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REVIEW ARTICLE

Clinical and structural outcomes after arthroscopic single-row versus double-row rotator cuff repair: a systematic review and meta-analysis of level I randomized clinical trials

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Background: The purpose of this study was to perform a systematic review and meta-analysis of all available level I randomized controlled trials comparing single-row with double-row repair to statistically compare clinical outcomes and imaging-diagnosed re-tear rates.
Methods: A literature search was undertaken to identify all level I randomized controlled trials comparing structural or clinical outcomes after single-row versus double-row rotator cuff repair. Clinical outcomes measures included in the meta-analysis were the American Shoulder and Elbow Surgeons, University of California–Los Angeles, and Constant scores; structural outcomes included imaging-confirmed re-tears. Meta-analyses compared raw mean differences in outcomes measures and relative risk ratios for imaging-diagnosed re-tears after single-row or double-row repairs by a random-effects model.
Results: The literature search identified a total of 7 studies that were included in the meta-analysis. There were no significant differences in preoperative to postoperative change in American Shoulder and Elbow Surgeons, University of California–Los Angeles, or Constant scores between the single-row and double-row groups ($P = .440$, .116, and .156, respectively). The overall re-tear rate was 25.9% (68/263) in the single-row group and 14.2% (37/261) in the double-row group. There was a statistically significant increased risk of sustaining an imaging-proven re-tear of any type in the single-row group (relative risk, 1.76 [95% confidence interval, 1.25-2.48]; $P = .001$), with partial-thickness re-tears accounting for the majority of this difference (relative risk, 1.99 [95% confidence interval, 1.40-3.82]; $P = .039$).
Conclusion: Single-row repairs resulted in significantly higher re-tear rates compared with double-row repairs, especially with regard to partial-thickness re-tears. However, there were no detectable differences in improvement in outcomes scores between single-row and double-row repairs.
Level of evidence: Level I, Meta-analysis.

Keywords: Single row; double row; rotator cuff repair; systematic review; meta-analysis

Institutional Review Board approval: None required.

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Advances in arthroscopic technique have allowed most rotator cuff tears to be repaired all-arthroscopically. Numerous methods of tendon-bone repair have been reported; however, controversy exists about the superiority of

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either single-row or double-row fixation constructs with regard to subjective, objective, and structural outcomes.

Biomechanical studies have demonstrated increased mechanical strength, decreased gap formation, improved tendon to bone contact, increased footprint coverage, and watertight isolation of the healing zone interface from the synovial fluid environment in double-row repairs.[2,8,22,26,28,29,32-34,36,37,42,46,47] These favorable biomechanical properties are thought to aid in the healing process while also allowing more aggressive postoperative physical therapy.[2,8]

However, clinical evidence comparing the efficacy of single-row versus double-row repair has been inconsistent. Whereas some studies report no clinical or anatomic differences between these techniques,[1,7,9,13,17,20,24,38,40,41,48] others have shown significantly improved subjective, objective, or radiographic outcomes after double-row repair compared with the single-row method.[6,10,11,14,16,25,30,39,43,45] These conflicting results bring into question the cost-effectiveness of double-row repair, given its increased expense and time to perform compared with the single-row method.[3,19]

Several systematic reviews and meta-analyses have compared the two techniques.[11,13,16,38,40,41] However, the inclusion of level II and III studies inhibits the interpretation of these studies. Therefore, the purpose of this study was to perform a systematic review and meta-analysis of all available level I randomized controlled trials comparing single-row with double-row repair to statistically compare their clinical outcomes and imaging-diagnosed re-tear rates. We hypothesized that there would be no statistically significant differences between techniques in this study.

Methods

Study design

This research was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[35] and the research protocol described by Wright et al[50] in 2007. In January 2013, the authors conducted a systematic review and meta-analysis in which only published, full-text, English-language, level I randomized controlled clinical trials comparing clinical or structural outcomes after arthroscopic single-row and double-row rotator cuff repairs were included. All other studies that did not fit these strict criteria were excluded.

Literature search

Two independent reviewers searched the PubMed and Ovid MEDLINE databases using the search terms "single row rotator cuff," "double row rotator cuff," and "single row double row rotator cuff." Major orthopaedic journals were also queried with the same search terms. All of the resulting titles and abstracts were screened for possible inclusion. After this initial search, the citations of included articles were carefully examined to locate further studies. In addition, the literature search was repeated in September 2013 to identify any new includable studies that had become available between the time of the initial search and completion of the study.

