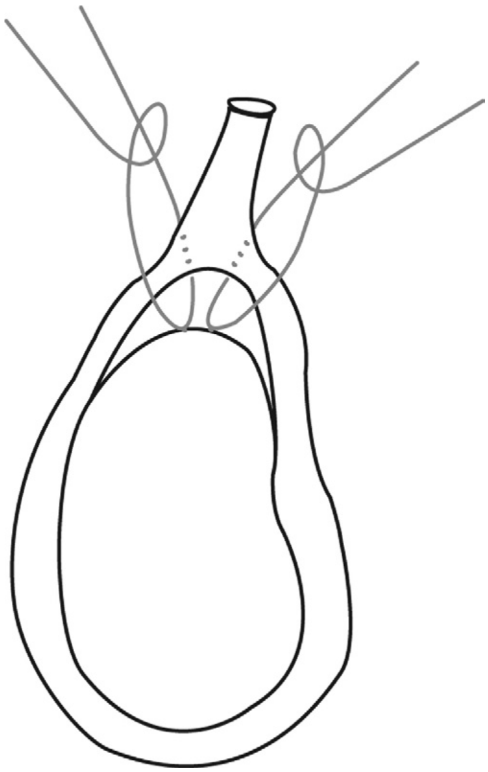

FIGURE 2. Two suture anchors with simple sutures tied around labrum (group 2).

404XL). The biceps tendon was cut 4 cm from the labrum, and the free end of the tendon was sandwiched between two 1-cm^2 strips of sandpaper by use of Krazy Glue (Elmer's Products, Columbus, OH). This end was clamped to a 500-N load cell (ML-100T; Transducer Techniques, Temecula, CA). A 7-mm hemispheric optical marker was placed in the superior glenoid bone, 10 mm medial to the glenoid rim. A second marker was placed in the biceps tendon approximately 25 mm from the glenoid marker. An optical linear strain measurement system (I-MAQ Vision; National Instruments, Austin, TX) positioned above the shoulder was used to measure the displacement of the biceps tendon–anchor complex from the glenoid bone (Fig 4).

The testing method was based on the protocol of DiRaimondo et al.[8] A traction load was applied to the biceps tendon in a linear fashion under displacement control at an angle perpendicular to the glenoid face. A 10-N preload was initially applied. Specimens were cyclically loaded with the target load beginning at 20 N and increasing by 10-N increments with each cycle. Between cycles, the traction was returned to the baseline load of 10 N for 20 seconds. Testing was halted when a peak load of 200 N was reached or when the soft tissues or implants failed. The testing control system including collection of displacement and load data was performed with LabVIEW software (version 6.0; National Instruments). Testing was performed on the intact specimens and after creation and repair of the SLAP lesion.

Outcome Measures

Strain failure was defined as 2 mm of permanent displacement of the biceps anchor–labrum complex

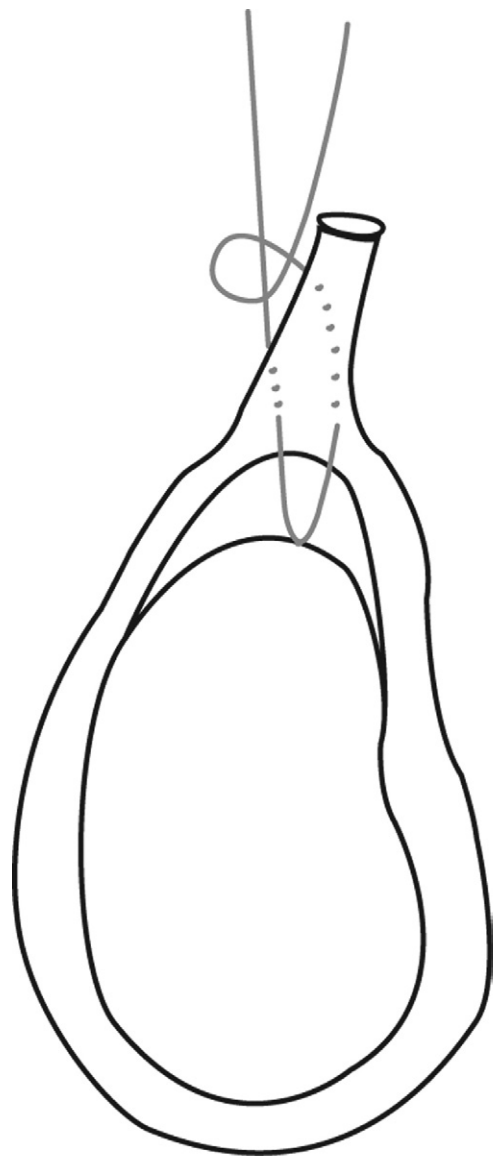

FIGURE 3. Single suture anchor with horizontal mattress suture through biceps anchor (group 3).

