Arthroscopic Rotator Cuff Repair Using a Suture Bridge Technique : Is the Repair Integrity Actually Maintained?

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Arthroscopic Rotator Cuff Repair Using a Suture Bridge Technique

Is the Repair Integrity Actually Maintained?

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Background: Suture bridge repair has been recognized to have superior biomechanical characteristics, as shown in previous biomechanical studies. However, it is not clear whether the tendon heals better in vivo after suture bridge repair.

Purpose: To evaluate the clinical results and repair integrity after arthroscopic rotator cuff repair using a suture bridge technique for patients with rotator cuff tears.

Study Design: Case series; Level of evidence, 4.

Methods: One hundred twenty-three shoulders (120 patients) that underwent arthroscopic suture bridge repair for full-thickness rotator cuff tear were enrolled for this study. The mean duration of follow-up was 25.2 months (range, 16-34 months). The postoperative repair integrity was analyzed with use of magnetic resonance imaging (MRI) in 87 shoulders. According to the retear patterns on postoperative MRI, the cases were divided into type 1 (failure at the original repair site) or 2 (failure around the medial row).

Results: At the last follow-up, the University of California at Los Angeles (UCLA) score improved from the preoperative mean of 13.2 points to 29.7 points ($P < .001$). The rotator cuff was completely healed in 58 (66.7%) of the 87 shoulders, and there was a recurrent tear in 29 shoulders (33.3%). The incidence of retear tended to increase with age older than 60 years at the time of surgery ($P = .002$). When there was a larger intraoperative tear, the rate of retear was also higher ($P = .002$). When the severity of preoperative fatty degeneration of the cuff muscles was higher, there was a greater chance of a recurrent tear ($P < .001$). The retear patterns on postoperative MRI in 29 shoulders with recurrent failures were classified as type 1 in 12 shoulders (41.4%) and type 2 in 17 shoulders (58.6%). The preoperative cuff tear size did not have an influence on retear patterns ($P = .236$), but the percentage of type 1 retear increased with the severity of fatty degeneration or muscle atrophy ($P = .041$, .023).

Conclusion: Arthroscopic suture bridge repair of full-thickness rotator cuff tears led to a relatively high rate of recurrent defects. However, the mean 25-month follow-up demonstrated excellent pain relief and improvement in the ability to perform the activities of daily living, despite the structural failures. The factors affecting tendon healing were the patient's age, the size and extent of the tear, and the presence of fatty degeneration in the rotator cuff muscle. The retear in cases with a suture bridge technique tended to be more frequently at the musculotendinous junction.

Keywords: shoulder; rotator cuff tear; arthroscopic repair; suture bridge technique; retear

Recently, arthroscopic repair has been widely accepted for treatment of rotator cuff tears, with equal or better results than those from open repair reported.[3,20,26,33] With recent arthroscopic instrument development and wide surgical experience, most symptomatic tears of the rotator cuff can be managed successfully by an arthroscopic approach. Moreover, technical advances to optimize the healing at a repaired rotator cuff insertion are needed for improving the outcome. Nevertheless, retears may occur after arthroscopic rotator cuff repair, with Galatz et al[15] reporting a retear rate as high as 94%. In an effort to prevent retears, operative techniques have evolved with time. One of the changes was the introduction of the concept of footprint reconstruction, which resulted in the use of double-row repair that provided a wider interface between the tendon and the original footprint of the humeral head.[7,22,25,34] More recently, a suture bridge repair technique has received great attention.[28-30] According to biomechanical comparative studies, the suture bridge repair

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technique has been proven to produce better results than other arthroscopic repair techniques.[7,29,30] However, few studies have reported clinical outcomes of arthroscopic repair of rotator cuff tears using a suture bridge technique. Moreover, the reports of Frank et al[13] and Voigt et al[36] are the only studies that provide objective evaluation of repair site integrity after arthroscopic transosseous-equivalent suture bridge rotator cuff repair. In addition, even this technique has not been sufficient to prevent development of retears according to our clinical experience. In particular, a subset of patients is often seen with an unusual pattern of tendon failure after arthroscopic suture bridge rotator cuff repair.[6] Until now, suture bridge repair has been recognized to have superior biomechanical characteristics that were shown in previous biomechanical studies. However, it is not clear whether the tendon heals better in vivo after suture bridge repair.

The purpose of our study was to evaluate the clinical results and repair integrity of arthroscopic rotator cuff repair using a suture bridge technique for patients with full-thickness rotator cuff tears, to analyze the factors affecting the structural failures of arthroscopically repaired rotator cuff tears, and to evaluate retear patterns in the cases with structural failure after arthroscopic suture bridge repair with use of MRI as an imaging modality. On the basis of several previous biomechanical studies, we hypothesized that in a suture bridge repair, preoperative cuff tear size would not affect final clinical outcomes because it initially reconstructs a stronger footprint of the rotator cuff, but the severity of preoperative fatty degeneration or muscle atrophy would be associated with inferior results. We also hypothesized that in arthroscopic rotator cuff repair using a suture bridge technique, the structural failures would be developed at the musculotendinous junction more often than at the original footprint because of it providing an initial stronger repair.