Data extraction

Two independent reviewers separately and in duplicate extracted data from the included studies. Data included study characteristics, clinical and radiographic follow-up intervals, patient demographics, initial tear sizes, and complications along with clinical and radiographic outcomes. Clinical outcomes measures included preoperative and postoperative American Shoulder and Elbow Surgeons (ASES),[23] University of California–Los Angeles (UCLA), and Constant-Murley (Constant) scores[12] at final follow-up; structural outcomes included all reported imaging-diagnosed re-tears at final radiographic follow-up. Physical examination findings such as range of motion and strength at final follow-up were not included in the meta-analysis because no more than 2 studies reported these variables in a similar fashion. In general, data for a given variable were included in the meta-analysis when 3 or more studies similarly measured that variable such that data could be pooled and meaningful comparisons could be made.

Quality appraisal

Evaluation of each study for potential risk of bias was undertaken. Two reviewers independently reviewed each of the included studies for selection bias, performance bias, detection bias, and attrition bias along with any other limitation that may inhibit study interpretation.

Synthesis of results

Meta-analyses were performed comparing arthroscopic single-row with double-row repairs in terms of (1) the raw mean differences of preoperative to postoperative change in ASES, UCLA, and Constant scores, (2) the overall relative risk ratio for development of an imaging-diagnosed re-tear, and (3) the overall relative risk ratio for development of a full-thickness or partial-thickness imaging-diagnosed re-tear.[4] The change in outcomes scores (θ) was defined as the difference between preoperative and postoperative outcomes scores for both the single-row and double-row groups.

A random-effects model,[15] estimated by the restricted maximum likelihood method, was chosen to combine the treatment effects for subjective outcome scores and imaging-diagnosed re-tear rates from each study. This method was chosen over the fixed-effects model for several reasons. First, formal heterogeneity tests are substantially underpowered for the number of studies in our review.[5] Second, although there were minimal statistical differences in population characteristics between the single-row and double-row groups (Table I), there were considerable differences in experimental methodology and sample demographics among the included studies (Tables II and III). Thus, we did not rely on statistical heterogeneity testing to make our modeling decisions; however, estimates of I^2, the proportion of variability attributable to heterogeneity among the included studies, along with corresponding 95% confidence intervals are provided.[44] Third, random-effects models allow better generalizability of conclusions when differing surgical techniques and patient populations are included.[21] The software

Table I Preoperative patient population characteristics across all included studies

Variables	Total	Single-row group	Double-row group	Differences (DR − SR)*	Studies reporting
Number of patients randomized	567	285	282	−3	7
Number lost to imaging follow-up	43	22	21	−1	7
Number lost to clinical follow-up	42	22	20	−2	6
Mean follow-up (months)	21.3[†]	23.0	23.4	+0.4	6
Male (%)	44.2	43.7	44.8	+1.1	5
Mean age (years)	58.1	58.5	57.6	−0.9	5
Mean sagittal tear length (cm)	1.94	1.93	1.98	+0.05	4
Tears <3 cm (number of cases)	137	69	68	−1	3
Tears >3 cm (number of cases)	115	57	58	+1	3
Crescent-shaped tears (number of cases)	151	78	73	−5	3
L- and reverse L–shaped tears (number of cases)	81	42	39	−3	3
U- and V-shaped tears (number of cases)	52	23	29	+6	3
Mean preoperative ASES score (scale, 0-100)	42.8	42.5	43.2	+0.7	3
Mean preoperative UCLA score (scale, 0-35)	13.8	13.9	13.8	−0.1	3
Mean preoperative Constant score (scale, 0-100)	54.7	53.5	55.8	+2.3	3

ASES, American Shoulder and Elbow Surgeons; *UCLA,* University of California–Los Angeles.
* A negative number indicates that the single-row (SR) group had a greater value than the double-row (DR) group.
† Includes all 7 studies.

OpenMeta[Analyst] for Windows[49] was used for statistical calculations. Statistical significance was declared for P values <.05.

Results

Study selection

The process for study selection is presented in Figure 1. Literature searches of the Ovid and PubMed databases along with query of major orthopedic journals revealed a total of 593 individual titles and abstracts, including duplicates. After initial screening and removal of duplicates, 566 studies were eliminated, leaving a total of 27 articles for full-text review. After a thorough review of these articles and their citations along with a repeated search of the literature, a total of 7 level I randomized controlled trials were included in the meta-analysis.[9,10,17,18,20,24,25]

Study characteristics

Table I compares preoperative patient population characteristics between the single-row and double-row groups for the entire cohort. Table II documents the surgical and rehabilitation protocols for each study. Table III summarizes the distinctive population characteristics and relevant findings of each individual study. Although the interventions and study aims were similar across each study, there were significant differences in population characteristics, follow-up intervals, initial tear sizes, repair configurations, and outcomes measures used. Table IV summarizes the results of the risk of bias evaluation for each study. There were no perioperative or intraoperative complications reported in either the single-row or double-row group in any study; only Lapner et al[25] documented the need for revision surgery in 4 of 90 patients (1 single-row repair, 3 double-row repairs; 4.4%).

