Early Structural and Functional Outcomes for Arthroscopic Double-Row Transosseous-Equivalent Rotator Cuff Repair

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Background: The arthroscopic double-row transosseous-equivalent (TOE) rotator cuff repair is growing in popularity. The current body of literature supports this technique; however, the number of patients in these studies is relatively small. The authors conducted this study to learn more about the natural history of this construct in a large sample of patients.

Hypothesis: The double-row TOE rotator cuff repair will have an acceptable structural failure rate with improved clinical outcomes at 1-year follow-up.

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

Methods: Between June 2006 and October 2007, 225 patients underwent an all-arthroscopic rotator cuff repair at 2 surgical centers. A total of 155 TOE primary rotator cuff repairs were performed, and 154 of these patients met the inclusion criteria. Assessment of structural integrity was based on evaluation of postoperative magnetic resonance imaging or computed tomography arthrogram at a minimum of 12 months after surgery. The Constant scores, visual analog pain scale, range of motion, strength, and complications were the clinical outcomes analyzed for the study. Seventeen patients (of 154) had postoperative shoulder stiffness at follow-up.

Results: The 154 patients were clinically and radiologically evaluated at a mean of 15 months postoperatively (range, 12-26.1 months). The study included 47 small (30.5%), 89 large (57.1%), and 19 massive (12.3%) rotator cuff tears. Analysis of postoperative imaging demonstrated that 92%, 83%, and 84% of the small, large, and massive rotator cuff tears, respectively, were intact. The mean Constant score improved from 44.42 points preoperatively to 80.47 points postoperatively ($P < .001$). The mean preoperative pain score improved from 3.83 to 12.77 ($P < .001$) postoperatively. The mean forward flexion improved from 123.06° preoperatively to 162.39° postoperatively ($P < .001$). Seventeen patients (of 154) had postoperative shoulder stiffness at follow-up.

Conclusion: The short-term results of this study indicate that the clinical outcomes and structural integrity of TOE double-row rotator cuff repair (the suture-bridge technique) have results that compare favorably with those reported for other double-row suture anchor techniques employed in rotator cuff repairs. Long-term follow-up will be necessary to determine if the durability of these repairs and the structural integrity of these constructs maintain their performance over time.

Keywords: rotator cuff; double-row; shoulder; suture bridge

Arthroscopic rotator cuff repair is being performed by an increasing number of orthopaedic surgeons. The principles, techniques, and instrumentation have evolved over the past 15 years such that most repairable rotator cuff tears can be reconstructed arthroscopically despite significant retraction and result in good clinical outcomes.[4,7,12] However, successful healing of these rotator cuff repair constructs remains challenging.

Several studies have demonstrated that short-term clinical outcomes after arthroscopic rotator cuff repair are comparable with those of the traditional open and mini-open repair.[27,30,40,41] Several published studies have compared radiographic integrity of arthroscopic repairs with clinical outcomes with widely varying results, many of which are underpowered. Single-row cuff repairs have shown high failure rates with follow-up radiographic evaluation.[2,19,24,29] Lafosse et al[27,28] have recently published that rotator cuff repair with the use of the double-row suture anchor technique results in a much lower rate of failure than had previously been reported in association with either open or arthroscopic repair methods. In their study, Lafosse et al[27,28] demonstrated an 11.4% (12 of 105)

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failure rate with significant improvements in Constant score, strength, abduction, active forward flexion, and pain scores, suggesting that double-row suture anchor technique may be a superior mode of fixation over single-row rotator cuff repair. However, long-term clinical outcome studies as well as blinded randomized (to single-row repairs) trials are lacking.

The purpose of the present study is to evaluate the structural integrity and clinical outcomes of arthroscopic rotator cuff repairs using the double-row transosseous-equivalent (TOE) suture anchor technique and to learn more about potential complications of this repair in a large patient population. We hypothesize that the double-row TOE rotator cuff repair will have an acceptable structural failure rate with improved clinical outcomes at 1-year follow-up.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

Between June 2006 and October of 2007, 225 all-arthroscopic primary rotator cuff repairs were repaired by 2 senior surgeons at 2 surgical centers. All shoulders in the present study had either an isolated supraspinatus tear or a supraspinatus tear with an infraspinatus extension and or subscapularis extension. Other inclusion criteria were repair with a TOE construct, must have preoperative and postoperative imaging at a minimum of 1 year, and must be available for clinical follow-up at a minimum of 1 year. Exclusion criteria for this study included all patients who (1) did not have a TOE double-row suture anchor repair, (2) underwent revision procedures, (3) had complete rupture of the subscapularis, or (4) had fatty infiltration of the rotator cuff greater than Goutallier stage II.[22,23] The inclusion criteria were met for 154 shoulders of the 225 patients. All shoulders had postoperative arthrography, a CT arthrogram, or an MRI arthrogram at a minimum of 12 months to evaluate the integrity of the rotator cuff repair. Patients who were later unable to be followed up at 1-year or declined postoperative imaging were later excluded from the study. The present study received institutional review board approval and all patients were enrolled in compliance with this protocol.