METHODS

Final approval of exemption from review by the Institutional Review Board was obtained for this study because this study was retrospective in nature (KHNMC IRB 2010-062).

Patient Selection

One hundred twenty-three shoulders (120 patients) that underwent arthroscopic suture bridge repair for full-thickness rotator cuff tear between March 2007 and September 2008 were enrolled in this study. Patients who had partial rotator cuff tear, acromioclavicular arthritis that required distal clavicle resection, advanced glenohumeral arthritis, or rotator cuff tears with a workers' compensation claim or those who needed tenotomy or tenodesis of the long head of the biceps were excluded from the study. Patients undergoing revision procedures were also excluded. There were 59 male and 61 female patients. The mean patient age at the time of operation was 55.4 years (range, 36-75 years), and the mean duration of follow-up was 25.2 months (range, 16-34 months). The right shoulder was involved in 89 cases and the left shoulder in 34 cases. One hundred two patients had involvement of the dominant arm. According to the classification of DeOrio and Cofield,[11] the extent of the tear was determined intraoperatively under direct arthroscopic visualization after debridement of the degenerated tendon edges. The tear size was measured in the anterior-posterior dimension using a calibrated probe introduced through the posterior portal while viewing from the lateral portal.

Preoperative and Postoperative Evaluations

All patients underwent a physical examination 1 day before the operation. Postoperative evaluations were performed regularly on an outpatient basis, and the results of the last follow-up were analyzed. Preoperative and postoperative subjective pain score was measured with the visual analog scale (VAS). Quantitative muscle strength measurements of the rotator cuff were assessed with use of a portable, handheld Nottingham Mecmesin Myometer (Mecmesin Co, Nottingham, UK). Elevation strength was tested with the patient in the seated position with the arm flexed to 90° in the scapular plane. External and internal rotation was tested with the shoulder in a neutral position and the elbow in 90° of flexion. For shoulder range of motion (ROM), forward flexion, external rotation at the side, internal rotation to the back, and abduction were assessed before and after the operation. The Constant score[8] and the Shoulder Rating Scale of the University of California at Los Angeles (UCLA)[12] were used for clinical assessment.

Operative Techniques

All operations were performed by the senior author with the patient in a beach-chair position. Both shoulders were examined under general anesthesia for ROM. After adequate visualization, preparation, and release of the tendon, the upper surface of the greater tuberosity was abraded widely with a shaver, removing all soft tissue and cortical bone, to create a bleeding cancellous bone bed. The greater tuberosity was gently debrided and smoothed of irregularities, and the superficial bone was decorticated, but the medullary canal was not exposed. A formal bone trough was not made.

For transosseous-equivalent (suture bridge) repairs, the suture anchor, a 5.5-mm Bio-Corkscrew FT (Arthrex, Naples, Florida) prethreaded with two #2 FiberWire sutures, was placed at the sulcus or articular margin through the accessory superolateral portal. The rotator cuff repair was performed by first placing a suture shuttle through the tendon with the use of a suture hook (Linvatec, Largo, Florida) or Banana SutureLasso (Arthrex). A suture hook or Banana SutureLasso was inserted through the working portal or modified Neviaser portal. By manipulating the direction of the handle, the edge of the rotator cuff tendon could be pierced with ease.[32] The suture passed through the tendon as medial as possible, ideally 10 to 12 mm medial to the lateral edge of the rotator cuff tear,

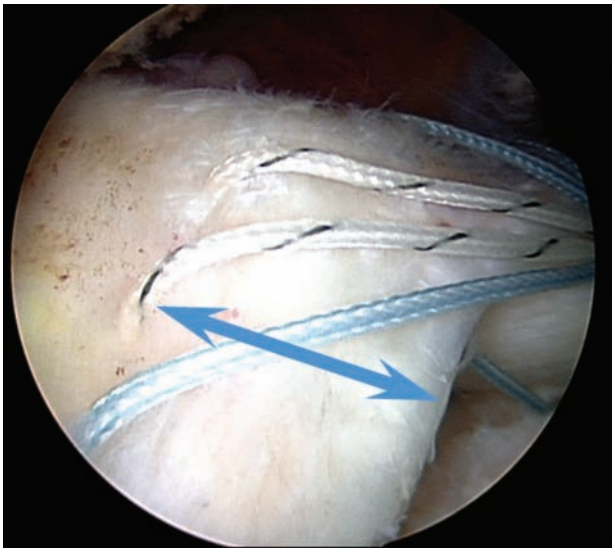

Figure 1. Even in cases when a large portion of the rotator cuff has to be captured, it may be helpful to capture it in a way to achieve the tendon passage to the lateral rather than at the musculotendinous junction. The arrow indicates the ideal width of the tendon to be captured.