Outcomes

The results of our meta-analysis with regard to ASES, UCLA, and Constant scores are presented in Table V. Whereas each outcome score improved significantly over preoperative levels, there were no statistically significant differences between the single-row and double-row techniques with respect to preoperative to postoperative change in ASES, UCLA, or Constant scores. However, we did find a statistically significant improvement in postoperative UCLA scores in those patients treated with the double-row construct. This difference is driven by the significant effect sizes of the data presented by both Carbonel et al[10] and Franceschi et al[17] due to their observed between-patient variability, which were drastically smaller than those presented in the other included studies.

Re-tear rates

Table VI documents the occurrence and relative risk of imaging-diagnosed re-tears for single-row repair compared with double-row repair across each study. Included forest plots compare the individual and overall relative risk ratios (with corresponding 95% confidence intervals and estimated effect sizes) of all imaging-diagnosed re-tears (including whether the re-tear was a full-thickness or partial-thickness re-tear) between the single-row and double-row groups.

Table II Surgical and rehabilitation protocols for each included study

	Mean number of suture anchors	Materials and techniques	Rehabilitation protocol
Gartsman et al[18]	**SR:** 2 in all cases **DR:** 4 in all cases	**SR:** Double-loaded suture anchor **DR:** 2 single-loaded suture anchors for medial row, 2 suture anchors for lateral row (transosseous-equivalent repair) **Knot type:** **SR:** Simple stitches 8 mm distal to the greater tuberosity **DR:** Mattress stitches for medial row, suture limbs inserted into 2 lateral anchors in transosseous-equivalent configuration	• Immobilization with abduction pillow for 6 weeks • Active shoulder elevation/abduction "forbidden" • Circumduction exercises only for 6 weeks • After 6 weeks, supine active-assisted elevation, followed by supine active elevation, followed by standing active-assisted elevation, then standing active elevation as comfort permits
Carbonel et al[10]	**SR:** 1.83 (range, 1-3) **DR:** 2.99 (range, 2-4)	**SR:** Double-loaded No. 2 FiberWire **DR:** Double-loaded No. 2 FiberWire **Knot type:** Sliding, locking knot with backup half-hitches (L- and U-shaped tears repaired by side-to-side stitching before osseous fixation)	• Sling with abduction pillow for 6weeks • PROM within first week • Supine AAROM at 4-6weeks • Full AROM at 6-8weeks • Strengthening at 10-12weeks
Lapner et al[25]	**SR:** Median 1 (range, 1-2) **DR:** Median 2 (range, 2-3)	**SR:** Double-loaded No. 2 high-tensile sutures (metal or bioabsorbable anchors) **DR:** Double-loaded No. 2 high-tensile sutures (metal or bioabsorbable anchors) **Knot type:** Sliding, locking knots with alternative half-hitches; medial and lateral rows were not linked	• Pendulum exercises on postoperative day 1 • AAROM at 6weeks • AROM at 8-12weeks • Strengthening at 12weeks
Koh et al[24]	**SR:** ~2 **DR:** ~3	**SR:** Double-loaded metal or bioabsorbable anchors **DR:** Double-loaded metal or bioabsorbable anchors **Knot type:** Simple stitches for SR and lateral row of DR, mattress sutures for medial row of DR	• Abduction brace for 3weeks • PROM at 4weeks • AROM begun after full PROM achieved • Strengthening at 12weeks
Burks et al[9]	**SR:** 2.25 **DR:** 3.2	**SR:** Double-loaded No. 2 FiberWire **DR:** Double-loaded No. 2 FiberWire **Knot type:** Sliding, locking knot with backup half-hitches	• Sling with abduction pillow • PROM within first week • Supine AAROM at 4-6weeks • Full AROM at 6-8weeks (longer if larger initial tear size) • Strengthening at 10-12weeks
Grasso et al[20]	**SR:** Median 1 (range, 1-2) **DR:** 1-2 (medial) and 1-3 (lateral)	**SR:** 5.0-mm metal anchors double loaded with No. 2 FiberWire **DR:** 5.0-mm metal anchors double loaded with No. 2 FiberWire **Knot type:** **SR:** Simple sliding knot followed by 3 alternating half-hitches **DR:** Duncan loop and 3 alternating half-hitches for lateral row and mattress sutures secured with nonsliding Revo knot in medial row	• Sling without abduction for 3weeks • Range of motion exercises at 4-8weeks (PROM, AAROM, then AROM) • Strengthening (closed chain) at 9-12weeks • Strengthening (open chain) at 13-16weeks
Franceschi et al[17]	**SR:** 1.9 (range, 1-2) **DR:** 2.3 (range, 2-4)	**SR:** Double-loaded No. 2 FiberWire **DR:** Double-loaded No. 2 FiberWire **Knot type:** Side-to-side stitches in L- and U-shaped tears (margin convergence)	• Sling with abduction pillow for 6weeks • Terminal elbow extension restricted • Passive external rotation on postoperative day 1 • Overhead stretching restricted for 6weeks • Sling removed at 6weeks, overhead stretching with rope/pulley begun • Full activities at 6-10months

SR, single row; *DR,* double row; *PROM,* passive range of motion; *AAROM,* active-assisted range of motion; *AROM,* active range of motion.

