

Tape Versus Suture in Arthroscopic Rotator Cuff Repair

Biomechanical Analysis and Assessment of Failure Rates at 6 Months

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Background: Rotator cuff retears after surgical repair are associated with poorer subjective and objective clinical outcomes than intact repairs.

Purpose: The aims of this study were to (1) examine the biomechanical differences between rotator cuff repair using No. 2 suture and tape in an ovine model and (2) compare early clinical outcomes between patients who had rotator cuff repair with tape and patients who had repair with No. 2 suture.

Study Design: Controlled laboratory study and cohort study; Level of evidence, 3.

Methods: Biomechanical testing of footprint contact pressure and load to failure were conducted with 16 ovine shoulders using a tension band repair technique with 2 different types of sutures (No. 2 suture [FiberWire; Arthrex] and tape [FiberTape; Arthrex]) with the same knotless anchor system. A retrospective study of 150 consecutive patients (tape, n = 50; suture, n = 100) who underwent arthroscopic rotator cuff repair by a single surgeon with tear size larger than 1.5 × 1 cm was conducted. Ultrasound was used to evaluate the repair integrity at 6 months postsurgery.

Results: Rotator cuff repair using tape had greater footprint contact pressure (mean ± standard error of the mean, 0.33 ± 0.03 vs 0.11 ± 0.3 MPa; $P < .0001$) compared with repair using No. 2 sutures at 0° abduction with a 30-N load applied across the repaired tendon. The ultimate failure load of the tape repair was greater than that for suture repair (217 ± 28 vs 144 ± 14 N; $P < .05$). The retear rate was similar between the tape (16%; 8/50) and suture groups (17%; 17/100).

Conclusion: Rotator cuff repair with the wider tape compared with No. 2 suture did not affect the retear rate at 6 months postsurgery, despite having superior biomechanical properties.

Keywords: shoulder; rotator cuff; muscle injuries; biology of tendon; biomechanics of tendon

Rotator cuff tears are a common cause of debilitating shoulder pain and can lead to severe loss of function.

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Surgical interventions aim to repair the abnormal anatomical relationship of the damaged rotator cuff tendons by reattaching the torn tendons back to the humeral head and restoring the shoulder to its preinjury state.¹⁰

Advances in surgical equipment have enabled surgeons to have a greater choice in the type of repair and materials used. However, retear postsurgery for larger sized tears is a common phenomenon.^{13,20} Preoperative tear size is one of the best predictors of repair integrity, particularly anteroposterior tear length.^{9,19} The retear rates of large tears remain high, ranging from 10% up to 41% by 6 months in recent studies.^{2,11} Although many patients improve symptomatically after surgery despite recurrent tears of the rotator cuff, an intact repair results in a superior clinical outcome.^{4,11}

A number of studies have shown that repair techniques that include more sutures and more anchors provide better

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repair construct strength. In theory, repairs with better construct strength are less likely to fail. Intact repairs have been shown to yield significantly superior clinical results than return repairs.⁹ Contact pressure of the tendon to the rotator cuff footprint may also be important. Increased footprint contact pressure may lead to better healing of the tendon-bone interface.^{1,6,15} Miller et al¹¹ in 2011 and Iannotti et al⁷ in 2013 have shown that in most repairs, especially in relatively larger tears as shown in our study, failure occurs within the early postoperative period (<3 months).

A thicker tape such as FiberTape (Arthrex) could be used in rotator cuff repair with the intention to maximize the contact pressure at the tendon-to-bone interface, which might be beneficial to healing. Biomechanical studies have shown that rotator cuff repair with a wider tape in place of a No. 2 suture had higher failure load and tendon-to-bone contact pressure.³ There have been no studies to examine whether this favorable biomechanical result translates to superior clinical outcomes.

This is a 2-part study examining using tape in rotator cuff repair. For the biomechanical component, our hypothesis was that rotator cuff repair with tape will have superior footprint contact pressure and higher load to failure compared with suture repair. Clinically, our hypothesis is that rotator cuff repair with tape will lead to a lower retear rate compared with rotator cuff repair with the traditional No. 2 suture. The primary aim of this study was therefore to determine whether tape repair leads to a lower retear rate compared with suture repair at 6 months postoperatively.