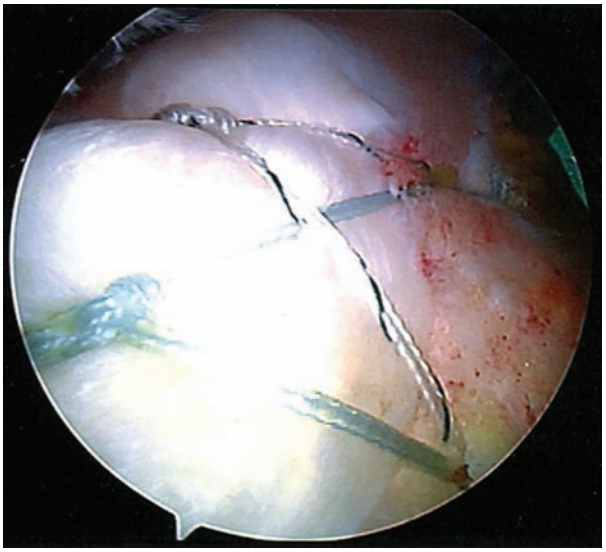

Figure 2. Repair configuration after arthroscopic rotator cuff repair using a suture bridge technique.

to maximize the amount of lateral tendon available for compression (Figure 1).[28] The remaining sutures were repeated to create a horizontal mattress configuration. A medial row was created with suture anchors that use mattress repairs. After the medial row was repaired, the suture limbs were then used to create suture bridges over the tendon. The lateral fixation points were placed 1 cm distal-lateral to the lateral edge of the tuberosity footprint insertion. One FiberWire strand from each Bio-Corkscrew FT was retrieved and threaded through the Bio-PushLock (Arthrex) eyelet on the distal end of the driver. The distal tip of the Bio-PushLock was brought to the edge of the pilot hole to reduce the tendon to its desired position on the footprint while holding onto the suture tails. The driver was then advanced into the pilot hole completely, until the anchor body contacted bone. While keeping adequate tissue tension by pulling on each suture strand independently, the anchor body was tapped into the pilot hole. Finally, the sutures were cut flush. Using the same steps, the other FiberWire strand from each Bio-Corkscrew FT was also fixed by the Bio-PushLock for the lateral row (Figure 2). The number of suture anchors (Bio-Corkscrew FT and Bio-PushLock) used depended on the size of the tear. The arm was immobilized in a sling following routine portal closure.

Postoperative Rehabilitation

All patients followed a standard postoperative rehabilitation program. From the day of operation, passive exercises, including pendulum exercise, passive forward flexion, and external rotation exercises, were performed. Active exercises were not allowed until 6 weeks postoperatively or until regaining full passive range of motion. Active-assisted exercises were started at 6 weeks postoperatively, and muscle strengthening exercises were introduced thereafter gradually. A return to recreational activity with heavy demands on the shoulder or to manual labor was delayed for 6 months.

Assessment of Tendon Healing

To assess tendon healing, anatomic evaluation of the cuff repair was done with the use of MRI as the investigation of choice, as it provides the benefits of multiplanar imaging of the postoperative shoulder. Of the 123 shoulders undergoing arthroscopic rotator cuff repair using a suture bridge technique, 87 shoulders had preoperative and postoperative MRI scans. For the other 36 shoulders, the patients were not lost to follow-up but declined to be evaluated because of the cost. The demographic data on the 87 shoulders that had postoperative MRIs and the 36 that did not were similar (small-sized tears in 7 [8%] and 4 [11%], medium-sized tears in 41 [47%] and 18 [50%], large-sized tears in 32 [37%] and 12 [33%], and massive tears in 7 [8%] and 2 [6%], respectively). These postoperative MRIs were performed at a minimum of 6 months after surgery. All studies were obtained with a 1.5-T unit (Signa; GE Medical Systems, Milwaukee, Wisconsin) by using the routine pulse sequences. The images were reviewed by 1 experienced senior radiologist who was informed that the patients had undergone surgery for rotator cuff repair and blinded to the size and location of the tear that had been repaired. Continuity and rerupture of the tendon were assessed on magnetic resonance images according to established MRI criteria.[18] When a fluid-equivalent