Table III Summary of individual study characteristics and relevant findings

Individual study characteristics							Relevant findings
	Intervention	N*	Population differences	Tear length (sagittal plane)	Mean follow-up (months)	Outcomes	
Gartsman et al[18] (2013)	SR vs DR; re-tear rate	83 (40 SR, 43 DR)	• Included any repairable full-thickness tear • Excluded smokers, steroid users, bilateral cuff repairs, suprascapular nerve decompressions	SR: <2.5 cm DR: <2.5 cm	SR: N/R DR: N/R Mean: 10 (6-12)	**Subjective:** N/R **Objective:** N/R **Imaging:** US	• DR had significantly decreased re-tear rate (7%) compared with SR (25%) ($P = .024$)
Carbonel et al[10] (2012)	SR vs DR; clinical outcome and re-tear rate	160 (80 SR, 80 DR)	• Excluded OA, tears >5 cm, Fuchs >4, steroid users	SR 1-3 cm: 51 SR 3-5 cm: 29 DR 1-3 cm: 53 DR 3-5 cm: 27	SR: 24 DR: 24 MRI SR: 24 MRI DR: 24	**Subjective:** ASES, UCLA, Constant **Objective:** Physical examination, SSI, ROM in degrees **Imaging:** MRI	• DR significantly improved over SR in 1- to 3-cm tears with respect to degrees of flexion and abduction, internal rotation SSI, and external rotation SSI • DR significantly improved over SR with respect to all measured variables in 3- to 5-cm tears except for Constant score, abduction SSI, and external rotation SSI
Lapner et al[25] (2012)	SR vs DR; clinical outcome and re-tear rate	80 (40 SR, 40 DR)	• Included any full-thickness tear • Excluded SSx <6 months, GFDI >3, ACH distance <7 mm	SR: Mean 1.89 cm DR: Mean 2.38 cm	SR: 24 DR: 24 MRI SR: 24 MRI DR: 24	**Subjective:** ASES, WORC, Constant **Objective:** Strength (in kg) **Imaging:** MRI/US	• DR had significantly decreased re-tear rate • Smaller coronal tear sizes resulted in improved healing rates • Patients with re-tears had larger initial tear sizes • Those with re-tears had significantly decreased strength
Koh et al[24] (2011)	SR vs DR; clinical outcome and re-tear rate	71 (37 SR, 34 DR)	• Included OA, smokers • Excluded those without complete footprint coverage on postoperative MRI	SR: Mean 1.72 cm DR: Mean 1.75 cm (all tears 2-4 cm in sagittal oblique or coronal oblique plane)	SR: 31.0 DR: 32.8 MRI SR: 27.4 MRI DR: 27.6	**Subjective:** ASES, UCLA, VAS **Objective:** ROM (FF, ER, IR) in degrees **Imaging:** MRI	• DR showed improvement over SR with respect to internal rotation capacity (approaches statistical significance; $P = .053$) • No other clinical or radiographic differences between DR and SR groups reported
Burks et al[9]	SR vs DR; clinical outcome and	40 (20 SR, 20 DR)		SR 1-3 cm: 18 SR > 3 cm: 2	SR: 12 DR: 12	**Subjective:** ASES, UCLA, Constant,	

(*continued on next page*)

Table III (*continued*)

Individual study characteristics							Relevant findings
	Intervention	N*	Population differences	Tear length (sagittal plane)	Mean follow-up (months)	Outcomes	
(2009)	re-tear rate		• Excluded smokers, steroid users, U tears, and workers' compensation • Included OA	DR 1-3 cm: 15 DR > 3 cm: 5	MRI SR: 12 MRI DR: 12	SANE, WORC **Objective:** ROM, strength (IR/ER in N-m) **Imaging:** MRI	• Differences in clinical or radiographic outcomes between SR and DR
Grasso et al[20] (2009)	SR vs DR; clinical outcome only	80 (40 SR, 40 DR)	• Excluded OA, AC arthritis, workers' compensation, very small or very large tears	SR: Mean 1.56 cm DR: Mean 1.61 cm	SR: N/R DR: N/R Mean: 24.8	**Subjective:** DASH, WorkDASH, Constant **Objective:** strength in pounds **Imaging:** N/R	• No difference in clinical outcomes between SR and DR
Franceschi et al[17] (2007)	SR vs DR; clinical outcome and re-tear rate	60 (30 SR, 30 DR)	• Included SSx 3 months, OA • Excluded tendon retraction, SSx instability	SR 3-5 cm: 18 SR > 5 cm: 8 DR 3-5 cm: 21 DR > 5 cm: 5	SR: N/R DR: N/R Mean: 22.5 MRA: N/R	**Subjective:** UCLA **Objective:** FF, ER, IR (degrees) **Imaging:** MRA	• No differences in clinical or radiographic outcomes between SR and DR