The indication for surgery was the failure of nonoperative treatment, defined as a trial of physical therapy with the goal of strengthening of the rotator cuff, deltoid, as well as scapular stabilizer muscles. The study cohort included 83 men (54%) and 71 women (46%). Of the operated shoulders, 114 (74%) were the right shoulder and 40 (26%) were the left shoulder; 147 (95%) of the patients had the surgery on the dominant shoulder. Postoperative imaging and clinical follow-up was done at a minimum of 12 months (range, 12-26.1 months). Clinical outcome measures evaluated included visual analog pain scores, forward flexion, strength, and Constant scores.

Classification of Rotator Cuff Tears

Each rotator cuff lesion was evaluated in both the coronal and sagittal planes at the time of arthroscopy. In the coronal plane, the lesion was evaluated according to the classification system of Patte[38]: type 1 (small tears) indicates retraction to the margin of the articular surface on the humerus, type 2 (large tears) indicates retraction between the articular margin of the humerus to the glenoid, and a Patte type 3 (massive tears) indicates retraction of the tendon to the level of the glenoid or medial. In our cohort, 47 (30.3%) had type 1 lesions, 88 (57.4%) had type 2 lesions, and 19 (12.3%) had type 3 lesions.

Patient Evaluation and Determination of the Structural Integrity of Repair

All patients underwent a standard history and physical examination. Specifically, the patients were asked if there were a specific traumatic event, activity status, job status, history of shoulder problems, functional status, and duration of symptoms. A shoulder examination was conducted to evaluate limitations on range of motion; Speed test, acromioclavicular pain, Jobe test, O'Brien test, and deltoid muscle atrophy were assessed. Outcomes measures evaluated preoperatively and postoperatively included the visual analog score for pain (0-15 points, with 0 representing maximal pain), the Constant score,[13] active range of motion (forward flexion in the plane of the scapula), and strength recorded for each shoulder. Patients had either a CT arthrogram or MRI arthrography preoperatively and at their follow-up visit. All of the MRI and CT arthrograms were evaluated by 2 board-certified radiologists at 2 different institutions who specialize in musculoskeletal imaging. However, each of the radiologists evaluated the images deriving from their respective centers. The integrity of the rotator cuff repairs on these shoulder images were classified into 4 groups based on a previously published classification scheme for evaluating rotator cuff repair integrity: normal, intratendinous leakage, transtendinous leakage, and complete rupture of repair.[27] Rotator cuff repairs with either no leakage or a small amount of contrast leakage traveling down the suture were considered intact. Rotator cuff repairs with transtendinous or complete ruptures of the footprint were categorized as

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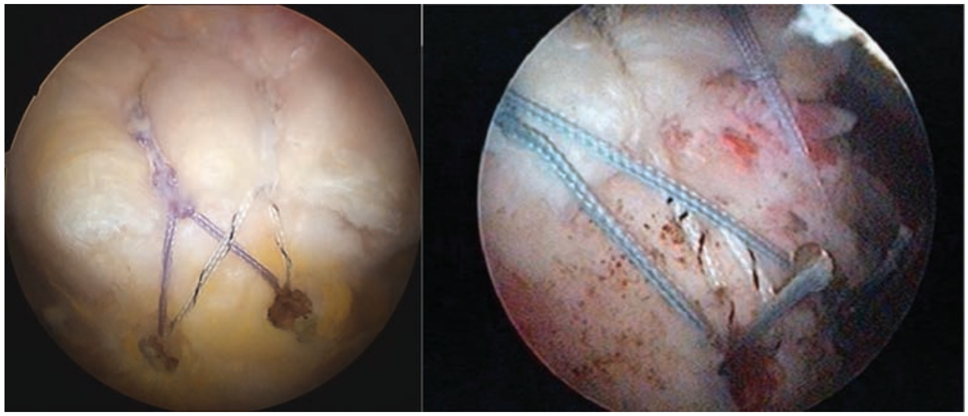


Figure 1. Examples of complete TOESB constructs.

failed repairs. Intratendinous leakage within the footprint reconstruction was classified as intact because the leakage was likely the result of contrast traveling along the suture line.[27] In the cases with small tears, resection or release of the rotator interval was never necessary, thus structural failure of the rotator cuff was considered to have occurred when there was any extravasation of contrast medium into the subacromial space. In cases of large and massive tears, an intact repair was defined as a normal-appearing anatomic footprint. In our experience, operative repair in large and massive tears often requires resection of the rotator interval as part of the release necessary to mobilize these tears so that leakage of contrast medium into the subacromial space cannot be the criterion used to evaluate the structural integrity of these repairs. Rather, the presence of transtendinous leakage with detachment of the rotator cuff footprint signified a failure of the repair.