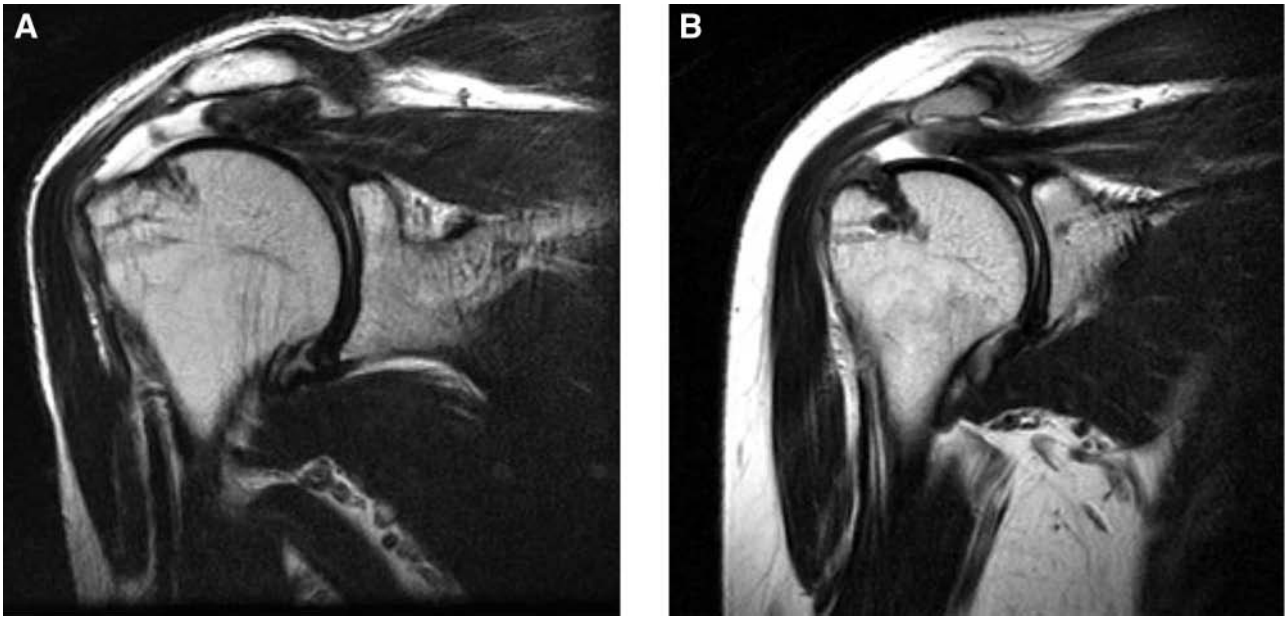

Figure 3. The retear patterns on postoperative coronal MRI scans in shoulders with recurrent tear after suture bridge repair. A, This image shows type 1 retear (if no remnant of tendon tissue remained attached to the original footprint on the greater tuberosity). B, This image shows type 2 retear (if the tendon did heal to the humerus but a new disruption occurred just proximal to the medial row of anchors).

signal or nonvisualization of the supraspinatus, infraspinatus, or subscapularis tendon was found on at least one T2-weighted or proton density–weighted image, the diagnosis of a full-thickness retear, anatomic failure of healing, was made. According to the retear patterns on postoperative MRI, the cases were divided into type 1 (Figure 3A), if the cuff tissue repaired at the insertion site of the rotator cuff was not observed to be remaining on the greater tuberosity, or type 2 (Figure 3B), if the remnant cuff tissue remained at the insertion site despite the retear.[6] Fatty degeneration was evaluated for each muscle with the 5-stage grading system developed by Goutallier et al[16,17] and validated by Fuchs et al[14] for MRI. A global fatty degeneration index (GFDI), the mean value of the 3 muscles, was calculated for each shoulder.[17] Muscle atrophy was evaluated at the most lateral oblique sagittal plane image on which the scapular spine was in contact with the rest of the scapula with the 4-stage grading system (normal, mild, moderate, or severe) developed by Warner et al.[37]

Statistical Analysis

The paired t test and Wilcoxon signed rank test were performed to assess the difference in preoperative and postoperative results. Pearson's chi-square test and likelihood ratio test for trend were used to analyze the factors affecting the healing of repaired rotator cuff tears and to evaluate the correlation between the retear pattern and variable factors. Univariate logistic regression analysis was used to determine significant associations between the factors and the retear rate. Significance was set at an α level of 0.05 with associated 95% confidence intervals. The SPSS software package (version 12.0; SPSS, Inc, an IBM Company, Chicago, Illinois) was used for all statistical analyses.

RESULTS

Arthroscopic Findings

Tears were classified into small (<1 cm), medium (1-3 cm), large (3-5 cm), and massive (>5 cm) according to the measurements performed during surgery. Arthroscopic findings included small tears in 11 shoulders (8.9%), medium tears in 59 (48.0%), large tears in 44 (35.8%), and massive tears in 9 (7.3%).

Pain

The subjective pain score (VAS) at rest decreased from the preoperative mean of 1.9 (range, 0-7) to 0.4 (range, 0-4) at the last follow-up ($P < .001$). The mean VAS during motion declined to 2.2 (range, 0-7) from 6.2 (range, 1-10) preoperatively ($P < .001$) (Table 1).

