

# A Prospective Randomized Clinical Trial Comparing Arthroscopic Single- and Double-Row Rotator Cuff Repair

## Magnetic Resonance Imaging and Early Clinical Evaluation

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**Background:** Double-row arthroscopic rotator cuff repair has become more popular, and some studies have shown better footprint coverage and improved biomechanics of the repair.

**Hypothesis:** Double-row rotator cuff repair leads to superior cuff integrity and early clinical results compared with single-row repair.

**Study Design:** Randomized controlled trial; Level of evidence, 1.

**Methods:** Forty patients were randomized to either single-row or double-row rotator cuff repair at the time of surgical intervention. Patients were followed with clinical measures (UCLA, Constant, WORC, SANE, ASES, as well as range of motion, internal rotation strength, and external rotation strength). Magnetic resonance imaging (MRI) studies were performed on each shoulder preoperatively, 6 weeks, 3 months, and 1 year after repair.

**Results:** Mean anteroposterior tear size by MRI was 1.8 cm. A mean of 2.25 anchors for single row (SR) and 3.2 for double row (DR) were used. There were 2 retears at 1 year in each group. There were 2 additional cases that had severe thinning in the DR repair group at 1 year. The MRI measurements of footprint coverage, tendon thickness, and tendon signal showed no significant differences between the 2 repair groups. At 1 year, there were no differences in any of the postoperative measures of motion or strength. At 1 year, mean WORC (SR, 84.8; DR, 87.9), Constant (SR, 77.8; DR, 74.4), ASES (SR, 85.9; DR, 85.5), UCLA (SR, 28.6; DR, 29.5), and SANE (SR, 90.9; DR, 89.9) scores showed no significant differences between groups.

**Conclusions:** No clinical or MRI differences were seen between patients repaired with a SR or DR technique.

**Keywords:** rotator cuff repair; single row; double row

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Arthroscopic rotator cuff repair is becoming increasingly popular with a significant amount of research being performed evaluating techniques and outcomes. Most studies have used a single row of anchors for attaching the rotator cuff tendon to bone when doing the repair. With the recent emphasis on anatomy of the rotator cuff footprint, techniques attaching the rotator cuff tendon over more of its normal footprint have gained popularity.<sup>§</sup> In vitro studies have analyzed repair techniques using various combinations

<sup>§</sup>References 7, 11, 18, 21, 42, 47-49, 51, 52, 55, 64, 65.

of transosseous sutures and bone anchors to affect repairs.<sup>||</sup> These techniques have been evaluated to assess rotator cuff footprint coverage, contact pressure the sutures apply over the covered bone, and the mechanical strength of these various repairs.<sup>||</sup>

On the clinical side, single-row repairs have proven to be effective.<sup>#</sup> More recently, double-row techniques have been employed, and recent clinical studies evaluating double-row techniques show promising results.<sup>2,25,34,39</sup> Whether these new double-row techniques are capable of delivering superior results compared with single-row techniques has not been established.<sup>25,54,61,62</sup>

This clinical study was performed to address the question of whether a double-row rotator cuff anchor repair gives superior results to a single-row anchor repair. It was the hypothesis of this study that a double-row repair would result in better clinical outcome scores and that magnetic resonance imaging (MRI) evaluation of the healed tendons would show more intact rotator cuff tendons and better healing than the single-row method.

## MATERIALS AND METHODS

The study was approved by the Institutional Review Board. Patients were enrolled in the study by the 2 senior surgeons at the University of Utah Orthopaedic Center. Patients presenting or referred to the 2 senior authors with complaints of shoulder pain or loss of function underwent routine standard of care evaluation and treatment. Those in which a diagnosis of rotator cuff tear was made and who were deemed to be appropriate for surgical treatment were considered for the study. Only patients with a preoperative MRI finding that revealed a full-thickness rotator cuff tear were questioned as to whether they were willing to participate in the study.

### Patient Selection

Inclusion criteria included the following: (1) a full-thickness tear as seen on MRI, (2) the ability of the patient to complete serial MRI examinations, (3) willingness to comply with the standardized rotator cuff physical therapy program, (4) willingness to be randomized to a single- or double-row repair, and (5) a tear pattern that was amenable to repair with either single- or double-row fixation when evaluated at the time of surgery. We were not always able to repair very large tears using a double-row technique, and therefore only tears amenable to repair using either technique were included.