Strength Testing

Manual strength testing was performed for each shoulder preoperatively and postoperatively with a portable isometric dynamometer (Isobex 2.0, Cursor, Bern, Switzerland). Strength testing was performed with the arm in 90° of abduction in the scapular plane and neutral rotation while the patient was standing with the dynamometer at shoulder level. The patient was instructed to hold this position with a maximum force for 3 seconds during the measurements.

Arthroscopic Rotator Cuff Repair

All patients received a preoperative interscalene block. The patients were placed in the beach-chair position with the arm forward-flexed with approximately 3 kg of traction. Three to 6 arthroscopic portals were used to perform the surgery (posterior, posterolateral, lateral, anterolateral, anterior, and anteroinferior). The subacromial space was inspected and cleared of bursa, reactive synovitis, and subdeltiod adhesions. In our patient population, all 154 patients underwent an acromioplasty and 28 (18.2%) had an acromioclavicular joint resection. The coracohumeral ligament, the superior capsule, and/or the rotator interval were released as needed to maximize the mobility of the rotator cuff before the repair. Adequate release of the cuff was achieved when the tissue edges could be easily reduced over the greater tuberosity with the use of a grasper instrument.

The greater tuberosity was prepared (gently decorticated) with a bur. On average, 2.25 (range, 1-4; standard deviation, ±0.51) medial row anchors (4.5-mm Biocorkscrew FT, Arthrex, Naples, Florida) were placed in the medial row.[3,35] The number of medial row anchors did vary depending on the size of the rotator cuff tear. Five patients received 1 medial row anchor, 110 patients received 2 medial row anchors, 37 patients received 3 medial row anchors, and 2 patients received 4 medial row anchors. In our patient population, 2.04 PushLock anchors (Arthrex) (range, 2-3; standard deviation, ±0.19) were used on the lateral row. A total of 148 patients received 2 lateral row anchors and 6 received 3 anchors. The medial sutures were passed through the rotator cuff from posterior to anterior and the sutures were tied with either a horizontal mattress configuration or with the use of a modified lasso-loop stitch,[42] depending on surgeon preference. The suture bridge was constructed by placing 2 knotless lateral row 4.5-mm PushLock anchors that held at least 1 suture strand from each of the medial row mattress knots. The anchor is inserted into the lateral aspect of the greater tuberosity with the sutures under tension so as to effect pressure across the rotator cuff footprint (Figure 1). Any sutures from the medial mattress knots that were not passed through the PushLock anchor were cut. In those patients with biceps tendon involvement, the operative management of the long head of the biceps tendon included tenotomy or arthroscopic tenodesis. The patient's arm was placed in a sling with abduction before the patient left the operating room.

Rehabilitation

We used a previously published rehabilitation protocol including unrestricted passive range of motion under the

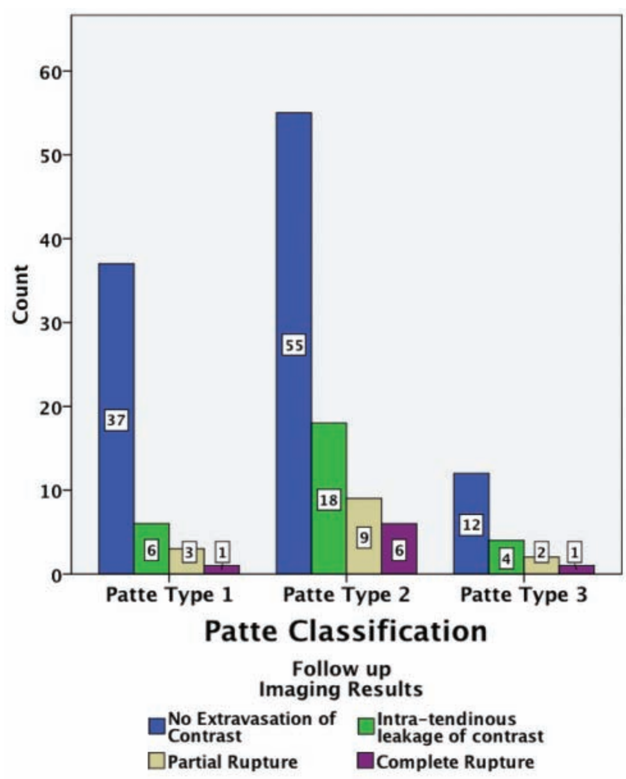


Figure 2. Postoperative MRI/CT arthrogram results stratified by tear size. The y-axis (count) represents the number of people in each group.

supervision of a qualified physical therapist for the first 6 weeks after surgery, then active range of motion at 6 weeks and strengthening at 3 months.[27]

Subjective Outcome Score

At the last follow-up visit, patients were asked (questionnaire) to rate how happy they were with their rotator cuff repair on a 10-point scale, with 1 being unhappy and 10 being happy with their results.