METHODS

Part 1: Biomechanical Study

Rotator Cuff Repair Model. Sixteen ovine shoulders (local Merino breed) of almost identical size and weight were used in this experiment, with equal distribution of left to right shoulders randomized into 2 groups. The ovine infraspinatus tendon was used because of its similarity to the human supraspinatus tendon and our experience with this model.^{1,14,16} Each shoulder was prepared by removing all tissues with the exception of the humerus, infraspinatus tendon, and scapula. The infraspinatus tendon was completely detached from its footprint on the proximal humerus. The “bite” was standardized to 13 mm. Two bone holes were created using a punch 5 mm lateral to the footprint and 18 mm apart using a custom-made drill guide plate. This was done to mimic a full-thickness rotator cuff tear in a human shoulder and so that the anchor placement would be exactly the same for each specimen. The torn infraspinatus tendon was then repaired back to the proximal humerus using 1 of 2 materials: No. 2 FiberWire (Arthrex) or 2-mm FiberTape (Arthrex), using an inverted mattress configuration as described below. Figure 1 shows the repair and test construct. The medial-lateral and anterior-posterior dimensions of the infraspinatus footprint and tendon thickness were measured using a digital caliper (RS193-252; Mitutoyo).

Group 1: Rotator Cuff Repair With FiberWire. The repair was performed using two 5.5-mm knotless suture anchors

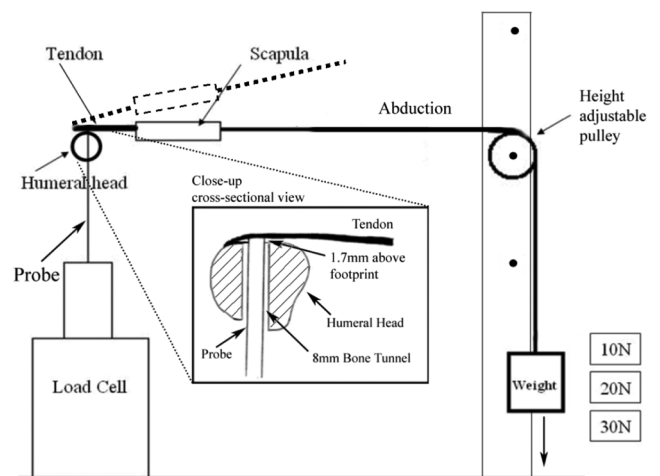


Figure 1. Schematic of the biomechanical construct.

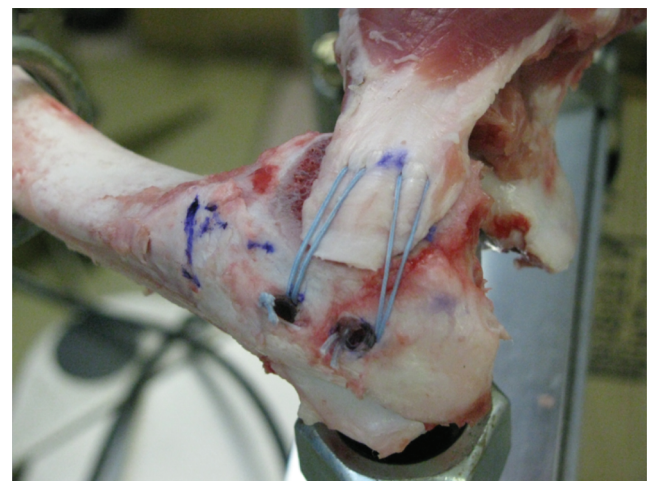


Figure 2. Ovine cuff repair model using FiberWire.

(SwiveLock C; Arthrex). Prior to placing the anchors, 2 inverted mattress sutures (FiberWire) were passed through the infraspinatus approximately 13 mm medial to the torn edge of the tendon using a suture passer (Scorpion Suture Passer; Arthrex). Two pilot holes were created in the proximal humerus 5 mm lateral to the infraspinatus footprint with a 4.5-mm-diameter punch (Arthrex). Two anchors were used regardless of tear size. There were no side sutures placed. The free ends of each inverted mattress suture were delivered over the tendon and through an eyelet of a knotless anchor forming a tension band construct. Each knotless anchor was placed in the appropriate pilot hole and locked into bone. The suture was tensioned until the tendon was reduced over the bony footprint, then the anchor was screwed into the bone for fixation (Figure 2).