SR, single row; *DR,* double row; *N/R,* not reported; *ASES,* American Shoulder and Elbow Surgeons score; *DASH,* Disability of the Arm, Shoulder and Hand score; *GFDI,* Global Fatty Degeneration Index; *SANE,* Single Assessment Numeric Evaluation score; *SSI,* Shoulder Strength Index; *UCLA,* University of California–Los Angeles score; *VAS,* visual analog scale (pain); *WORC,* Western Ontario Rotator Cuff index; *AC,* acromioclavicular; *ACH,* acromiohumeral; *ER,* external rotation; *FF,* forward flexion; *IR,* internal rotation; *MRI,* magnetic resonance imaging; *OA,* glenohumeral osteoarthritis; *ROM,* range of motion; *SSx,* signs and symptoms; *US,* ultrasound.

* *N,* Number of patients randomized.

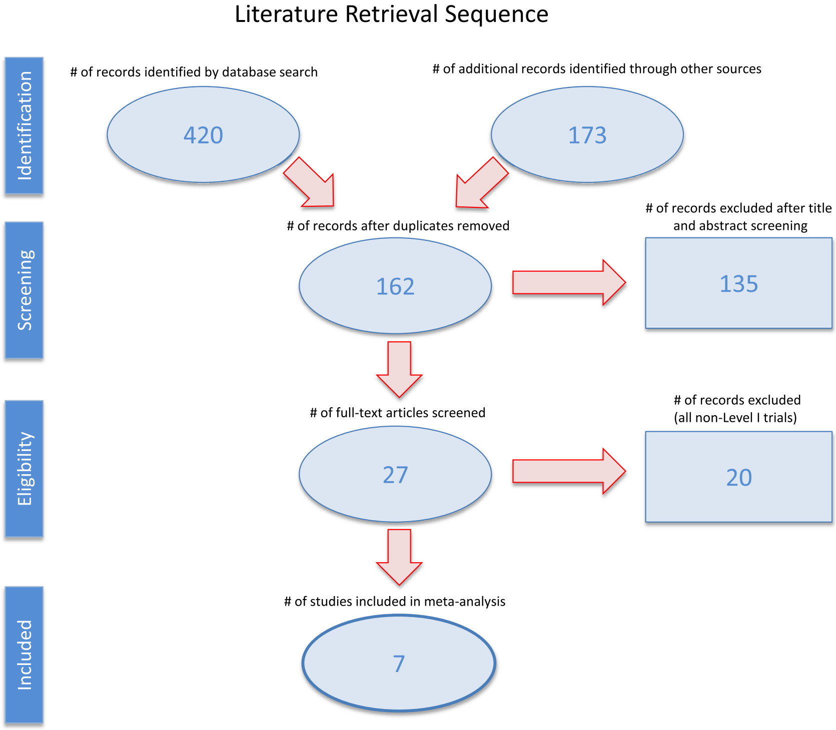


Figure 1 Sequence of literature retrieval.

Overall, single-row repairs were 76% more likely to sustain an imaging-diagnosed re-tear (relative risk, 1.76 [95% confidence interval, 1.25-2.48]; $P = .001$), with the majority of this increase accounted for by the high rate of partial-thickness re-tears (relative risk, 1.99 [95% confidence interval, 1.04-3.82]; $P = .039$).

Discussion

The results of this meta-analysis partially confirmed the hypothesis that there would be no statistically significant differences between single-row and double-row rotator cuff repair with regard to clinical outcomes scores and imaging-proven re-tear rates. In this study, there were no statistically distinguishable preoperative to postoperative differences in ASES, UCLA, and Constant scores between single-row and double-row repair after a mean 23.2-month follow-up period. However, a 76% increase in overall risk of imaging-proven re-tears was found after single-row repair, a difference primarily explained by the increase in partial-thickness re-tears.

Clinical outcomes

Of the 6 included studies that reported clinical outcomes, Carbonel et al[10] were the only investigators to report substantial differences in clinical outcomes between single-row and double-row repairs. With these results, it is puzzling that none of the 5 previous level I trials (plus subsequent meta-analyses) comparing single-row and double-row repair were able to detect differences in outcomes scores between the techniques. However, Carbonel et al[10] stratified their results by initial tear size and found that in patients with tears measuring between 3 and 5 cm, subjective (UCLA and ASES scores) and objective outcomes (abduction and external rotation strength) were significantly improved after double-row repair compared with the single-row method at final 2-year follow-up. In addition to the improvements seen in larger tears, patients with tears measuring between 1 and 3 cm also improved with regard to internal and external rotation strength and range of motion after double-row repair compared with single-row repair.