Range of Motion

The mean active range of motion for forward flexion improved from 144.1° (range, 50°-170°) preoperatively to 155.8° (range, 100°-170°) at the last follow-up ($P < .001$); external rotation at the side, from 45.6° (range, 5°-80°) to 48.6° (range, 20°-80°) ($P = .068$); internal rotation to the back, from T12 (range, L5-T7) to T10 (range, L3-T7)

TABLE 1
Clinical Outcomes of Arthroscopic Suture Bridge Repair[a]

Variables	Preoperative	Postoperative	*P* Value
VAS (pain at rest)	1.9 (0-7)	0.4 (0-4)	<.001
VAS (pain during motions)	6.2 (1-10)	2.2 (0-7)	<.001
Forward flexion, deg	144.1 (50-170)	155.8 (100-170)	<.001
External rotation at the side, deg	45.6 (5-80)	48.6 (20-80)	.068
Elevation strength, kg	4.28 (0.96-10.84)	5.85 (1.30-12.19)	<.001
Constant score	48.0 (21-79)	80.3 (47-97)	<.001
UCLA score	13.2 (6-20)	29.7 (17-35)	<.001

[a]VAS, visual analog scale; UCLA, University of California at Los Angeles.

TABLE 2
Anatomic Results of Arthroscopic Suture Bridge Repair (in 87 Shoulders)[a]

Variables	Complete Healing Group (n = 58)	Retear Group (n = 29)	*P* Value
Age, y	53.8 (36-69)	60.1 (41-75)	.001
VAS (pain at rest)	0.3 (0-2)	0.7 (0-4)	.012
VAS (pain during motions)	1.9 (0-6)	2.9 (0-7)	.006
Forward flexion, deg	157.4 (100-170)	153.3 (140-170)	.070
External rotation at side, deg	48.9 (20-80)	47.6 (20-75)	.671
Elevation strength, kg	6.23 (2.41-12.19)	4.98 (1.30-9.73)	.005
Constant score	82.8 (64-97)	75.1 (47-89)	<.001
UCLA score	30.8 (25-35)	27.6 (17-34)	<.001

[a]VAS, visual analog scale; UCLA, University of California at Los Angeles.

(P = .023); and abduction, from 138.4° (range, 40°-180°) to 162.3° (range, 100°-180°) (P < .001) (Table 1).

Muscle Strength

The muscle strength for forward flexion, external rotation, and internal rotation increased from the preoperative mean of 4.28, 5.94, and 6.92 kg, respectively, to 5.85, 6.25, and 7.41 kg at the last follow-up (P < .001, P = .123, P = .007) In the muscle strength for forward flexion and internal rotation, there was statistically significant improvement at the last follow-up (Table 1).

Clinical Assessment

The Constant score increased from the preoperative mean of 48.0 points (range, 21-79 points) to 80.3 points (range, 47-97 points) at the last follow-up (P < .001). The UCLA score improved from the preoperative mean of 13.2 points (range, 6-20 points) to 29.7 points (range, 17-35 points) at the last follow-up (P < .001). These results were recorded as excellent in 28 (22.8%) cases, good in 87 (70.7%) cases, and poor in 8 (6.5%) cases. There was statistically significant improvement in clinical assessments (Table 1).

Anatomic Results

The postoperative repair integrity was analyzed with use of MRI in 87 (70.7%) of the 123 shoulders undergoing arthroscopic rotator cuff repair using a suture bridge technique, performed at mean 8.5 months (range, 6-12 months) postoperatively. The results showed the rotator cuff was completely healed in 58 (66.7%) of the total 87 shoulders and had a recurrent tear in 29 shoulders (33.3%).

The mean age at the time of operation was significantly younger (P = .001) in the complete healing group at 53.8 years (range, 36-69 years), whereas it was 60.1 years (range, 41-75 years) in the group with recurrent tears. The mean VAS score at rest at the last follow-up was significantly lower in the group with complete healing, 0.3 (range, 0-2), than in the group with recurrent tears, 0.7 (range, 0-4) (P = .012). The VAS score during motion averaged 1.9 (range, 0-6) in the group with complete healing, slightly superior to the 2.9 (range, 0-7) in the group with recurrent tears (P = .006). With regard to the mean active range of motion, forward flexion was 157.4° (range, 100°-170°) and external rotation was 48.9° (range, 20°-80°) in the group with complete healing, whereas it was 153.3° (range, 140°-170°) and 47.6° (range, 20°-75°), respectively, in the group with recurrent tears. Although the mean postoperative range of motion was greater in the group with complete healing, this difference did not reach statistical significance (P = .070, .671). At the last follow-up, the mean elevation strength was higher in the group with complete healing, 6.23 kg (range, 2.41-12.19 kg), than in the group with recurrent tears, 4.98 kg (range, 1.30-9.73 kg) (P = .005). The Constant score at the last follow-up increased to 82.8 points (range, 64-97 points) in the group with complete healing and to 75.1 points (range, 47-89