Group 2: Rotator Cuff Repair With FiberTape. In this repair group, the same tension band construct was used as described above; however, 2-mm suture tape (FiberTape) was used in place of the No. 2 sutures (FiberWire) (Figure 3).

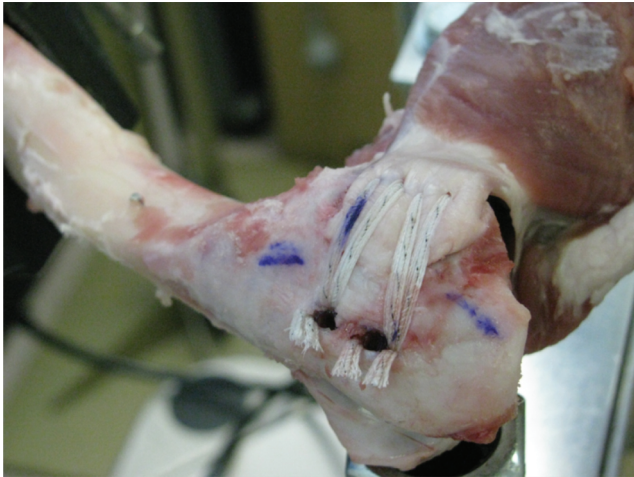


Figure 3. Ovine cuff repair model using tape.

TABLE 1
Tear Size of the Infrapinatus Footprint^a

| | Suture (n = 8) | Tape (n = 8) | P Value |
|-------------------------------|-------------------|-----------------|------------|
| Anterior-posterior length, mm | 21 ± 0.6 | 21 ± 0.9 | <.01 |
| Medial-lateral length, mm | 15 ± 0.5 | 16 ± 0.09 | <.01 |
| Tendon thickness, mm | 37 ± 0.2 | 37 ± 0.1 | <.01 |

^aValues are presented as mean ± standard error of the mean.

Mechanical Testing: Part 1—Footprint Contact Pressure. Footprint contact pressure measurements were recorded using a custom-built testing jig.^{1,14,16} Prior to rotator cuff repair, an 8-mm hole was drilled through the center of the infrapinatus footprint. The tear size of the infrapinatus footprint for the suture and tape repairs is shown in Table 1. The specimens were secured, and a 4.5-mm metal probe connected to a load cell was passed through the 8-mm tunnel in the proximal humeral specimens. The infrapinatus tendons were then repaired over this probe using the 2 repair techniques described. The load cell probe was positioned in the center of the footprint with a 1.7-mm protrusion from the footprint. The load cell was zeroed before testing for each repaired shoulder.

To apply tension to the repaired infrapinatus tendons, a hook was passed through a hole in the medial border of the scapula and sets of calibrated weights (10, 20, and 30 N) were attached via a steel cable and pulley system. Each tendon was cyclically loaded 10 times at 5-second intervals with a 30-N weight.

Each repair construct was cyclically loaded with a 30-N weight immediately postrepair. The footprint contact pressure was assessed with 10, 20, and 30 N of force pulling across the repaired tendon. Contact pressure measurements were recorded via a computer connected to the load cell (10-kN Dynacell; Instron). To test the effect of shoulder abduction/adduction, the pulley system was raised and

lowered in 10° increments. The repaired tendon was unloaded between each variation (abduction angles/different weights), with a rest period of 3 minutes before the next test. Footprint contact pressure was calculated using the compressive force data obtained from the sensor probe: pressure (MPa) = compressive load on sensor (N)/sensor area (mm²). Stiffness of the biomechanical construct was also calculated by using the linear section of the load-displacement curve.

Mechanical Testing: Part 2—Load-to-Failure Testing. After the contact pressure was tested, each specimen was labelled and stored at -20°C before pull-to-failure testing. After thawing to room temperature, pull-to-failure tests were performed using a mechanical tensile testing machine (Instron 8874; Instron). The humerus of each specimen was secured to a base plate with an 8-mm bolt. The infrapinatus tendons were secured with tendon-grasping clamps that pulled perpendicular to the sagittal plane and parallel to the transverse plane of the tendon. The infrapinatus muscle was detached from the scapula before pull-to-failure testing. The repairs were tested with the direction of pull 90° to the shaft of the humerus. The specimens were preloaded with 10 N for 30 seconds; the repaired tendon was then pulled at a rate of 1.25 mm/s to failure, with the data captured at 100 Hz on a computer.^{1,14,16}