Statistical Analysis

Statistics were carried out with SPSS 17.0 (SPSS Inc, Chicago, Illinois). Measurements are expressed as the mean and the standard deviation. These data were collected prospectively. To evaluate patient outcomes, a paired t test was used (comparing samples before and after surgery) for continuous variables. An independent sample t test was used to evaluate differences in demographic data (sex). Analysis of variance was used to compare rotator cuff lesion types (Patte type 1, 2, and 3) and rotator cuff imaging outcomes (intact vs failure) with clinical outcome parameters. The level of significance was set at $P < .05$. Multivariate regression analysis was used to determine if relationships between the cause of the rotator cuff tear (traumatic, degenerative, etc), the age of the patient, sex of the patient, operative side, dominant side, job status (employed, retired, workers' compensation, homemaker, etc), athletic activity (sedentary, active but does not exercise, athletic but does not participate in competition, and participates in competitive athletic activities), the duration of symptoms (acute, <3 months; subacute, 3-6 months; chronic, >6 months) had significant effects on clinical outcomes.

RESULTS

Analysis of Structural Integrity of Rotator Cuff Repairs

All patients in the study had a postoperative MRI arthrogram or CT arthrogram at a mean of 15 months after surgery to evaluate the structural integrity of their rotator cuff repair. Of the original 225 patients, 155 had a primary double-row TOE repair. One patient declined postoperative imaging and was excluded from the remainder of the study. Seventy patients were initially excluded because they either received a single-row repair or they underwent a revision procedure. In our cohort, 154 patients had adequate postoperative imaging (100 MRI and 54 CT). Of the 154 patients with adequate imaging studies, 132 patients (86%) had an intact repair on their postoperative imaging study and 22 patients (14%) had a failure of their rotator cuff repair. If the rotator cuff repairs are categorized according to the size of the rotator cuff tear, then 92% (43 of 47) of the small rotator cuff tears, 83% (73 of 88) of the large rotator cuff tears, and 84% (16 of 19) of the massive rotator cuff tears were intact on the postoperative imaging studies. Of these, 6 of the small tears, 18 of the large tears, and 4 of the massive tears were found to have intratendinous leakage but were graded as intact according to the classification scheme we used in this study. If the structural integrity of all of these repairs is analyzed grading only "watertight" repairs as intact, then 79% (37 of 47) of the small, 63% (55 of 88) of the large, and 63% (12 of 19) of the massive tears were intact (Figure 2).

Pain Score, Strength, and Motion

Overall, the patients experienced marked pain relief after their rotator cuff repair. The mean pain score on the visual analog scale improved from 3.83 (standard deviation, ±2.82) to 12.77 (±2.8) ($P < .001$) (Table 1). Both intact and failed repairs showed significant improvement in pain scores (Table 2). Shoulders with intact repairs did not have a significant improvement in mean pain scores over those patients with failed rotator cuff repairs (postoperative pain score minus preoperative pain score). The mean improvement in the pain score for those patients with intact rotator cuff repairs was 9.05 compared with 8.36 ($P = .474$) for the group with failed rotator cuff repairs.

A separate analysis (1-way analysis of variance with a post hoc Tukey HSD [honestly significant difference] test) was done to assess the clinical effect of biceps tendon management on rotator cuff repair outcomes. In this study,

TABLE 1
Preoperative, Postoperative, and Mean Improvement in Constant Scores, Pain Scores, Range of Motion, and Force[a]

	Preoperative			Postoperative			
	Mean	SD	Range	Mean	SD	Range	Mean Improvement
Constant score	44.42	8.88	23-66	80.47	9.3	40-96	36.05
P value							<.001
Pain score	3.83	2.82	0-10	12.77	2.8	5-15	8.94
P value							<.001
Forward flexion, deg	123.06	26.99	60-170	162.39	15.57	15-170	39.33
P value							<.001
Force, kg	2.594	1.14	0-6	8.38	4.42	2-22	5.786
P value							<.001

[a]SD, standard deviation.