Exclusion criteria included the following: (1) an active history of smoking,<sup>45</sup> (2) an autoimmune or rheumatological disease, (3) the active use of steroids, (4) previous rotator cuff surgery on the affected shoulder, (5) a tear at the time of surgery that was not deemed to be repairable using the

double-row technique as employed in this study, (6) workers' compensation patients,<sup>50</sup> (7) a significant subscapularis tear, and (8) a tear pattern that required a significant side-to-side repair of the tendon.<sup>9</sup> These large "U"-shaped tears were excluded, as failures may have been more indicative of in situ tendon failure than a failure of tendon-to-bone healing.

### Clinical Evaluation

Preoperative and postoperative clinical evaluations were performed by an independent physical therapist blinded to the surgical repair technique performed. Evaluations were performed on all patients preoperatively, at 3 months postoperatively, and at 1 year postoperatively. Data were collected to allow a determination of the University of California, Los Angeles (UCLA) score, Constant-Murley score, Western Ontario Rotator Cuff Index,<sup>37</sup> SANE (Single Assessment Numeric Evaluation),<sup>66</sup> and American Shoulder and Elbow Surgeons score. Internal rotation strength was measured in the neutral position with the arm at the side and the elbow bent to 90°. External rotation strength was measured in the neutral position with the arm at the side with the elbow again bent to 90°. Elevation strength was measured with the arm actively held by the patient at 90° of elevation in the scapular plane. All strength measurements were performed using the Lafayette manual muscle test system (model 01163, Lafayette Instrument, Lafayette, Indiana) positioned at the wrist.<sup>33</sup> Three measurements were taken for 5 seconds each with a 5-second rest between repetitions, and the 3 measurements were averaged. Additionally, a seated active flexion, abduction, and external rotation range of motion were evaluated with the use of a goniometer.

### MRI Evaluation

Nonarthrographic MRI studies were performed on all patients preoperatively, at 6 weeks, 3 months, and 1 year after repair. This has been shown to be a reliable method of evaluating the repaired rotator cuff.<sup>26,35,56,63</sup> All MRI studies were done on a Siemens 1.5-T Avanto scanner (Berlin, Germany) with a dedicated shoulder coil with a 256 × 192 matrix. The following sequences were performed: coronal and sagittal T1-weighted with TR 500/TE 15, coronal and sagittal FSE T2-weighted with fat saturation 4500/60, and axial FSE proton density with fat saturation 2500/12.

All scans were read by 2 musculoskeletal specialty radiologists who had no knowledge of the patients' clinical information or surgical history. A consensus of these 2 radiologists was used to determine the MRI results. Size of the tear in the anteroposterior dimension and retraction of the tendon medially were recorded. Anteroposterior tear dimension was used to categorize tears into 2 groups: (1) 10 to 30 mm and (2) greater than 30 mm. Postoperative scans were evaluated for the presence of a full-thickness tear, defined as fluid signal and/or absence of visible tendon fibers extending across the entire tendon from inferior to superior. Tendons without a recurrent tear were evaluated for footprint size, tendon thickness, and tendon signal. Each of these parameters was each graded numerically on a scale from 1 to 4. Size of the

<sup>||</sup>References 1-3, 5, 8, 10, 12, 13, 19, 29, 30, 44, 46-48, 51, 57, 58, 60, 65.

<sup>||</sup>References 1-3, 19, 37, 44, 47-49, 53, 54, 61, 65.

<sup>#</sup>References 8, 9, 15, 24, 26, 32, 38, 40, 59.

tendon footprint was compared with footprint of a normal supraspinatus tendon, which covers the entire greater tuberosity from medial to lateral. In cases where the tendon attachment was medialized, width of the medialized footprint was compared with width of the greater tuberosity. Grade 4 coverage was present when coverage was >75% of width of greater tuberosity, grade 3 coverage was 51% to 75%, grade 2 coverage was 26% to 50%, and grade 1 coverage was <25% of greater tuberosity but with some continuous fibers inserting on the greater tuberosity.