Part 2: Clinical Outcomes

A retrospective cohort study was performed using data collected prospectively. Patients underwent primary rotator cuff repair with tear size larger than 1.5 cm × 1 cm (anterior-posterior × medial-lateral) by a single senior surgeon (G.A.C.M.) between June 2010 and July 2012. Ethical approval for this study was sought and obtained from the South Eastern Sydney Local Health Network Human Research Ethics Committee—Southern Sector. Between November 2011 and July 2012, all tears with size greater than 1.5 cm × 1 cm were repaired with tape. Prior to this, all tears were repaired with suture.

Exclusion criteria included ipsilateral shoulder pathology, previous fracture, partial-thickness rotator cuff tear, revision surgery, isolated subscapularis tears, and rotator cuff repair with a polytetrafluoroethylene (PTFE) patch.

The tear sizes were measured using a diagnostic preoperative ultrasound by an experienced musculoskeletal ultrasonographer. During the study period (from June 2010 to July 2012), there were 691 rotator cuff repairs, of which 58 were excluded due to being revision surgeries and 53 being repaired with synthetic PTFE patches. Of the remaining 580 rotator cuff repairs, 55 were performed using tape in an inverted mattress single-row configuration. Two were excluded due to ipsilateral shoulder pathology and 3 were revision surgeries, leaving 50 patients in the tape group. Using a 2:1 ratio, the control group consisted of 100 consecutive cases of rotator cuff repair, performed during the study period, using the regular No. 2 suture with the same repair configuration and minimum tear size (1.5 cm × 1 cm).

Rehabilitation Protocol

Patients were discharged on the same day, and the operated arm was placed in a sling with a small abduction pillow (UltraSling; DJO). The patients were initially started on pendulum exercises. At the 1-week postoperative follow-up, the patients were introduced to passive external rotation range of motion exercises. At the 6-week postoperative visit, active range of motion and simple isometric strengthening exercises were initiated. Isokinetic exercises were allowed at 3 months. Finally, at the 3-month follow-up, the patients were allowed to proceed to free overhead throwing activities and lifting 5 kg or more. Return to sports occurred at 6 months for most patients.

Cuff Integrity Evaluation

Ultrasound was used to evaluate the rotator cuff integrity 6 months after surgery. Ultrasound accuracy has been validated at our institution for evaluation of rotator cuff tear size preoperatively.¹⁸ A recurrent tendon defect was diagnosed when a distinct defect could be visualized in both the transverse and longitudinal planes.¹⁸ A number of studies have shown that most failures after rotator cuff repair occur in the early postoperative period, prior to 3 months.^{7,11}

Data Analysis

A sample size calculation was performed by using data collected in a preliminary study using 6 sheep shoulders at our institution. A difference in contact pressure of 0.08 MPa between repair groups was considered relevant because this indicates a 2-fold increase in contact pressure between the 2 groups. With alpha of 0.05 and power of 0.80, at least 4 specimens per group were needed to detect differences in tendon to bone contact pressure between groups. Data in this study are reported as mean \pm standard error of the mean (mean \pm SEM). Differences in footprint contact pressure and load to failure in the ovine model were analyzed using unpaired Student *t* tests and with Mann-Whitney rank-sum tests for nonparametric data. All *P* values reported were for a 95% confidence interval. Stiffness of the biomechanical material was calculated from the linear section of the load-displacement curve using MATLAB software (R2007; The MathWorks). Differences in retear rates were analyzed using chi-square and Fisher exact tests.

RESULTS

Biomechanical Study

Footprint Dimensions and Tendon Thickness. The mean (\pm SEM) anterior-posterior footprint dimension of the specimens used in the FiberWire repair group was 21 mm (\pm 0.6 mm), and the mean medial-lateral footprint dimension was 15 mm (\pm 0.5 mm). The mean anterior-posterior footprint dimension of the specimens used in the FiberTape

