

Arthroscopic Rotator Cuff Repair: Biomechanical and Functional Effects and Long-Term Integrity of Double-Row Fixation in Comparison to Traditional Techniques

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CLINICAL DILEMMA

Repair of rotator cuff injuries has traditionally involved open or mini-open surgical procedures. Although the use of such procedures has allowed for flexibility in repair protocols, it is also associated with significant post-operative morbidities. The occurrence of such morbidities has stimulated the development of arthroscopic techniques. Initially, such arthroscopic techniques involved only debridement of the tissue, but advancement of the methodology over the last decade has progressed to a point where complete repairs may be made of tears previously thought to be irreparable. Traditional attachment protocols utilized have included single-row technique, transosseous suture configuration as well as other methods.

While the early clinical results of arthroscopic repairs have been quite good, longer term follow-up has show a gradual deterioration of results and shortcomings in the recovery of normal strength. Recently, using ultrasonography and magnetic resonance imaging (MRI), various investigators¹⁻² have measured failure rates of up to 94% for arthroscopic repairs of rotator cuff tears at a minimum follow-up time of 12 months. Failure modes have included knot or anchor failure and suture pull-through. Moreover, variability based on the attachment technique utilized has been observed and has a profound implication on the long-term integrity of the repair.

In light of these observations, multiple investigators have been inspired to perform studies aimed at a determination of the causes of the failures. Additionally, new techniques have been proposed to increase the biomechanical strength, functionality, and long-term structural integrity of the repair. Of these, the most recent development is a "double-row" or "dual-row" fixation technique for arthroscopic repair. This technique employs a single row of anchors in the medial aspect of the tendon footprint and another single row in the lateral aspect. Such a configuration is hypothesized to maximize contact, which may optimize biological healing and long-term outcomes. The following sections describe the most recent in vitro and in vivo studies comparing the dual-row fixation technique to traditional methodologies.

IN VITRO STUDIES

Generally, intact shoulders are obtained from fresh-frozen cadavers and randomized to various fixation procedures.

The supraspinatus tendon is then cut and repaired by the randomized procedure specified. In biomechanical studies, the shoulder is then placed in an apparatus that applies tension in a manner intended to replicate the physiological pull on the tendon. Various biomechanical measures have been developed to test the strength of fixation techniques in rotator cuff repair and have included conditioning elongation of the tendon, peak-to-peak elongation, ultimate tensile load, etc. In other studies, the contact area of the repaired rotator cuff to the humeral head is measured and compared to the intact footprint area.

Several key biomechanical studies have been performed. Waltrip, et al.³ compared an anatomical double-layer repair employing a suture anchor and transosseous fixation technique incorporating a mattress suture procedure to isolated suture anchor repair and isolated transosseous tunnel repair. After pretensioning each specimen to 180 Newtons (N), each specimen was cyclically loaded to 180 N at a rate of 33 mm/second up to a maximum of 5000 cycles. The double-layer repair displayed a significantly higher mean number of cycles to failure than either of the two other methods (Table 1) and eight of twelve of the double-layer repairs lasted to the maximum of 5000 cycles compared to only two for the isolated suture anchor and none for the transosseous repair.

Similarly, Ma and coworkers⁴ compared double-row fixation to simple single fixation, massive cuff fixation, and arthroscopic Mason-Allen fixation in a cadaver study. Each repaired rotator cuff was subjected to a 5 N pre-load then cyclically loaded from 5 to 100 N at 0.25 Hz for fifty cycles. Conditioning elongation (difference in peak to peak displacement between first and fiftieth cycles) and peak-to-peak elongation (average of the difference between the local minimum and maximum of the 48th-50th cycles) were measured. Each repair was also subjected to a load-to-failure test and peak force was determined. No differences in conditioning elongation were found, but both the double-row and massive cuff repairs had lower peak to peak elongation than the simple and Mason-Allen techniques and the double-row technique displayed the highest mean ultimate tensile load at failure (Table 1).

Table 1: In vitro biomechanical measures of repair integrity - Comparison of double-row to single-row techniques of fixation

Author/ Measure	Double-row	Single-row	Arthroscopic		
			Mason-Allen	Massive Cuff	Transosseous
Waltrip, et al. ³					
# cycles to failure	3694 ± 1980‡	1414 ± 1888	-	-	528±683
% repairs lasting to 5000 cycles	66.7	16.7	-	-	0.0
Ma, et al. ⁴					
Conditioning elongation (mm)	1.3 ± 0.1	2.0 ± 0.3	2.3 ± 0.3	1.5 ± 0.3	-
Peak to peak elongation (mm)	1.1 ± 0.1†	1.4 ± 0.2	1.5 ± 0.2	1.1 ± 0.1	-
Ultimate tensile load (N)	287± 24‡	191 ± 18	212 ± 21	250 ± 21	-
Meier, et al. ⁵					
# cycles to failure	5000‡	822 ± 198	-	-	62 ± 12
# repairs lasting to 5000 cycles	100.0	0.0	-	-	0.0

† p<0.05 vs. Mason-Allen

‡ p<0.05 vs. all other techniques

Table 2: In Vitro restoration of footprint area - comparison of double-row to single-row techniques of fixation

Author/ Measure	Double-row	Mattress double	Modified mattress		Transosseous
		anchor	double anchor	Single-row	
Tuoheti, et al. ¹⁰					
Increase in contact area v. single row (%)	60	-	-	-	31
Mazzocca, et al. ¹¹					
Repaired width (mm)	-	14.79 ± 1.46†	15.65 ± 2.25	8.34 ± 1.81	-
Repaired contact area (mm ²)	-	354.05 ± 56.71†	348.28 ± 150.72	210.48 ± 50.13	-