Tendon thickness was compared with normal tendon using quartile divisions as described for footprint. Tendon signal intensity was divided into quartiles where grade 4 is normal signal intensity (low signal on all sequences), grade 3 is increased signal intensity in the tendon involving a less than 1-cm distance or <25% of tendon width, grade 2 is increased signal intensity in the tendon involving a 1- to 2-cm distance or 25% to 50% of tendon width, and grade 1 is increased signal intensity in the tendon involving more than 2-cm distance or >75% of tendon width. Footprint size, tendon thickness, and tendon signal intensity scores were added together to create a rotator cuff score. On this scale, a tendon repair with a completely normalized appearance had a score of 12.

### A Priori Paper Analysis

A review of the literature revealed that a retear rate of approximately 40% for single-row repair could be anticipated.<sup>4,22,27,31,41</sup> To achieve a clinically meaningful effect from double-row repairs, it was thought the anatomical failure rate should be at least halved to a 20% retear rate. Allowing for a 15% standard deviation within groups, it was determined that 20 patients per group would provide sufficient statistical power (80%) to detect a significant difference between groups ( $P \leq .05$ ) for retear rate.

### Surgical Technique

All operations were performed with the patient in the seated beach-chair position under general anesthesia. A supplemental interscalene block was performed on all patients to help control postoperative pain. A standard arthroscopic pump was used in all cases, and standard posterior and anterior portals were established to perform a thorough diagnostic examination and address any intra-articular injury. After the standard intra-articular examination, the scope was placed in the subacromial space via the posterior portal, and a lateral portal was developed. Subacromial bursal tissue was removed to gain a clear view of the rotator cuff and to evaluate the tear. A bipolar electrocautery ablation device was used to facilitate bursal tissue removal. After the tear had been debrided and evaluated for its configuration, it was assessed for its reparability by either a single- or double-row technique. If the tear was amenable to either repair, the patient was randomized at that time to single-row or double-row repair by means of a sealed envelope. The envelope contained a card on which was printed SR (single row) or DR (double row). The order of cards was developed by a random number generator (MATLAB,

MathWorks, Natick, Massachusetts) to create a random but equal selection of SR or DR cards. Accessory portals for gaining visibility or placing instruments or suture passing instruments were used as needed. The standard operating portals included the lateral portal for instrumentation, an accessory superior portal for anchor placement, and the previously established anterior and posterior portals. Frequently the scope was placed in an accessory posterolateral portal for better visualization of the rotator cuff tear, leaving the direct lateral portal free for instrumentation. An acromioplasty was performed before the cuff repair in 38 of the 40 cases. The footprint area of the greater tuberosity was thoroughly cleaned of soft tissue, and then a full radius resector was used on high speed to lightly buff the outer cortex; bleeding was induced, but the surface was not removed down to cancellous bone.

For single-row repairs, anchors were placed along the lateral edge of the greater tuberosity within the footprint of the rotator cuff and spaced at 5- to 10-mm increments. Bio FT anchors loaded with 2 No. 2 FiberWire sutures (Arthrex, Naples, Florida) were used in the study. After placement of the anchors through the superior portal, sutures were individually passed from the double-loaded anchors into the lateral edge of the tendon, taking a 10- to 15-mm bite of tissue using an antegrade suture passer or other instruments as deemed necessary to place a simple suture. When sutures had been placed, they were sequentially tied using a locking, sliding knot with back-up half-hitches.

For the double-row repair, the lateral row was established in a fashion similar to what had been done for the single row, but the medial row was also established with a diamond pattern of double-loaded anchors. In general, if 2 lateral anchors were used, one medial anchor was placed at the articular margin midway between the 2 lateral anchors. If 3 lateral anchors were used, 2 medial anchors were placed in a similar orientation.<sup>34,46</sup> The medial sutures were passed first, in a horizontal mattress fashion, near the muscle tendon junction of the rotator cuff, and the lateral sutures were then passed in a fashion similar to the single-row technique, taking a slightly smaller bite of tissue due to the location of the medial row of sutures. After the sutures had been passed, the lateral row was then sequentially tied and cut. The medial row was sequentially tied and cut only after securing all lateral-row sutures. One surgeon performed 7 DR and 11 SR repairs, and one surgeon performed 13 DR and 9 SR repairs.