This method of reporting outcomes by initial tear size has been used previously by Park et al,[39] who also found double-row repairs to be clinically superior in larger tears. They found significantly improved subjective outcomes (Constant and ASES scores) after double-row repair in tears >3 cm^2 at 2-year follow-up. However, similar to the results of our meta-analysis, there were no significant differences between the techniques when all tears were included. A prospective, randomized level II study by Ma et al[29] concluded that patients with initial tears >3 cm in sagittal length treated with the double-row technique had improved strength compared with the single-row method. A study by Lorbach et al[27] also concluded that initial tear size is an independent factor related to the biomechanical

Table IV Results of risk of bias evaluation for each included study

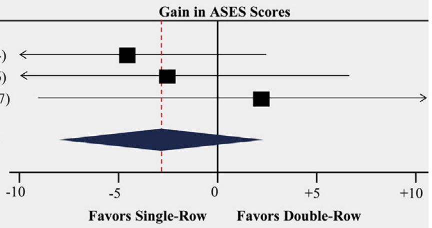
	Selection bias	Performance bias	Detection bias	Attrition bias
Gartsman et al[18]	No ITT analysis No CONSORT statement Includes only tears <2.5 cm in sagittal length	No mention of tear patterns Unclear if both SR and DR groups received similar concomitant treatments	No blinding reported Short follow-up period Unclear if partial-thickness tears were sought 17/90 patients (18.9%) initially had “inconclusive” findings on US Postoperative US performed by operating surgeon; thus, possible preconceived notion that transosseous-equivalent repairs may perform better because of presence of published evidence before initiation of the study Unknown level of operator experience with rotator cuff US	92.2% minimum 6-month US follow-up
Carbonel et al[10]	Many more tears 1-3 cm than 3-5 cm No CONSORT statement	Three surgeons with same implants MRIs read by 2 musculoskeletal radiologists	No blinding reported No Bonferroni adjustment for stats	None detected
Lapner et al[25]	No ITT analysis No CONSORT statement	Two surgeons Metal anchor and bioabsorbable anchor No report on concomitant procedures	Patient and research assistant blinded; unclear if radiologist is blinded 65 (85.5%) patients underwent US and 11 (14.5%) underwent MRI for analysis of re-tears	81% 2-year clinical follow-up 84% 2-year imaging follow-up
Koh et al[24]	No ITT analysis Includes only tears 2-4 cm in sagittal oblique or coronal oblique plane	Outdated technique used compared with other included studies	Unclear if patients blinded to treatment; only the orthopedists reading MRI and clinical assessors were blinded	87% 2-year clinical follow-up 66% 2-year MRI follow-up
Burks et al[9]	Many more tears <3 cm than >3 cm No CONSORT statement	More distal clavicle excisions in the DR group Two surgeons	Shorter follow-up period may result in fewer confirmed re-tears	None detected
Grasso et al[20]	No ITT analysis No CONSORT statement	Two surgeons SR anchors placed at articular margin	No blinding of patient or clinician reported	90% 2-year clinical follow-up (92.5% SR, 87.5% DR)
Franceschi et al[17]	Many more 3- to 5-cm tears than >5 cm	Difference in tear configuration, size, and treatments No mention of concomitant treatments	Unstated if blinding done for patient, clinician, or radiologist MRA may have detected more partial-thickness tears than other studies that used MRI or US	87% 2-year clinical follow-up 87% 2-year MRA follow-up

ITT, intention-to-treat; *CONSORT,* Consolidated Standards of Reporting Trials; *SR,* single-row repair; *DR,* double-row repair; *US,* ultrasound; *MRI,* magnetic resonance imaging; *MRA,* magnetic resonance arthrography.