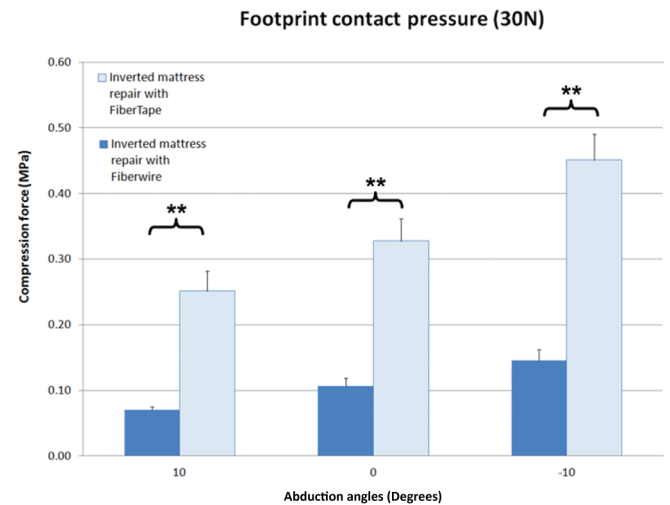


Figure 4. Footprint contact pressure across different angles of abduction. Data are displayed as mean \pm standard error of the mean ($n = 8$ for suture group and $n = 8$ for tape). ** $P < .01$.

repair group was 21 mm (\pm 0.9 mm), and the mean medial-lateral footprint dimension was 16 mm (\pm 0.9 mm). The mean tendon thickness of the FiberWire repair group was 3.7 mm (\pm 0.2 mm), and that of the FiberTape repair group was 3.7 (\pm 0.1 mm). There were no significant differences in footprint dimensions and tendon thickness between the 2 groups.

Footprint Contact Pressure. Rotator cuff repair with tape had 3 times higher footprint contact pressure compared with repair using No. 2 suture (0.33 ± 0.03 vs 0.11 ± 0.3 MPa, $P < .0001$) at 0° rotation with a 30-N load across the tendon (Figure 4). Footprint contact pressures of the tape repair group was significantly higher than the suture repair group at all rotation/tension combinations. Table 2 shows the comparison between suture and tape repair.

Footprint contact pressure increased as the tendon was loaded from 10 to 30 N and as the scapula was externally rotated. These effects of increase footprint contact pressure with more loads and higher external rotation abduction angles were amplified with the wider tape. There was a 3- to 4-fold increase in footprint contact pressure with the tape repair compared with suture repair.

Load to Failure. Ultimate failure load of the tape repair group was significantly higher than the suture repair group (218 ± 28 vs 145 ± 14 N, $P = .04$) (Figure 5). There were no significant differences between the 2 groups in total energy ($P = .14$) or peak energy to failure ($P = .13$) and repair stiffness ($P = .22$).

Failure Mechanism. The majority of repairs (15/16, 94%) failed with suture or tape pulling through the tendon; 1 suture pulled out from the anchor in the suture repair group.

Clinical Results

Demographics. The demographics of the 2 groups are depicted in Table 3. The tape group consisted of 32 women and 18 men, with a mean age of 60 years (range, 41-82

TABLE 2
Footprint Compression

| Load Applied Across the Scapula | Footprint Compression, MPa, Mean (SEM) | | P Value (Suture Repair vs Tape Repair) |
|---------------------------------|--|-------------|--|
| | Suture Repair | Tape Repair | |
| Abduction angle (-10°) | | | |
| 10 N | 0.07 (0.01) | 0.24 (0.02) | <.0001 |
| 20 N | 0.11 (0.01) | 0.34 (0.03) | <.0001 |
| 30 N | 0.15 (0.02) | 0.45 (0.04) | <.0001 |
| Abduction angle (0°) | | | |
| 10 N | 0.05 (0.01) | 0.19 (0.01) | <.0001 |
| 20 N | 0.08 (0.01) | 0.27 (0.01) | <.0001 |
| 30 N | 0.11 (0.01) | 0.33 (0.03) | <.001 |
| Abduction angle (10°) | | | |
| 10 N | 0.04 (0.01) | 0.15 (0.02) | <.0001 |
| 20 N | 0.05 (0.01) | 0.20 (0.02) | <.001 |
| 30 N | 0.07 (0.01) | 0.25 (0.03) | <.001 |