Postoperatively all patients used an abduction sling (Ultrasling, DonJoy Inc, Vista, California) and started on a rehabilitation program. Under supervision, passive range of motion (ROM) was started in the first week. Active assisted ROM was typically started in a supine position starting at 4 to 6 weeks postoperatively, and full active ROM was commenced at 6 to 8 weeks with the longer time periods for very large tears. Strengthening exercises were typically delayed for 10 to 12 weeks.

### Statistical Methods

To test the hypothesis that double-row rotator cuff repairs provided superior clinical results to single-row repairs,

preoperative, 3-month, and 1-year scores from the patients were entered into a repeated measures ANOVA. To further determine whether there were significant differences between single- and double-row repairs for each of the individual clinical scores, at any given time point, each of the following variables were considered in a 2-tailed *t* test: WORC, UCLA, Constant, SANE, ASES, and internal rotation and external rotation strength. Significance level was set to .05 for all tests. The MRI data were analyzed by comparing total MRI-combined rotator cuff tendon healing scores as well as absolute retear rates between groups. Scores were evaluated to determine differences between single- and double-row groups at any given time interval. A 2-tailed *t* test was used with significant level set to  $\leq .05$ .

## RESULTS

The average preoperative duration of symptoms for the patients in the study was 16.8 months (range, 1 month to 12 years). The average age of patients for the entire study group was 56.5 years (SR: 56 years, range 43-74; DR: 57 years, range 41-81). Twenty-five of the patients reported some antecedent trauma causing the symptoms, and 15 reported that the symptoms started insidiously.

Associated pathological lesions evaluated and treated at the time of the surgery included 12 distal clavicle resections, 2 cases of biceps tenodesis, 5 cases of biceps tenotomy, and 1 type IV SLAP lesion, which was debrided. There were more distal clavicle resections performed in the double-row group ( $n = 8$ ) than in the single-row group ( $n = 4$ ), but no other differences between the groups were found in treated associated lesions. There were also 6 cases (3 in each group) of some fraying of the upper subscapularis tendon, which was debrided. In each group, 1 patient had 1 anchor placed at the upper subscapularis to reinforce the subscapularis. This anchor was not included in the anchor count when determining overall number of anchors used in the single- and double-row repairs.

No patients were lost to follow-up, and all completed the 1-year evaluation. The average number of anchors used was 2.25 for single-row and 3.2 for double-row repairs. Excluding the issue of a retear, there were no complications in the groups. There were no neurological injuries, no infections, and no anchor pull outs.

The preoperative MRI was the primary means of determining the size of the rotator cuff tear. Based on MRI measurements, mean size of the tear was 18 mm in the anteroposterior direction for the single-row group and 19 mm in the double-row group. Tears ranged in size from 10 mm to 45 mm. When tears were divided into size categories, the single-row group had 18 tears 1 to 3 cm in size and 2 larger than 3 cm. In the double-row group, there were 15 tears 1 to 3 cm in size and 5 larger than 3 cm.

Clinical outcome as evaluated using the Constant, WORC, ASES, UCLA, and SANE scores, as well as manual muscle testing and pain scores, showed significant improvement over time in all parameters for the entire group of 40 patients (Table 1). However, double-row repairs

TABLE 1  
Means and Standard Deviations (SDs) for  
Clinical Scores Preoperatively and 1 Year After  
Surgery for Participants Undergoing Single  
and Double Rotator Cuff Repairs<sup>a</sup>

	Preoperative	1 Year
WORC	31.1 (18.4)	86.3 (19.0) <sup>b</sup>
Constant	44.8 (19.3)	76.1 (14.4) <sup>b</sup>
ASES	39.3 (20.2)	85.7 (17.0) <sup>b</sup>
UCLA	12.9 (4.3)	29.1 (4.6) <sup>b</sup>
SANE	40.8 (22.2)	90.4 (15.9) <sup>b</sup>
External rotation (N·m)	9.2 (5.3)	17.0 (7.5) <sup>b</sup>
Internal rotation (N·m)	16.9 (9.8)	28.5 (13.9) <sup>b</sup>

<sup>a</sup>WORC, Western Ontario Rotator Cuff Index; Constant, Constant-Murley; ASES, American Shoulder and Elbow Surgeons; UCLA, University of California, Los Angeles; SANE, Single Assessment Numeric Evaluation. All patients significantly improved at 1 year compared with preoperative scores. Internal and external rotation strength also improved at 1 year compared with preoperative values.