Table V Summary of outcomes scores

ASES Scores

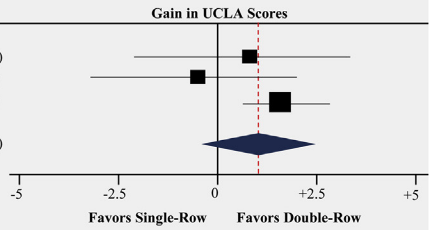
Investigators	Single-Row		Double-Row		Differences (DR - SR)[a]		θ[b] (CI)[c]
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	
Carbonel et al[10]		83.0 ± 6.1		84.5 ± 3.2		-1.5 (-0.02, 3.0)	
Lapner et al[25]	47.8 ± 17.6	87.9 ± 16.9	54.0 ± 19.0	89.3 ± 17.5	+6.2 (-1.4, 13.8)	+1.4 (-6.5, 9.3)	-4.8 (-13.0, 3.4)
Koh et al[24]	38.8 ± 14.0	85.9 ± 15.2	38.1 ± 11.1	83.4 ± 20.9	-0.7 (-7.0, 5.6)	-2.5 (-12.3, 7.3)	-1.8 (-10.2, 6.6)
Burks et al[9]	41.0 ± 21.5	85.9 ± 14.0	37.6 ± 19.3	85.5 ± 20.0	-3.4 (-16.1, 9.3)	-0.4 (-11.1, 10.3)	+3.0 (-8.7, 14.7)
				Weighted Mean	+1.4 (-16.1, 6.8)	+1.4 (-0.1, 2.8)	-2.1 (-7.3, 3.2)
				***P* values**	**0.613**	**0.067**	**0.440**



Heterogeneity Testing
τ^2=0.000, Q=1.150, I^2=0% (95% CI [0, 0.903]), *P*=0.563

UCLA Scores

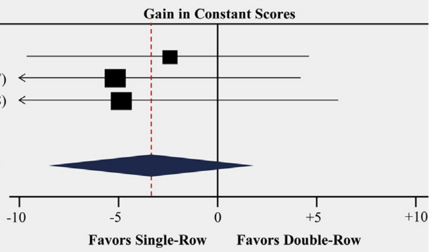
Investigators	Single-Row		Double-Row		Differences (DR - SR)[a]		θ[b] (CI)[c]
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	
Carbonel et al[10]		28.3 ± 2.2		29.1 ± 1.5		+0.8 (0.2, 1.4)	
Koh et al[24]	18.0 ± 4.8	29.3 ± 5.2	17.7 ± 4.0	29.8 ± 6.7	-0.3 (-2.5, 1.9)	+0.5 (-2.7, 3.7)	+0.8 (-2.0, 3.6)
Burks et al[9]	12.1 ± 3.9	28.6 ± 3.6	13.6 ± 4.6	29.5 ± 5.6	+1.5 (-1.1, 4.1)	+0.9 (-2.0, 3.8)	-0.6 (-3.4, 2.2)
Franceschi et al[17]	11.5 (6-14)[d]	32.9 (29-35)[d]	10.1 (5-14)[d]	33.3 (30-35)[d]	-1.4 (-0.2, -2.6)	+0.4 (-0.4, 1.2)	+1.8 (0.8, 2.8)
				Weighted Mean	-0.4 (-2.0, 1.2)	+0.7 (0.2, 1.2)	+1.1 (-0.3, 2.5)
				***P* values**	**0.619**	**0.005***	**0.116**



Heterogeneity Testing
τ^2=0.617, Q=2.805, I^2=29% (95% CI [0, 0.907]), *P*=0.246

Constant Scores

Investigators	Single-Row		Double-Row		Differences (DR - SR)[a]		θ[b] (CI)[c]
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	
Carbonel et al[10]		78.1 ± 6.8		78.8 ± 5.6		+0.7 (-1.3, 2.6)	
Lapner et al[25]	55.1 ± 15.0	85.6 ± 14.0	58.2 ± 19.2	86.3 ± 14.2	+3.1 (-4.1, 10.3)	+0.7 (-5.8, 7.2)	-2.4 (-9.7, 4.9)
Koh et al[24]	61.4 ± 18.1	85.4 ± 13.8	63.5 ± 17.6	82.5 ± 21.9	+2.1 (-6.8, 11.0)	-2.9 (-12.7, 6.9)	-5.0 (-14.7, 4.7)
Burks et al[9]	44.1 ± 18.8	77.8 ± 9.0	45.6 ± 20.3	74.4 ± 18.4	+1.5 (-10.6, 13.6)	-3.4 (-12.4, 5.6)	-4.9 (-15.6, 5.8)
Grasso et al[20]	*73.2 ± 19.0*[e]	*100.5 ± 17.8*[e]	*77.5 ± 14.7*[e]	*104.9 ± 21.8*[e]	*+4.3*	*+4.4*	*+0.1*
				Weighted Mean	+2.5 (-2.5, 7.6)	+0.4 (-1.4, 2.2)	-3.7 (-8.8, 1.4)
				***P* values**	**0.336**	**0.668**	**0.156**



Heterogeneity Testing
τ^2=0.000, Q=1.150, I^2=0% (95% CI [0, 0.903]), *P*=0.563

*[a]DR = Double-Row; SR = Single-Row; [b]θ =Postoperative Difference – Preoperative Difference: a negative value indicates the single-row group had a greater improvement in outcomes compared to the double-row method while a positive value indicates the double-row group had a greater improvement in outcomes compared to the single-row group; [c]CI = 95% Confidence Interval; [d] Ranges presented in parentheses, standard deviations (sd) were estimated by sd=range/4; [e]These scores were not included in the meta-analysis due to baseline score adjustment as reported in original study; *Statistically significant difference (P<0.05).*

properties of rotator cuff repairs. Specifically, their study revealed that larger initial tear sizes resulted in inferior mechanical properties after repair. These results suggest that comparison of single-row and double-row repairs in tears of all sizes may not be sufficient to detect differences in clinical outcomes between techniques. Therefore, the stratification of outcomes data with initial tear sizes is an important parameter that should be considered in future studies.