TABLE 2
Mean Improvement in Clinical Outcomes Stratified by Intact and Failed Repairs: Postoperative Imaging Results[a]

	Intact (n = 132) (85.7%)				Failed (n = 22) (14.3%)			
	Mean Preop	Mean Postop	Mean Improvement	*P* Value	Mean Preop	Mean Postop	Mean Improvement	*P* Value
Pain score	3.93	12.98	9.05	<.001	3.14	11.5	8.36	<.001
Range	0-10	5-15	−5-15		0-10	5-15	0-14	
SD	2.88	2.62	4.15		2.42	3.53		
Forward flexion, deg	124.43	163.26	38.83	<.001	116.82	157.27	40.46	<.001
Range	60-170	15-170	−85-110		70-160	130-170	6-46	
SD	26.31	15.92	27.20		29.66	12.79		
Strength, kg	2.67	8.86	6.20	<.001	2.27	5.73	3.45	.002
Range	0-6	2-21	1-18		1-4	3-22	0-20	
SD	1.15	4.24	4.24		0.94	4.59		
Constant score	44.78	81.79	37.01	<.001	42.86	72.82	29.96	<.001
Range	23-66	51-96	5-70		31-62	40-62	6-46	
SD	8.85	8.41	10.42		8.82	11.09	12.47	

[a]N = 154 (1 patient did not return for imaging). SD, standard deviation.

54 patients had a biceps tenotomy, 55 patients had a biceps tenodesis, 40 patients had no treatment of their biceps, and 5 patients had biceps tendons that had undergone spontaneous rupture. In all 4 subgroups (no intervention, tenotomy, tenodesis, and rupture), the clinical outcomes significantly improved after repair of the rotator cuff. Interestingly, those patients having biceps tenodesis (pain score average = 10.9) demonstrated inferior outcomes in terms of pain score when compared with the patients having no biceps treatment (14.1), rupture (13.4), or tenotomy (13.6) ($P \leq .05$).

The overall strength improved in this patient population. Mean preoperative strength was increased from 2.59 kg (±1.14 kg; range, 0-6) to a mean postoperative strength of 8.38 kg (±4.42 kg; range, 2-22) ($P < .001$). Both intact and failed rotator cuff repair cohorts showed significant improvement in strength. Shoulders with intact repairs were significantly stronger when compared with failed repairs with an improvement in strength of 6.19 kg versus 3.46 kg ($P = .006$), respectively. Not surprisingly, there was a significant association between increased postoperative strength and sex (males) ($P = .03$).

There was also a significant improvement in mean forward flexion in both intact and failed rotator cuff repair patients. Overall, the mean preoperative forward flexion was 123.06° (±26.99°; range, 60°-170°) and increased to 162.39° (±15.57°; range, 15°-170°). Shoulders with an intact repair were not significantly different from those with a failed repair ($P = .79$). No factors in the multivariate analysis were significant.

Constant Score

The mean Constant score was 44.42 (±8.88 points; range, 23-66) preoperatively and 80.47 (±9.3 points; range, 40-96) with a mean improvement of 36.05 points at postoperative follow-up ($P < .001$). Patients with an intact repair (n = 132) had a mean preoperative Constant score of 44.78 (±8.85) and a mean postoperative Constant score of 81.79 points (±8.41 points) with a mean improvement of 37.01 points (±10.41, $P < .001$). Patients with a failed repair (n = 22) also had improved Constant scores, with a mean preoperative score of 42.86 points and a mean postoperative score of 72.82 points and a mean improvement of 29.96 points ($P < .001$). Patients with an intact rotator cuff repair had significantly better improvement in Constant scores than those with failed repairs ($P = .005$).

TABLE 3
Mean Improvement in Clinical Outcomes Stratified by Tear Size[a]

	Small Tear		Large Tear		Massive Tear	
	Preop	Postop	Preop	Postop	Preop	Postop
Contant score	45.55	81.33	44.79	80.88	39.89	76.95
P value		<.001		<.001		<.001
Pain score	3.91	12.66	3.75	12.91	3.95	12.42
P value		<.001		<.001		
Strength, kg	2.81	9.47	2.63	7.99	1.9	7.58
P value		<.001		<.001		<.001
Forward flexion, deg	125.53	159.89	124.21	163.31	111.58	164.21
P value		<.001		<.001		<.001

[a]Values expressed as means.