<sup>b</sup> $P < .000$ .

were not found to be significantly better than single-row repairs at each evaluation time ( $F = 0.359$ ;  $P = .789$ ) (Table 2). Further, when scores were considered individually, no significant differences for single row compared with double row were noted for any of the scores (Table 2). External and internal rotation strength was not significantly different at 1 year (Table 3).

The MRI results at 6 weeks revealed a complete retear in 1 double-row patient. The tear occurred at the tendon insertion. In addition, 1 single-row repair appeared torn at 6 weeks but on subsequent scans normalized and was thought to be a false positive by MRI. There were no additional retears at 3 months. At 1 year, there were 2 additional tears in the single-row group and 1 in the double-row group. All of these tears were away from the repair site. The incidence of recurrent tear in both groups was 10%. Also at 1 year, 2 patients in the double-row group appeared to have a nearly completely torn rotator cuff that had thinned markedly from 3 months and showing only a few residual fibers.

The appearance of the repaired intact tendons is summarized (Table 4) using the previously described scoring system. There was no significant difference between the 2 groups in tendon thickness, abnormal signal in the tendon, or footprint size. Mean footprint size score increased from 2.6 at 6 weeks to 3.8 at 1 year.

Figure 1 illustrates the range of appearance of the tendons 1 year after surgery. Rotator cuff tendon healing score (sum of scores for footprint size, tendon signal intensity, and tendon thickness) as described in Materials and Methods was used for comparison of the 2 groups. There was no significant difference in the scores between the 2 groups. At 1 year, excluding recurrent tears, both groups showed a rotator cuff score of 9 out of a possible score of 12.

TABLE 2  
Means and Standard Deviations (SDs) for Clinical Scores Preoperatively and 1 Year After Surgery for Participants Undergoing Single or Double Rotator Cuff Repairs<sup>a</sup>

	Preoperative Scores			1-Year Scores		
	Single Row	Double Row	<i>P</i>	Single Row	Double Row	<i>P</i>
WORC	30.3 (17.7)	31.8 (19.4)	.880	84.8 (18.4)	87.9 (20.0)	.236
Constant	44.1 (18.8)	45.6 (20.3)	.569	77.8 (9.0)	74.4 (18.4)	.980
ASES	41.0 (21.5)	37.6 (19.3)	.450	85.9 (14.0)	85.5 (20.0)	.673
UCLA	12.1 (3.9)	13.6 (4.6)	.176	28.6 (3.6)	29.5 (5.6)	.165
SANE	40.8 (23.3)	40.8 (21.6)	.867	90.9 (11.0)	89.9 (20.0)	.527

<sup>a</sup>WORC, Western Ontario Rotator Cuff Index; Constant, Constant-Murley; ASES, American Shoulder and Elbow Surgeons; UCLA, University of California, Los Angeles; SANE, Single Assessment Numeric Evaluation. Results of the paired *t* test indicate that there was no difference in scores for single- and double-row repairs preoperatively or at 1 year after surgery.

TABLE 3  
Means and Standard Deviations (SDs) for Internal and External Rotation Strength Preoperatively and 1 Year After Surgery for Participants Undergoing Single or Double Rotator Cuff Repairs<sup>a</sup>

	Preoperative Scores			1-Year Scores		
	Single Row	Double Row	<i>P</i>	Single Row	Double Row	<i>P</i>
External rotation (N·m)	8.7 (4.6)	9.6 (6.0)	.384	17.2 (7.7)	16.7 (7.5)	.862
Internal rotation (N·m)	15.8 (7.9)	18.1 (11.6)	.345	28.1 (13.8)	28.8 (14.4)	.687

<sup>a</sup>Results of the paired *t* test indicate that there was no difference in scores for single- and double-row repairs preoperatively or at 1 year after surgery.