TABLE 3
Prevalence of Tendon Healing According to Age (in 87 Shoulders)

	Age, y		
Age	≤50 (n = 22), No. (%)	51-60 (n = 37), No. (%)	≥61 (n = 28), No. (%)
Complete healing group	18 (81.8)	29 (78.4)	11 (39.3)
Retear group	4 (18.2)	8 (21.6)	17 (60.7)

TABLE 4
Prevalence of Tendon Healing According to Preoperative Tear Size (in 87 Shoulders)

	Preoperative Tear Size			
	Small (n = 7), No. (%)	Medium (n = 41), No. (%)	Large (n = 32), No. (%)	Massive (n = 7), No. (%)
Complete healing group	7 (100)	32 (78.0)	16 (50.0)	3 (42.9)
Retear group	0 (0)	9 (22.0)	16 (50.0)	4 (57.1)

TABLE 5
Prevalence of Tendon Healing According to Preoperative Cuff Muscle Fatty Degeneration (in 87 Shoulders)[a]

	Global Fatty Degeneration Index				
	<0.25 (n = 9), No. (%)	0.25-1.0 (n = 50), No. (%)	1.0-1.5 (n = 19), No. (%)	1.5-2.0 (n = 7), No. (%)	≥2.0 (n = 2), No. (%)
Complete healing group	9 (100)	36 (72.0)	11 (57.9)	2 (28.6)	0 (0)
Retear group	0 (0)	14 (28.0)	8 (42.1)	5 (71.4)	2 (100)

[a]Criteria for grading muscle fatty degeneration: grade 0, no fatty deposits; grade 1, some fatty streaks; grade 2, more muscle than fat; grade 3, as much muscle as fat; grade 4, less muscle than fat. For each shoulder, we evaluated fatty degeneration, not only in each cuff muscle individually but in all cuff muscles combined, by calculating the global fatty degeneration index as the mean value of the grades for the supraspinatus, infraspinatus, and subscapularis.

points) in the group with recurrent tears ($P < .001$). The improvement was also noted in the UCLA score with 30.8 points (range, 25-35 points) for the group with complete healing and 27.6 points (range, 17-34 points) for the group with recurrent tears ($P < .001$) (Table 2).

Factors Associated With Healing of the Tendon (in 87 Shoulders)

Age. For the assessment of tendon healing, the patients were subdivided into 3 groups according to age: those ≤50 years, 51 to 60 years, and ≥61 years of age. Complete healing was observed in 18 (81.8%) of 22 shoulders in the ≤50 years group, in 29 (78.4%) of 37 shoulders in the 51 to 60 years group, and in 11 (39.3%) of 28 shoulders in the ≥61 years group. The incidence of rotator cuff recurrent tears tended to increase with age older than 60 years at the time of surgery ($P = .002$; odds ratio [OR] = 1.1; 95% confidence interval [CI], 1.04-1.18) (Table 3).

Preoperative Tear Size. Complete healing was observed in 7 (100%) of 7 small tears, in 32 (78.0%) of 41 medium tears, in 16 (50.0%) of 32 large tears, and in 3 (42.9%) of 7 massive tears. The larger the intraoperative tear size, the higher the rate of retear ($P = .002$; OR = 3.0; 95% CI, 1.51-6.08) (Table 4).

Preoperative Fatty Degeneration of Cuff Muscles. Complete healing was found in 9 (100%) of 9 shoulders with a global fatty degeneration index of <0.25, in 36 (72%) of 50 shoulders with an index of 0.25 to 1.0, in 11 (57.9%) of 19 shoulders with an index of 1.0 to 1.5, and in 2 (28.6%) of 7 shoulders with an index of 1.5 to 2.0. The recurrence of tears was observed in all shoulders with an index ≥2. When the severity of the fatty degeneration of the cuff muscles was higher preoperatively, there was a greater chance of a recurrent tear ($P < .001$; OR = 10.0; 95% CI, 2.98-33.71) (Table 5).

Patterns of Tendon Retear

The retear patterns on postoperative MRI in 29 shoulders with recurrent tear were classified as type 1 in 12 shoulders (41.4%) and type 2 in 17 shoulders (58.6%). The retear patterns according to preoperative tear size, the extent of preoperative cuff muscle fatty degeneration, and the

extent of preoperative cuff muscle atrophy were analyzed (see the Appendix, available in the online version of this article at http://ajs.sagepub.com/supplemental/). The preoperative cuff tear size did not have an influence on retear patterns (P = .236; OR = 0.29; 95% CI, 0.05-1.72). However, the percentage of type 1 retears increased with the severity of preoperative fatty degeneration (P = .041; OR = 0.18; 95% CI, 0.35-0.94) and muscle atrophy (P = .023; OR = 0.13; 95% CI, 0.21-0.88).