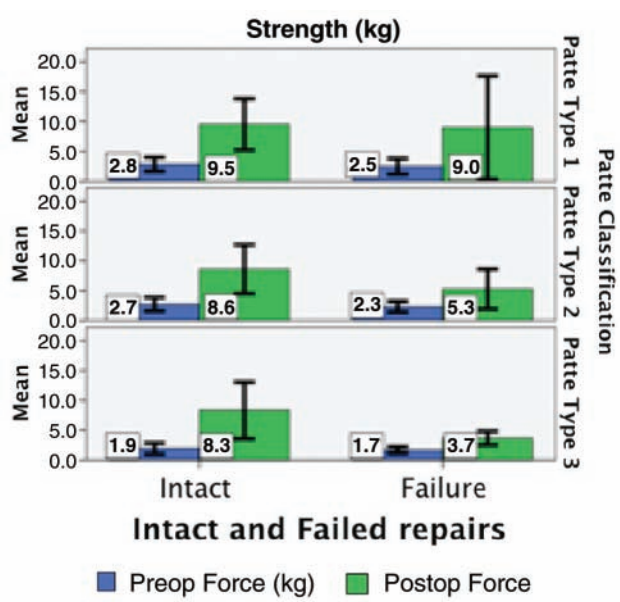


Figure 3. Mean improvement in strength stratified by tear size. Error bars: ±1 standard deviation.

None of the patients had a negative change in Constant score. Two patients had an improvement of <10, and 11 patients had an improvement of 10 to 20 points. A total of 13 patients had an improvement in Constant score of <20 points.

Effect of the Size of the Rotator Cuff Tear on Clinical Outcomes

The size of the rotator cuff tear was classified by the Patte classification at the time of surgery (as described above). In our cohort, 47 (30.5%) of the patients were classified as having small rotator cuff tears (Patte 1), 88 patients (57.1%) were classified as having large rotator cuff tears (Patte 2), and 19 patients (12.3%) were classified as having massive rotator cuff tears (Patte 3). All 3 cohorts significantly improved in pain scores, strength,

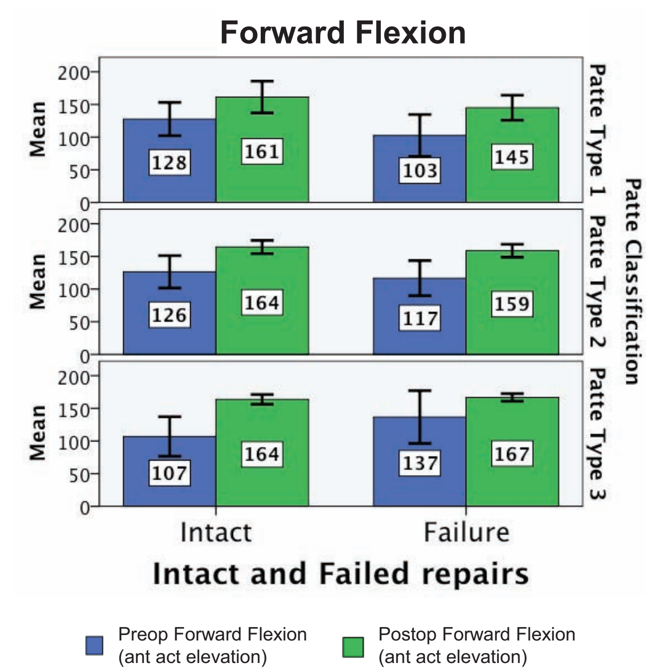
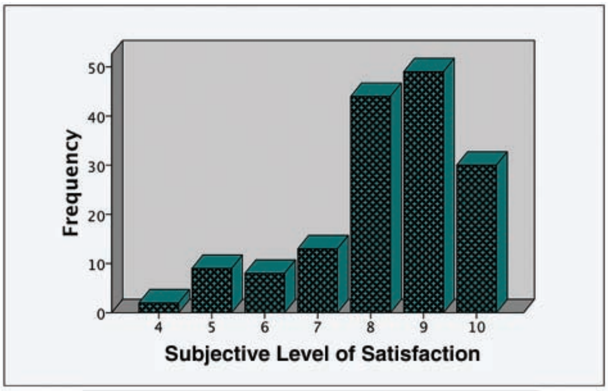


Figure 4. Mean improvement in range of motion stratified by tear size. Error bars: ±1 standard deviation.

forward flexion, and Constant scores (Table 3) (Figures 3 and 4).

Subjective Level of Repair

All the patients filled out a questionnaire assessing how happy they were with their shoulder repair. The mean response to this question was 8.29 ± 1.43 (range, 4-10), with a median of 9 and a mode of 9, indicating that most patients were happy with their repair (Figure 5). Patients with a small rotator cuff tear had a mean subjective level of repair of 8.13 ± 1.66 (range, 5-10), patients with a large tear rotator cuff tear had a mean subjective level of repair of 8.47 ± 1.32 (range, 4-10), and patients with a massive rotator cuff tear had a mean subjective level of repair of 8.06 ± 1.21 (range, 5-10).