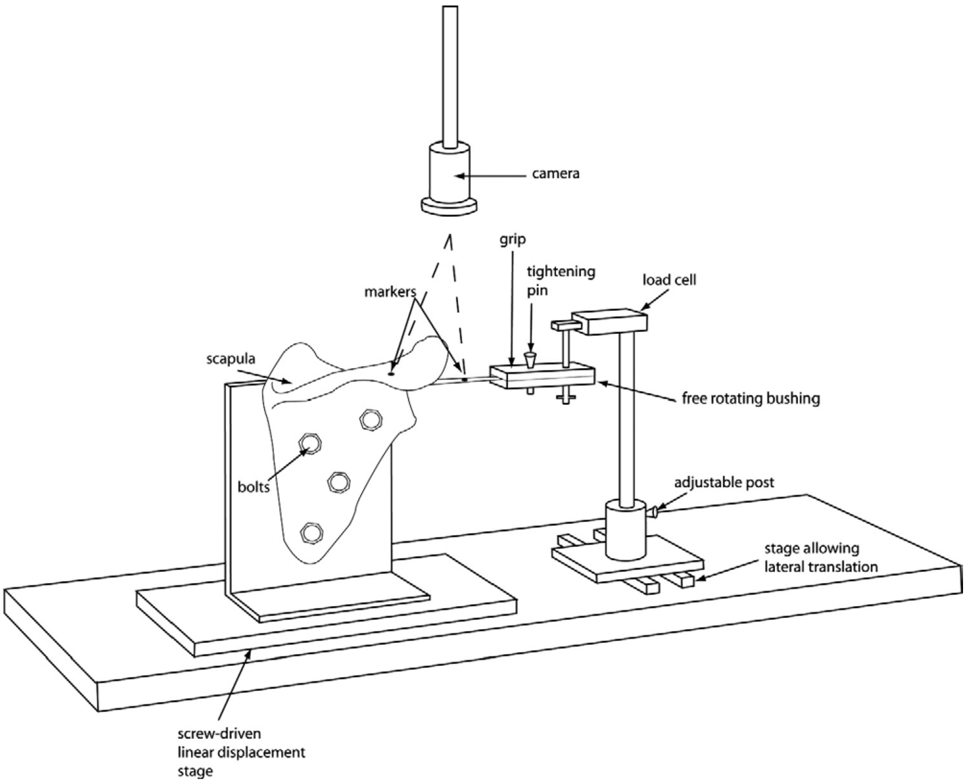

FIGURE 4. Testing apparatus.

after returning to the baseline load after completion of a cycle. Ultimate failure was defined as the maximum load tolerated before the implant broke or pulled out or the labrum or biceps anchor tore. Stiffness was defined as the force per unit displacement. The stiffness of the repaired specimen was measured as a percentage of the stiffness of the intact specimen.

Statistical Analysis

Power analysis was performed before the study was begun based on the results of DiRaimondo et al.[8] in their comparison of screw-in anchors and tacks. On the basis of an α of .05 and desired power of greater than 0.80, we chose to include 7 specimens per group. A second power analysis was performed based on the results of the first 4 specimens in each group. On the basis of this sample, it was calculated that a sample size of 6 per group would yield a power of 0.87. The study was therefore continued with the original sample size of 7 per group. Results were compared by use of the unpaired 2-tailed t test, with an α of .05.

RESULTS

The mean load to strain failure was 63 N in group 1, 70 N in group 2, and 106 N in group 3. The strain failure load was significantly higher in the mattress group than in either of the other two groups ($P < .05$). The mean load to ultimate failure was 140 N in group 1, 194 N in group 2, and 194 N in group 3. Groups 2 and 3 both had a significantly higher load to ultimate failure than group 1. These results are shown in Fig 5. All failures involved pullout of the suture from within the anchor.

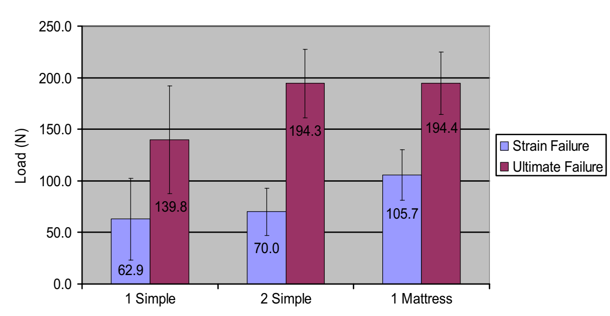

FIGURE 5. Load to strain failure and ultimate failure.

The stiffness of the repaired specimens as a percentage of the stiffness of the intact specimens was 17% for a single simple suture, 26% for two simple sutures, and 29% for a single mattress suture. The stiffness for the mattress suture was significantly greater than that for the single simple suture ($P < .05$). The other differences were not significant. These results are shown in Fig 6.