DISCUSSION

The integrity of the repair site after surgical treatment of full-thickness rotator cuff tears has been shown to correlate with clinical improvement, particularly the return of strength.[21,24] Therefore, rotator cuff tears should be fully repaired. After arthroscopic rotator cuff repair, numerous studies[3,5,19,20,23,26,35] have reported excellent clinical outcomes. However, long-term restoration of a functional, completely healed musculotendinous unit may not be always attainable in primary rotator cuff repair, and retears may occur after arthroscopic repairs. Galatz et al[15] reported a retear rate as high as 94%, and Bishop et al[4] also showed a high failure rate of 76% after arthroscopic repair of rotator cuff tears greater than 3 cm.

The causes for retears vary and include poor quality of tendon tissue, pullout of suture anchor, suture breakage, and inappropriate rehabilitation.[2,10,17] The commonly cited mechanism of failure of suture anchor-based rotator cuff repairs in most reports[9] was failure of the repair construct, leading to repair site gapping. In an effort to improve the biomechanics of rotator cuff repair constructs, advances in repair techniques are needed to optimize the healing environment after repair to facilitate restoration of function. Recently, the transosseous-equivalent (suture bridge) repair technique has received great attention.[1,27,28] Some studies have shown superior biomechanical characteristics with a suture bridge repair when compared with a double-row repair.[30] In addition, a suture bridge repair reconstructs the footprint of the rotator cuff better than does a double-row repair.[29] However, even though there are known advantages, the clinical outcomes after arthroscopic repair of rotator cuff tears using a suture bridge technique are not as well established as those after other arthroscopic repair procedures.

Prior published reports on the single-row repair technique have shown an anatomical failure rate of 22% to 25%.[5,7] Recent studies on structural healing after double-row rotator cuff repair, which shows superior biomechanical characteristics and reconstructs the footprint of the rotator cuff better than a single-row repair, demonstrated a lower rate (11%-17%) of recurrent tears.[19,23,35] Few studies have provided objective evaluation of repair site integrity after arthroscopic transosseous-equivalent suture bridge rotator cuff repair. According to the results of biomechanical studies, the suture bridge technique can improve pressurized contact area and mean pressure between the tendon and footprint and may help optimize

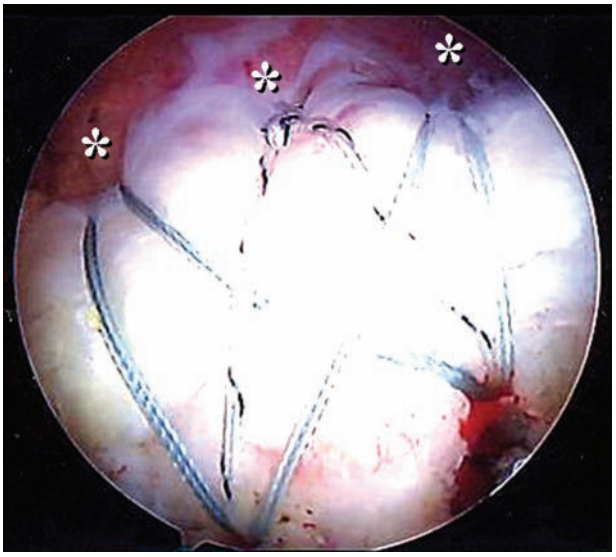

Figure 4. A medial row created with suture anchors that use mattress repairs (asterisks). When using a suture bridge technique, there may be a possibility of strangulation of the rotator cuff tendon at the medial row.

the healing biology at a repaired rotator cuff insertion.[29,30] On the basis of this background, Frank et al[13] first reported anatomical results of the suture bridge technique with a retear rate of 12%, which is better than other arthroscopic repair techniques. However, their study may have a limitation because sample size was small and relatively small-sized tears were mainly included. A more recent clinical study[36] of the suture bridge technique demonstrated retears in 13 (28.9%) of 45 patients on MRIs 12 months after surgery. In our study, the retear rate after suture bridge repair was 33.3% (29/87 patients). This relatively high rate of failure might be because patients with large to massive tears (43.1%) were mostly enrolled in this study. Even considering this fact, structural outcomes after suture bridge repair were not as good as we had expected. This unexpected high retear rate was associated chiefly with "medial cuff failure." Although the patients' rotator cuff footprints were intact, they had failure of the medial rotator cuff at the site where the medial row of mattress sutures passed through the rotator cuff. This pattern is not commonly observed in retears that occur after traditional single-row repair. Although many studies have used various imaging techniques to evaluate the rate of healing after rotator cuff repair, few have commented specifically on the location or configuration of recurrences.[31] This may be because the repairs almost always fail unremarkably at the tendon-bone interface. However, the tendon failure, commonly presented in our series after arthroscopic rotator cuff repair using a suture bridge technique, showed an unusual pattern. Recently, the authors[6] already described differences in retear patterns according to in vivo operative techniques. In the present study, there were similar retear patterns in 29 shoulders among which the recurrent tears were shown as type 1 in 12 cases (41.4%)