Subjective Level of Satisfaction	Frequency
4	2
5	9
6	8
7	13
8	44
9	48
10	30

Figure 5. A representation of number of people and their overall subjective satisfaction with their rotator cuff repair. 1 = unsatisfied, 10 = satisfied.

Complications

Seventeen patients complained of a "stiff" shoulder. All of these patients were considered as having a complication (secondary adhesive capsulitis). The mean pain score improvement in this group was 5.52 points (±5.60 points; range, 5-12), the mean improvement in forward flexion was 33.24° (±26.75°; range, 0°-100°), the mean improvement in strength was 5.47 kg (±4.47 kg; range, 0-17), and the mean improvement in Constant score was 27.06 points (±13.06; range, 5-52). The mean subjective level of repair in this group was 6.50 (±1.46; range, 4-8). There were 3 failures on follow-up imaging in this group.

Other complications included 1 infection that was treated with antibiotics and 1 pulmonary embolism that was managed medically. Both patients had improvements in pain scores, strength, forward flexion, and Constant scores at follow-up.

DISCUSSION

The results of our study demonstrate that the early clinical outcomes and results for structural integrity after arthroscopic rotator cuff repair with the TOE double-row rotator cuff repair (the suture-bridge technique) compare favorably with those previously reported in the literature.[16,19,21,40,41,44] The failure rate after repair for large and massive rotator cuff tears was 17% and 16%, respectively, and the overall failure rate for after rotator cuff repair in this series was 14%. Overall, all patients had significant improvement in the outcome measures evaluated including strength, pain, range of motion, and Constant score.

Failure rates of arthroscopic rotator cuff repair vary widely in the literature. In 2007, Sugaya et al[41] reported on their prospective series of 106 patient with rotator cuff tears fixed with a double-row technique. Although their overall failure rate was 17%, their failure rate in large to massive rotator cuff tears was 40%. Frank et al[18] obtained MRI scans on 25 patients who underwent a TOE suture-bridge repair at a mean follow-up of 14.61 months and demonstrated that 88% of the repairs were intact on imaging. In their series, they report a 100% healing rate in the patients with massive tears; however, only 3 of 25 patients had massive tears.[18] In our cohort of 154 patients, 86% of the repairs were intact at follow-up, regardless of tear size. When broken down into tear size, 92% of the small tears were intact, 83% of the large tears were intact, and 84% of the massive tears were intact when assessed by follow-up arthrography (either MRI or CT). To our knowledge, the present report is the largest prospective series collected on this type of repair.

In a series by Galatz et al,[19] 17 of 18 single-row repairs failed when assessed by ultrasound. In 2006, Bishop et al[4] reported a 47% failure rate in arthroscopic repair when assessed by MRI at 1 year. When broken down into tear size, tears greater than 3 cm had a failure rate of 76%.[4] In 2007, Franceschi et al[17] performed a prospective randomized trial comparing double-row (not the suture bridge) versus single-row techniques with an average follow-up of 22.5 months and found no differences in single- versus double-row repairs regarding structural integrity. However, this study was underpowered, with only 26 patients per group and only 53% (14 of 26) of the single-row repairs being intact versus 69% (18 of 26) of the double-row repairs being intact.[17] In a slightly better powered study, Charousset et al[10] showed that there was a difference between single- and double-row repairs (19 of 31 vs 14 of 35) with regard to anatomic tendon healing when using CT arthrography at 6 months ($P = 0.03$), with the double-row repairs showing a structural advantage. In both studies, both constructs showed significant clinical improvements with little clinical difference. Park et al[34] showed that single-row repairs may be adequate for small and medium tears, but there may be an advantage in using a double-row construct in large and massive tears. A more promising study on arthroscopic rotator cuff repairs in terms of low failure rates was by Lafosse et al,[27] in which they report an 11% failure rate in arthroscopic double-row repairs when assessed by CT arthrogram or MRI arthrogram. However, the failure rates were much higher in the large and massive repairs. Although arthroscopic surgical techniques have evolved to yield better clinical outcomes over the years, debate still exists about the best surgical technique for rotator cuff repair.

The postoperative structural repair of the rotator cuff was analyzed with either CT arthrography or MRI arthrography at a minimum of 12 months' follow-up. The accuracy of these modalities for the detection of both partial- and full-thickness rotator cuff repairs has been demonstrated to have a 99% sensitivity and a 100% specificity for detecting lesions in the supraspinatus.[9] Other authors have advocated the use of CT and/or arthrography for the evaluation of rotator cuff integrity.[8,15,33] Formalized classification schemes for assessing rotator cuff integrity after repairs, particularly for large and massive tears where rotator interval release has been performed, are sparse. Furthermore, there are no studies evaluating the reliability of classification schemes intended to analyze rotator cuff repair. The classification scheme we used to analyze the structural integrity of rotator cuff repairs was previously published by Lafosse et al.[27] We believe that the inclusion of intratendinous leakage as an intact repair is very reasonable because contrast can travel along the suture lines after the repair while the rotator cuff footprint remains completely intact.