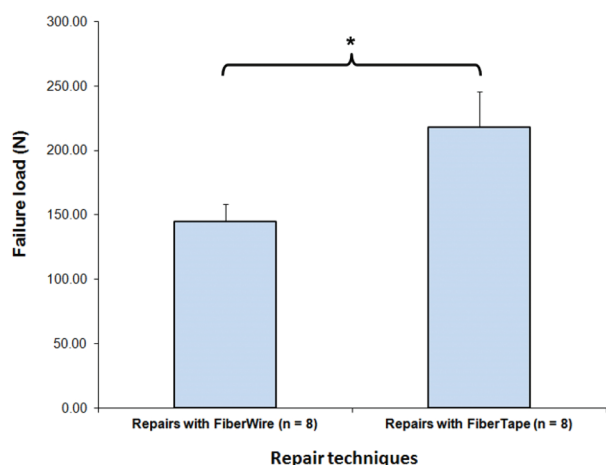


Figure 5. Load to failure. Data are displayed as mean ± standard error of the mean (n = 8 for suture group and n = 8 for tape). *P < .05.

years). In the suture group, 58 repairs were performed in women and 42 in men; the mean age was 61 years (range, 36-84 years). The average time from initial injury or initial complaint to repair was 4 months in the tape group (range, 1-240 months) and 8 months in the suture group (range, 1-488 months). In the tape group, 68% (34/50) of repairs were done in the right shoulder compared with 70% (70/100) in the suture group. Repairs in the tape group used on average of 2.3 ± 0.1 anchors, while repairs in the suture group used 2.6 ± 0.1 (P = .12). The number of anchors used depended on the tear size, with more anchors used for larger tears.

Intraoperative Findings. In the tape group, the mean tear length was 2.3 cm (range, 1.5-4.5 cm) anteroposteriorly and 2.3 mm (range, 1-5 cm) mediolaterally. For the suture group, the mean tear length was 2.5 cm (range, 1.5-4.5 cm) anteroposteriorly and 2.1 cm (range, 1-5 cm) mediolaterally. The mean tear area was 5.7 cm² (range, 1.8-16 cm²) for the

tape group and 5.6 cm² (range, 2-24 cm²) for the suture group. There were no significant differences between the 2 groups in tear length and area. The vast majority of the tears were crescent-shaped tears that needed only medial to lateral repair.

The mean operative time was 28 minutes (range, 11-97 minutes) for the tape group and 21 minutes (range, 7-45 minutes) for the suture group. All repairs were of the supraspinatus tendon. There were 2 acromioplasties in each of the tape and suture groups. Eight of 50 patients in the tape group had a torn biceps tendon (16%) compared with 30 (30%) of 100 in the suture group (P = .07). No patient had a distal clavicle excision.

Retear Rate. At the 6-month ultrasound, 8 (16%) patients had a retear in the tape group and 17 (17%) in the suture group (Figure 6). This difference was not statistically significant (P = .99). There were 4 (50%) patients in the tape repair group who had a retear at 6 months and had elected to undergo revision surgery compared with 6 (35%) patients in the suture group.

DISCUSSION

This was the first study to examine the biomechanical and clinical outcomes of rotator cuff repair with the thicker tape. Patient demographics were well matched with a relatively large sample size. All surgeries were performed by the same surgeon over a 2-year period.

Rotator cuff repair with the wider tape provided a 3-fold higher footprint contact pressure and 1.5 times load to failure compared with repairs using standard No. 2 suture. However, the clinical results of this study showed that using the thicker tape instead of No. 2 suture in rotator cuff repair did not result in a lower retear rate 6 months postsurgery.

Arthroscopic single-row repair is well described and is shown to have good clinical outcomes.^{5,8,10,12,17} This study is the first to compare the clinical outcomes of rotator cuff repair using tape with SwiveLock knotless suture anchors (Arthrex)

TABLE 3
Demographics

| Demographics | Tape | Suture | P Value |
|---|--------------|--------------|---------|
| No. of patients | 50 | 100 | |
| Male:female | 18:32 | 42:58 | .596 |
| Age at surgery, y, mean (range) | 60 (41-82) | 61 (36-84) | .948 |
| Time from initial injury to surgery, mo, mean (range) | 4 (1-240) | 8 (1-488) | .112 |
| Affected shoulder, right:left | 34:16 | 70:30 | .852 |
| Anteroposterior tear size, mm, mean (range) | 23.1 (15-45) | 24.5 (15-45) | .364 |
| Medial-lateral tear size, mm, mean (range) | 22.5 (10-50) | 21.2 (10-50) | .348 |
| No. of anchors used | 2.3 | 2.6 | .120 |