TABLE 4  
Means and Standard Deviations (SDs) for Radiology Scores at 6 Weeks, 3 Months, and 1 Year After Surgery for Participants Undergoing Single and Double Rotator Cuff Repairs<sup>a</sup>

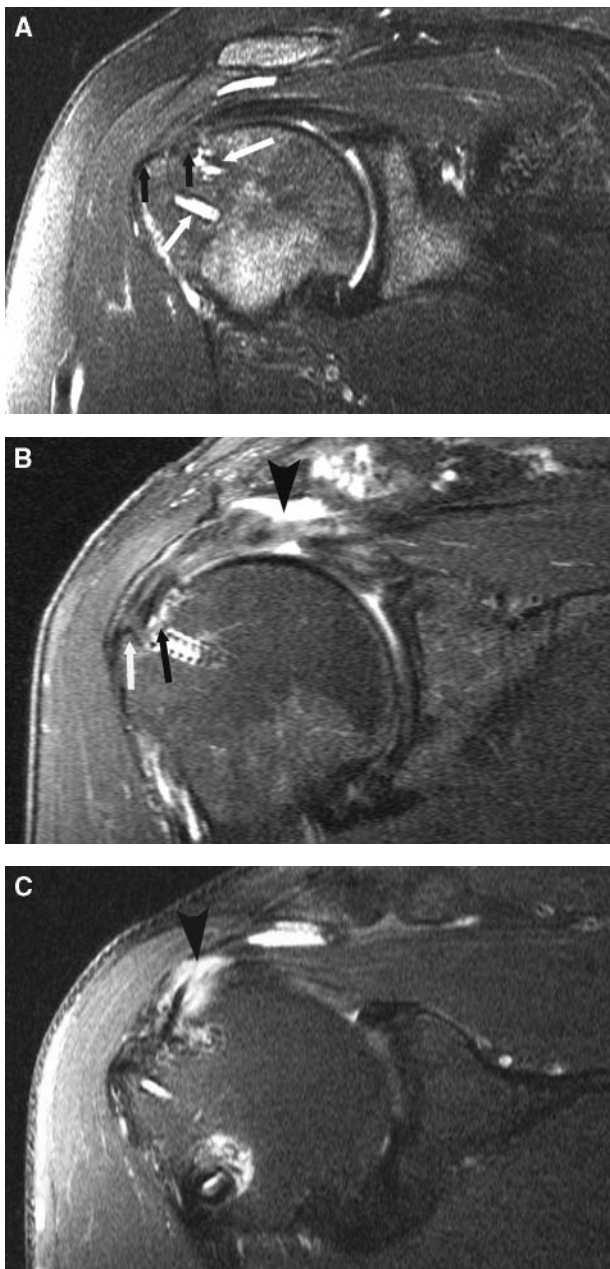
	6-Week Scores		3-Month Scores		1-Year Scores	
	Single Row	Double Row	Single Row	Double Row	Single Row	Double Row
Footprint	2.39 (0.78)	2.72 (0.89)	2.61 (1.20)	2.89 (0.79)	3.50 (0.79)	3.83 (0.51)
Signal	2.06 (0.87)	3.00 (0.54)	1.78 (0.94)	2.17 (0.68)	2.33 (0.84)	2.44 (1.10)
Thickness	2.39 (1.20)	3.11 (0.73)	2.17 (0.99)	2.44 (0.84)	2.72 (0.57)	2.78 (1.00)

<sup>a</sup>There were no significant differences in footprint, thickness, or signal content between single- and double-row repair groups at any of the time points presented.

## DISCUSSION

Recent arthroscopic repair techniques for rotator cuff tears have emphasized the potential for a double-row repair to add strength to the repair and hopefully decrease the anatomic failure rate.<sup>2,3,34,39,61,62</sup> Several studies have indicated that results in cases with anatomic failure, although clinically improved, are not as good as those that are anatomically intact, especially if strength measurements are made.<sup>2,4,6</sup> Therefore, trying to achieve and maintain an intact cuff is a paramount goal in cuff repair. Biomechanical studies have emphasized the potential improvement of outcomes by double-row repair technique.<sup>36,43,47,48,60,64</sup>