DISCUSSION

Arthroscopic repair of symptomatic type II SLAP lesions provides consistently good clinical results and has become the standard of care.[1-3,5-12] A variety of techniques and suture configurations have been described, but biomechanical data supporting the use of one over another are lacking.[1,9,12,14-24] In this study the initial repair strengths of three suture configurations were compared. A single suture anchor in a mattress configuration over the biceps anchor was found to withstand a higher load to strain failure than either of the other two suture configurations.

Incorporating the biceps anchor in the fixation of type II SLAP lesions is a logical option because it directly addresses the pathophysiology of the lesion. In type II SLAP lesions the long head of the biceps tendon and the superior labrum are detached from the insertion on the superior glenoid. Biomechanical studies have shown that the long head of the biceps tendon acts to depress the humeral head, limit shoulder external rotation, and confer anterior stability of the glenohumeral joint.[25,26] When this complex is disrupted, the shoulder is allowed to go into extreme external rotation, putting undo stress on the inferior glenohumeral ligament. This can eventually lead to subtle instability and continued pain. This phenomenon is believed to be the reason why nonoperative management and simple debridement of these lesions lead to poor clinical results.[27]

To our knowledge, there is only one previous study that has specifically investigated the initial fixation strength of type II SLAP lesions with suture anchors.[8] This study compared the fixation strength of two suture anchors in a simple configuration on either side of the biceps anchor (group 1), two anchors each fixed in a mattress suture configuration (group 2), and a bioabsorbable tissue tack (group 3). The mattress sutures did not incorporate the biceps anchor; instead, they were adjacent to it. The authors found that the suture anchors were slightly stronger than the tissue tack, but they found no difference between the simple and mattress sutures. In their study the mean load to repair failure was 123 N in group 1, 114 N in group 2, and 95 N in group 3. The mean load to ultimate failure was 163 N, 161 N, and 145 N, respectively. In our study the mean load to repair failure for the mattress configuration incorporating the biceps anchor was 106 N, whereas the mean load to ultimate failure was 194 N. As in our study, the previous authors also made the observation that all specimens failed at the glenoid-labrum interface just below the biceps anchor.

In an effort to give context to our findings, we used the testing protocol previously described by DiRaimondo et al.[8] The same parameters were used with regard to the model, the direction of applied traction, the rate at which load was applied, the starting load and maximum loads, the parameters that define failure, and the method to determine displacement. Our testing apparatus comprised a custom-designed uniaxial testing system in which traction on the long head of the biceps is applied through a load cell attached to a linear bearing, which allows alignment of the tendon in the direction of the pull. The previous study used a servohydraulic testing machine. In our study the markers were placed on the superior side of the glenoid-labrum complex, whereas in the previous study they were placed on the inferior side. It is unknown what difference, if any, this may cause.

Several limitations are inherent in this study. First, the open nature of our cadaveric model allowed direct visualization for ideal placement of the suture anchor into the glenoid and facilitated placing, passing, and tying of the sutures. These tasks can be quite challenging when performed arthroscopically, and differences in surgeon skill and experience may limit the generalizability of the findings presented in this study. The surgical technique for placement of a mattress suture through the biceps anchor has been described by Mileski and Snyder.[9]

Second, the manner in which the biceps anchor was loaded may not accurately reflect the strains seen in

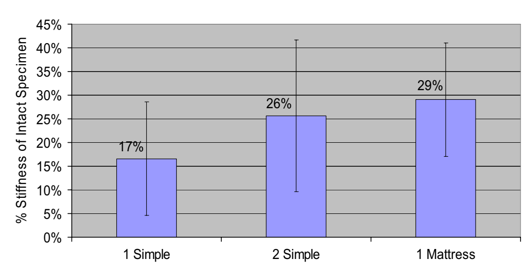

FIGURE 6. Stiffness of repaired specimens as a percentage of stiffness of intact specimens.

vivo. Our study only examined forces directed in one direction, 90° perpendicular to the face of the glenoid. Although this provided a simple model in which to compare many samples, it does not reflect the complex range of motion to which the shoulder is subjected. Further studies may be warranted to evaluate the strength of the repair with the shoulder in various positions.

Finally, this study was performed in vitro with human cadavers and may not accurately resemble the biologic environment seen in vivo. As with any orthopaedic implant, fixation of the labrum to the glenoid with suture anchors is a temporizing procedure until the tissue heals. The cadaveric model does not account for the role of healing in the strength of the repair. It is possible that certain suture configurations may result in strangulation of the tissue and inhibit healing. However, the vascular region of the labrum is at the periphery, so placement of sutures at the midportion should not disrupt blood flow.[28] In addition, cadavers are generally older than patients undergoing SLAP repairs, and therefore there may be differences in tissue quality.

CONCLUSIONS

When type II SLAP lesions were subjected to cyclic traction, the load to strain failure was greater with a single anchor and mattress suture than with one or two anchors with simple sutures around the labrum. Fixation with two simple sutures appears to provide intermediate load to strain failure.

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