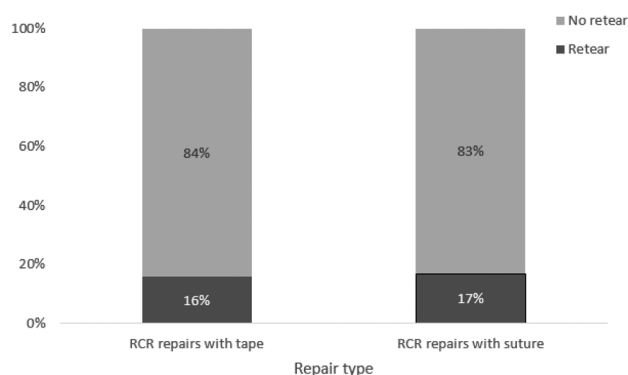


Figure 6. Retear rate at 6 months postoperatively. RCR, rotator cuff repair.

and traditional No. 2 suture with Opus Magnum anchors (ArthroCare) in a single-row inverted mattress construct.

Data from this biomechanical study showed that tape provided significantly higher footprint contact pressure and pull-out strength compared with the standard No. 2 suture. It should be noted that in ovine shoulders, the pull-out strength of the repairs would be lower than in cadaveric models as the fibers are less linear.⁶ Prior studies have shown that repair configurations with a higher footprint contact pressure and pull-out strength yields a reduction in postoperative retear rate.^{10,19} A study by De Carli et al³ also demonstrated that FiberTape repair resulted in a higher failure load compared with repair using FiberWire in an ovine model. Based on these biomechanical results, we hypothesized that patients who had a rotator cuff repair with the broader tape would have a lower retear rate and better overall postoperative outcomes compared with patients who had a repair using No. 2 sutures. However, the biomechanical advantage did not translate into better clinical outcomes.

There is evidence to show that most rotator cuff retears after repair occur in the first 6-month postoperative period. A multi-institutional prospective study of 113 patients by Iannotti et al⁷ showed the mean time to retear was 19.2 weeks, with only 1 additional retear (1/19) noted on magnetic resonance imaging occurring between 6 and 12 months postoperatively. An ultrasound follow-up study of 22 patients with larger tears by Miller et al¹¹ showed no retears between 6 and 12 months, with 77% of the retears occurring between 3 and 6 months.

The retear rates of this study, 16% to 17%, are lower than the current literature. A meta-analysis of level 1 randomized clinical trials conducted by Millett et al¹² in 2013 concluded in a mean retear rate of 26% (range, 15%-46%) at minimum 6-month ultrasonographic follow-up of single-row suture repairs, with a mean sagittal tear length of 1.9 cm. Tashjian et al¹⁷ conducted a retrospective study in 2013 of 51 patients with mean anteroposterior tear size of 3 cm in which the retear rate was 24% (as determined by magnetic resonance imaging). Gartsman et al,⁵ in a level 1 randomized controlled trial, used diagnostic ultrasound to show that 25% of patients with tears less than 2.5 cm with single-row repair had retears at 10 months.

The data reported in this article support the hypothesis that there are more factors at play than initial repair construct strength with regard to healing of the rotator cuff.¹² We speculate that the patient healing response may be just as, if not more, important than the initial repair construct strength.

Limitations

Biomechanically, ovine bony anatomy and tendon properties differ from those of the human shoulder. The model is *ex vivo* and did not assess any biological/healing effects. Our study design only measured contact pressure at the center of the footprint. Testing was also only performed at the time of repair. There was no cyclic testing.

Clinically, the 2 groups were chosen as consecutive temporal cohorts rather than randomized groups. More than 1 examiner performed the postoperative assessments, so there may be some variation in their measurement methods. The data presented are also limited to 6 months. Long-term clinical outcomes were not assessed.

CONCLUSION

Biomechanically, the tension band rotator cuff repair with tape provided a 3-fold increase in footprint contact pressure and a 1.5-fold increase in construct strength compared with No. 2 suture in suture anchor-based rotator cuff repair. However, there was no clinical difference in retear rate between the suture and tape groups; both had a comparatively high number of intact cuffs at 6 months postoperatively.

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