However, clinical studies have not yet validated this idea.<sup>25,54</sup> Anderson et al<sup>2</sup> reported on double-row cuff repair and overall had very good results but did report a 17% retear rate and had no comparable single-row group. Fealy et al<sup>23</sup> commented on a mini-open double-row technique using a combination of anchors as well as transosseous sutures and had excellent clinical results, but no data were given on cuff integrity. Huijsmans et al<sup>34</sup> used a surgical technique similar to the technique used in this study. Their repairs were followed by ultrasound, and the patients had 91% good and excellent clinical results and 83% intact cuffs at final follow-up. These results were again viewed as very good, but there were no comparison data given in their



**Figure 1.** A, normal-appearing tendon 1 year after rotator cuff repair. Coronal T2-weighted imaging with fat saturation. Black arrows point to footprint of supraspinatus tendon, completely filled with normal-appearing fibers. Tendon thickness and signal intensity are normal. White arrows point to tracks of bioabsorbable screws, surrounded by minimal signal artifact. B, thin tendon and incomplete footprint coverage 1 year after rotator cuff repair. Coronal T2-weighted imaging with fat saturation. White arrow shows portion of tendon footprint covered by tendon. Black arrow shows uncovered medial 50% of tendon footprint. This was classified as grade 2 coverage. Arrowhead shows thinning of tendon to 50% of normal thickness, classified as grade 2 tendon thickness. Fairly extensive high signal in the tendon was classified as grade 2 tendon signal. C, tendon tear 1 year after rotator cuff repair. Coronal T2-weighted imaging with fat saturation. Arrowhead shows tendon torn away from reattachment site. Tears were always confirmed in 2 planes, as single-plane imaging can be misleading.

paper to another repair technique. Lafosse et al<sup>39</sup> published on double-row repair with overall excellent results and a high percentage of intact cuffs, but this study once again did not include any comparative procedures.

Sugaya et al<sup>62</sup> performed a nonrandomized study to evaluate the results of single- and double-row repairs. This study was biased on patient inclusion in that the early patients were treated with a single-row repair and later patients were treated with a double-row repair. They were unable to find any difference between the groups in functional outcome. They did find that there was a significant difference in retear rate with a single-row retear rate of 26% and a double-row rate of 10%. Sugaya et al<sup>61</sup> subsequently published on a group of 86 patients treated with a double-row technique who had an overall retear rate of 17%. Franceschi et al<sup>25</sup> reported on 52 patients who had been randomized to single- or double-row repairs. Patients received UCLA scores for clinical evaluation and had MRI arthrograms at final follow-up. The authors were unable to find any difference between the groups in regard to percentage of healed cuffs, UCLA scores, or range of motion scores. Charouset et al<sup>14</sup> described a recent nonrandomized comparison of double-row and single-row patients. In this series, the lateral row was fixed with single-loaded Panalok RC (DePuy Mitek, Raynham, Massachusetts) anchors. The double row was performed using the same single-loaded anchors laterally and added a single Mitek cuff Tack placed medially (DePuy Mitek) in all but 2 cases. In the other 2, there were 2 medial tacks placed. The patients had computed tomography arthrograms done at 6 months postoperatively. At final follow-up, Constant scores showed no difference between the groups, and there was no difference when one analyzed for complete healing. The only difference found was that of “anatomic healing,” which they determined to be present in 61% of the cases of the double-row technique and 40% in the single-row technique.

The present study adds to the literature the finding that in a very closely followed group of patients, single-row and double-row repairs gave similar clinical results. Our MRI results showed 4 failures at a year for an overall failure rate of 10%. If the 2 additional cases of severe thinning in 2 double-row cases were included, the failure rate would be 15%. The fact that in our series failures and impending failures occurred later in the healing process calls into question the belief that most retears occur early.<sup>28</sup> This is, however, the rate at 1 year and most likely will increase with longer follow-up. This low failure rate may be partially attributable to patient age as our mean age was 56 years. Boileau et al<sup>6</sup> showed a significant increase in failure rates in patients older than 65 years of age. In addition, there were no massive cuff tears in the present series, and most tears were between 1 and 3 cm in size.

Although there are numerous biomechanical studies that can show superiority of certain cuff repair techniques compared with another technique at time zero, there are no reports of these effects on biologic healing. Indeed when analyzing the biomechanical studies of Mazzocca et al,<sup>46</sup> Park et al,<sup>53</sup> and Smith et al,<sup>60</sup> although the double-row repair had high ultimate load to failure, failures in the double row occurred more at the muscle-tendon junction or where the medial suture anchors had been placed. This raises a concern

that the double row could indeed increase stresses at the muscle-tendon junction, which may be a weak link in the repair.