† p<0.05 vs. Single-row

The superior integrity of double-row fixation has been confirmed by Meier and colleagues⁵ in a recent study of 21 fresh-frozen shoulders where all double row repairs survived 5000 cycles of loading to 180 N whereas single row repairs had a mean failure at 822 cycles and transosseous fixation displayed a mean failure at 62 cycles. In a separate study, Meier, et al.⁶ also demonstrated that double-row repairs provided equivalent anterior-posterior motion of tendon (relative to bone) to that of intact tendon (4.83 2.69 mm and 5.47 2.4 mm, respectively) whereas single row fixation and transosseous fixation demonstrated significantly higher range of motion and therefore less structural rigidity (both approximately 12 mm, p<0.05 vs. double row fixation).

Apreleva et al.⁷ observed that single row procedures restore only ~67% of the original footprint area of the rotator cuff and that transosseous repair restores ~85% of the area, which prompted Lo, et al.⁸ to argue for the need to re-establish the footprint of the tendon-bone interface using double-row fixation in arthroscopic rotator cuff repair. In 2002, DeBeer, et al.⁹ reported restoration of footprint area following a modified double-row technique using an interlocking suture method which yielded 89% retention of intact rotator cuff (as determined by ultrasonography) at 15 months average follow-up.

Using pressure-sensitive film and scanning to a 3-dimensional pressure-graphing system, Tuoheti and colleagues¹⁰ compared double row fixation to single row and transosseous fixation. The results showed significantly higher contact area via the double row fixation as compared to the two other methods (Table 2). Additionally, double row attachment yielded higher contact pressure than single row technique (Table 2). Mazzocca and coworkers¹¹ have compared single row repair to two types of mattress configuration dual-row repair: mattress double anchor technique (method of Millet¹²), and modified mattress double anchor technique. The results showed that the double row fixation methods yielded a higher footprint area than that for single row repair (Table 2). Perhaps most conclusively, Meier and colleagues¹³ have demonstrated a complete restoration of footprint area to intact tendon following double row attachment.

In summary, double-row fixation provides greater biomechanical integrity and restoration of native footprint area of the supraspinatus tendon to the humeral head. Single row and transosseous attachments consistently fall short in both strength and footprint area measurements.

IN VIVO STUDIES

Contact area/contact pressure and biomechanical strength/structural integrity are important and enlightening surrogate measures, but functional and structural outcomes are of critical clinical interest. In a 2002 study by Fealy, et al.¹⁴, 75 patients (49 males, 26 females) were treated for small (n=10), moderate (n=35) and large (n=30) rotator cuff tears with double-row fixation technique in a mini-open procedure and followed for a minimum of 24 months. No significant differences were found by tear size with patients reporting an average post-rehabilitation UCLA Shoulder Rating Scale score of 33.6 out of 35 and 83% of patients returning to pre-injury levels of activity.

However, the question must be asked whether the double row technique demonstrates superior functional outcome and long-term in vivo integrity of the repair as compared to traditional techniques?

Sugaya, et al.¹⁵ addressed this question in a retrospective cohort study of 78 patients in 2005. Of a total of 80 shoulders repaired, single row technique was used on 39 and double-row on 41. Postoperative cuff integrity was measured at an average follow-up of 35 months by MRI and each repair was classified into five categories ranging from sufficient thickness and homogeneously low intensity on imaging (type 1) to presence of major discontinuity (type 5). The results showed significantly higher structural integrity of the double row fixation technique in comparing small to medium tears (Table 3). Functional scores were assessed by the UCLA Shoulder Rating Scale and the index of the American Shoulder and Elbow Surgeons (ASES), but no differences were found between fixation techniques.

Thus, in at least one comparative study, double row technique has demonstrated superior long-term structural integrity of the repair to traditional single row procedure.

Table 3: Structural comparison of fixation techniques (extracted from Sugaya, et al. ¹⁵) - Percent of patients by integrity category at followup

Repair method and tear size	Type 1	Type 2	Type 3	Type 4	Type 5	N
Single-row (total)	28.2	15.4	30.1	10.3	15.4	39
Small to medium†	39.1	26.1	21.7	4.3	8.7	23
Large to massive	12.5	0.0	43.8	18.8	25.0	16
Double row (total)	53.7	19.5	17.1	9.8	0.0	41
Small to medium	70.4	22.2	7.4	0.0	0.0	27
Large to massive	21.4	14.3	35.7	28.6	0.0	14

Type 1 = Sufficient thickness with homogeneously low intensity on imaging

Type 2 = Sufficient thickness with partial high intensity

Type 3 = Insufficient thickness without discontinuity

Type 4 = Presence of a minor discontinuity

Type 5 = Presence of a major discontinuity

† p<0.05 between fixation techniques

CONCLUSIONS

Arthroscopic procedure for repair of rotator cuff injuries is associated with less pain, shorter rehabilitation time, and lower incidence of procedural-related morbidities than mini-open and open procedures. However, until recently, the range of fixation techniques that could be utilized was limited. With the investigation and introduction of double row fixation methods, patients undergoing arthroscopic rotator cuff repair enjoy fewer negative clinical sequelae of the procedure, greater biomechanical strength of the repair, appropriate range of motion, and greater long-term structural integrity. The introduction of products to facilitate the double row fixation method will make the technique more widely available to the population at large.

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