and type 2 in 17 cases (58.6%) compared with those in the above-referenced study (type 1 in 7 cases [25.9%] and type 2 in 20 cases [74.1%]). A number of potential factors may have contributed to the mode of failure observed after arthroscopic rotator cuff repair using a suture bridge technique. As with arthroscopic double-row rotator cuff repair, undue tension at the medial row may have played a major role, which eventually makes the musculotendinous junction weak and vulnerable to retears. When using a method of suture bridge technique, there may also be a possibility of strangulation and relatively quick necrosis of the rotator cuff tendon at the medial row (Figure 4). It results in failure at the musculotendinous junction that does not allow adequate time for the suture bridge technique to fail at the bone-tendon interface. Therefore, to get a better healing rate after arthroscopic suture bridge repair, details of surgical technique should be modified to avoid the unusual pattern of failure.

Several technical factors should be considered to prevent medial cuff failure in arthroscopic suture bridge repair. First, to avoid tension overload of the suture-tendon interface at the medial row, surgeons should not intend to achieve too much medial suture tendon passage for greater footprint coverage. They should also try to avoid the tendon passage obtained at the musculotendinous junction instead of the tendon portion. Even in the cases when a large portion of the rotator cuff has to be captured, it may be helpful to capture it in the way to achieve the tendon passage to the lateral rather than at the musculotendinous junction. Second, to avoid making a relatively larger hole in the rotator cuff by the oblique path of retrograde suture-passing instruments through the rotator cuff, surgeons should try to make a vertical path of suture passage through the rotator cuff. In addition, to reduce the possibility of strangulation and relatively quick necrosis of the rotator cuff tendon at the medial row, surgeons should try to choose an adequate placement of sutures at regular intervals rather than too many sutures too closely. Other subtle details, such as the style of knots chosen to secure the medial row and the amount of tension used to tie them, might also conceivably be considering factors.[31]

In the current study, arthroscopic suture bridge rotator cuff repair demonstrated excellent pain relief and improvement in the ability to perform the activities of daily living regardless of the structural failures. With regard to pain relief, muscle strength, and clinical scores at the last follow-up, the group with complete healing showed significantly better results compared with the group with recurrent tears, except the recovery of ROM. In the analysis of the factors associated with complete healing after arthroscopic suture bridge repair, the factors affecting tendon healing included the patient's age at the time of operation, the size and extent of the tear, and the presence of fatty degeneration in the rotator cuff muscle as previously reported in several studies. In cases in which the preoperative extent of muscle atrophy and fatty degeneration of the rotator cuff was severe, recurrent rotator cuff defects at the bone-tendon interface caused by the suture pulling through the tendon developed and revealed gapping at the repair site after suture bridge repair. In other words, when the tendon was of poor quality because of its own degeneration, the tendon portion was as weak as the musculotendinous junction, becoming vulnerable to retears at the original repair site as with the single-row repair.

Our study has a few limitations. First, being retrospective in nature, our study has limitations similar to other retrospective studies. However, we conducted a retrospective analysis of the prospectively collected patients' data on surgical procedures performed by a single surgeon. Second, with regard to preoperative or postoperative imaging evaluation, analysis of the postoperative repair integrity by use of MRI was not conducted in all cases. All patients in this study were intended to be evaluated by postoperative MRI. Those who were not studied by MRI were not lost to follow-up but declined to be evaluated because the cost of the MRI examination was expensive. There could be the possibility of a subtle selection bias. However, postoperative imaging evaluation was finally done in more than 70% of the total cases, confirming that arthroscopic suture bridge repair of full-thickness rotator cuff tears led to a relatively higher rate of recurrent defects than expected. Moreover, the demographic data of the 36 excluded patients were similar to those of the 87 who had postoperative MRIs.

In conclusion, arthroscopic suture bridge repair of full-thickness rotator cuff tears led to a relatively high rate of recurrent defects. However, the mean 25-month follow-up demonstrated excellent pain relief and improvement in the ability to perform the activities of daily living, despite the structural failures. The factors affecting tendon healing were the patient's age, the size and extent of the tear, and the presence of fatty degeneration in the rotator cuff muscle. The retear in cases with a suture bridge technique tended to be more frequently in the musculotendinous junction, but direct retear at the original repair site increased with severity of fatty degeneration or muscle atrophy.

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