Another issue is that many of the basic biomechanical studies compare double- and single-row techniques but have double the number of anchors for the double-row repair compared with the single-row repair.<sup>36,47,48,60,64</sup> Interestingly, when looking at the number of anchors used in the double-row repairs recently reported in clinical studies, the number of anchors used was actually not that high.<sup>2,25,34,62</sup> In fact, in the paper by Franceschi et al,<sup>25</sup> who included only large or massive tears in their comparisons, only 1.9 anchors were used for the single row and 2.3 anchors for the double row. This is actually a fewer number of anchors than was used in our study, which evaluated tears that were thought to be mainly small to medium in size. So although our study clearly had smaller tears and may not be applicable to results in large or massive tears, it is interesting that the mean number of anchors used (2.25 for SR and 3.2 for DR) is subsequently more than that of Franceschi et al,<sup>25</sup> who only studied large and massive tears. Sugaya et al<sup>62</sup> used on average 2.4 anchors for single row and 3.2 anchors for the double row. Anderson et al<sup>2</sup> used 1.2 anchors for the medial row and 1.6 anchors for the lateral row. Huijsmans et al<sup>34</sup> stated, "In our experience, the majority of the cases required no more than 2 or 3 anchors for a standard double row repair. . . ." It may be that surgeons find placing some of these anchors more difficult in the clinical setting than they do in the laboratory setting, which may explain why fewer anchors were used. Perhaps the added anchors were just not thought to be necessary. It seems clear however that to date, the clinical papers that have used double-row techniques often do not mimic what has been bench tested in the laboratory. There are new double-row techniques that may allow for more anchors to be placed while not worrying about crowding, but it still remains to be seen whether this will have a significant clinical affect.<sup>52,53</sup>

Another confounding issue is the number of sutures used per anchor. Studies have shown that increasing the number of sutures per anchor can significantly increase the holding strength.<sup>16,17</sup> However, several biomechanical studies and some clinical ones have used only single-loaded anchors.<sup>47,48,52</sup> Therefore, the comparisons between single row and double row are often more difficult given this variability that frequently is not discussed. In addition, Deutsch<sup>20</sup> presented on another variable of the increased strength and footprint coverage that a single-row repair can have with increased depth of bite of tissue.

The strength of the present study includes the fact that we had 100% follow-up and that multiple shoulder scoring systems were used to evaluate the groups. The double-row repairs were done in a way supported by a significant amount of basic research.<sup>36,46,60,64</sup> Anchors and sutures were uniform, so the pure focus was on just single- versus double-row repair. Patients were carefully selected to eliminate confounding issues in evaluating the results. All patients got preoperative, 6-week postoperative, 3-month postoperative, and 1-year postoperative MRIs to closely evaluate healing and to also determine timing of any failures.

A limitation of this study is the number of patients for comparison. We did not see the number of failures in the study that had been assumed from the literature, and so there could be an error (type II) in finding a true difference between single-row and double-row groups, which a larger number of patients could have revealed. However, given the results of these 40 patients, a very large study would have been needed to detect the smaller differences. Indeed, sample size analyses conducted on the results presented in Table 2 revealed that at least 80 patients would be required per group to detect a significant difference in external rotation strength at 3 months (the largest effect noted here). A minimum of 224 patients would be needed to show an effect in the Constant score at 1 year (the largest effect at 1 year). Another limitation is the short follow-up of 1 year. It is believed, however, that with healing at 1 year, results are unlikely to significantly change between the 2 techniques with longer follow-up. It is reasonable to assume that by 1 year the tendon is healed to the bone and subsequent failures would be related to intrinsic tendon disease, which should be equal between the groups. Another limitation was the average tear size of 1.8 cm in an anteroposterior direction. These were for the most part small and medium by conventional measures, and so results may not be able to be extrapolated to much larger tears.

In summary, this prospective randomized evaluation of single-row compared with double-row rotator cuff fixation did not show a significant difference in outcome in terms of clinical results or MRI results.

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