Biomechanical studies have extensively studied the concept of rotator cuff footprint restoration with the use of the double-row suture anchor repair. These studies suggest that one obtains better footprint coverage as well as reduced gap formation when utilizing a double-row repair when compared with a single-row repair.[6,26] One hypothesis is that with adequate restoration of anatomy, there will be a stronger tendon-bone interface leading to enhanced healing.[32] Furthermore, biomechanical failure rates are reported to be much lower in double-row repairs than in single-row repairs.[31,39] Other studies have specifically compared nonbridging double-row suture anchor rotator cuff repair and TOE techniques and have shown that TOE results in superior contact area, pressure, and failure rates.[36,37] When considering these biomechanical results along with our low failure results, we strongly believe that the TOE technique is a satisfactory option for arthroscopic rotator cuff repair.

Several studies have identified improved functional results and intact rotator cuff repairs.[19,21,25,44] Overall, in our cohort, mean pain scores, strength, forward flexion, and Constant scores all significantly improved. When stratified into tear size, small, large, and massive tears all significantly improved with regard to these 4 functional outcomes (mean pain scores, strength, forward flexion, and Constant scores). Our data as well as others support that in patients with less than grade 3 fatty infiltration, rotator cuff surgery is clinically beneficial.

In 2006, Anderson et al[1] showed no difference in intact versus failed double-row rotator cuff repairs with respect to clinical outcome parameters and when the construct was postoperatively analyzed with ultrasound, which agrees with our results as demonstrated by the patients with radiographic failures and their improvements in the means of all 4 of these clinical parameters ($P < .005$). In 2010, Dodson et al[14] showed that at an average of 7.9 years, patients with recurrent defects after rotator cuff repair still had an improvement in terms of pain, function, and satisfaction, thus further demonstrating that even patients with failed rotator cuff repairs gain some long-term benefit.

In a study that compares failures patterns in single- versus double-row suture-bridge technique, Cho et al[11] demonstrated that failure patterns in the single-row repairs differed from that of the failure patterns in the suture-bridge repairs. In this retrospective level 3 evidence report, failure patterns were classified as either type 1 or type 2 patterns. The authors found the retear pattern with the suture-bridge technique was mostly at the musculotendinous junction. This study and a small study by Trantalis et al[43] are the first studies to describe medial row failure in the TOE construct. In this current study, we did not specifically look for patterns of failure, but do think that future studies looking at retear patterns would be of benefit and may explain why this biomechanically superior construct may fail.

One of the potential weaknesses of this study is that it evaluates structural as well as clinical outcomes at a mean of 15 months. Boileau et al[5] have suggested, and we agree, that patients with an intact rotator cuff will continue to clinically improve with long-term follow-up. The question remains, what is the long-term structural outcome of this technique? In their prospective longitudinal study of rotator cuff repairs, Galatz et al[20] showed that Constant scores and subjective satisfaction scores remained stable at 10 years compared with 2 years. Because of the invasiveness of the imaging technique utilized in this study, it is doubtful that long-term structural results, with the type of imaging modalities used here (CT/MRI arthrography) will be available in large numbers. Other potential weaknesses are that only 2 surgeons performed the surgery, multiple procedures were performed (supraspinatus, ±infraspinatus, ±subscapularis, ±distal clavicle resection, etc), and the average follow-up is relatively short. Failure in this construct also may occur at the musculotendinous junction. Lastly, this technique was not directly compared with other rotator cuff repair techniques such as open, mini-open, single-row, and more traditional double-row techniques.

We use historical controls from the literature as outlined above, but prospective comparative well-powered studies are lacking. The data presented here show that large and massive tears have low structural failure rates with improved clinical outcomes but also that secondary arthrofibrosis is a recognized complication at 1-year follow-up.

CONCLUSION

Our data show that we had excellent short-term results with low failure rates in small, large, and massive rotator cuff tears. We used very stringent criteria to evaluate intact and failed repairs (CT/MRI arthrography) at greater than 1-year follow-up. To our knowledge, this is the largest reported series of patients who had their rotator cuff tears reconstructed with the TOE technique. Although long-term clinical outcomes are needed to completely evaluate this repair construct, we believe that arthroscopic double-row TOE suture-bridge technique appears to be a satisfactory method for rotator cuff repair.

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