Re-tear rates

In the present meta-analysis, a significant increase in imaging-diagnosed re-tear rates after single-row repair was demonstrated; however, this difference did not correlate with a decline in outcomes scores. Of the 7 included studies, Gartsman et al[18] and Lapner et al[25] reported significantly increased re-tear rates in patients treated with the single-row method. Similarly, a level II prospective study by Charousset et al[11] found a significantly increased rate of re-tears after single-row repair by computed tomographic arthrography after a minimum 2-year follow-up period. A few recent meta-analyses have reported similar results.[13,16] Because the increase in imaging-diagnosed re-tears did not correspond with worsening clinical outcomes scores in any study, it follows that these re-tears are likely to be asymptomatic initially and may require more than 2 years to become clinically detectable.

Mall et al[31] studied a large series of 195 patients with asymptomatic rotator cuff tears and found that only 23% of asymptomatic tears became symptomatic 2 years after study enrollment. In addition, Yamaguchi et al[51] observed 45 patients with asymptomatic rotator cuff tears and found that the majority (51%) of patients became symptomatic a mean of 2.8 years after study enrollment. The mean follow-up in this meta-analysis was 1.9 years (23.2 months). Thus, it is possible that the gradual transformation of partial-thickness to full-thickness re-tears and subsequent clinical symptoms may require more than 2 years to become clinically apparent. Therefore, longer term studies may detect a change in outcomes scores in those with partial-thickness rotator cuff re-tears (which occurred most commonly in the single-row group in this study).

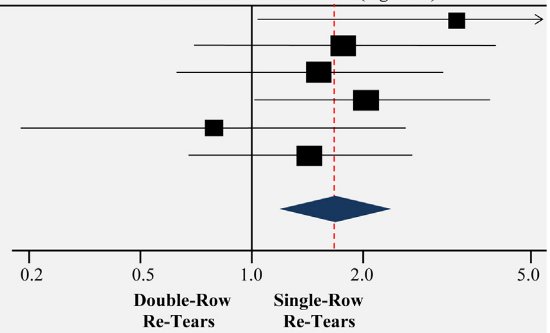
Table VI Summary of re-tears and relative risk of re-tears

All Re-Tears (Partial + Full-Thickness)

Investigators	Single-Row (%)	Double-Row (%)	Relative Risk[a] (CI)[b]
Gartsman et al[18]	10 (25.0)	3 (7.0)	3.58 (1.06, 12.09)
Carbonel et al[10]	15 (18.8)	8 (10.0)	1.88 (0.84, 4.17)
Lapner et al[25]	13 (33.0)	7 (18.9)	1.62 (0.73, 3.59)
Koh et al[24]	15 (62.5)	7 (30.4)	2.05 (1.03, 4.10)
Burks et al[9]	3 (15.0)	4 (20.0)	0.75 (0.19, 2.93)
Franceschi et al[17]	12 (46.2)	8 (30.8)	1.50 (0.74, 3.05)
Totals	68 (25.9)	37 (14.2)	1.76 (1.25, 2.48)
		p-value	**0.001***

Heterogeneity Testing
τ^2=0.000, Q=3.270, I^2=0% (95% CI [0.220, 0.909]), p=0.658

Relative Risk of All Re-Tears (log scale)

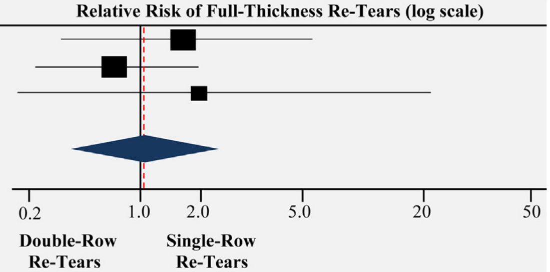


Full-Thickness Re-Tears

Investigators	Single-Row (%)	Double-Row (%)	Relative Risk[a] (CI)[b]
Carbonel et al[10]	5 (6.3)	3 (3.8)	1.67 (0.41, 6.74)
Koh et al[24]	4 (17.4)	6 (26.1)	0.64 (0.21, 1.98)
Franceschi et al[17]	2 (7.7)	1 (3.8)	2.00 (0.19, 20.72)
Totals	11 (8.5)	10 (7.8)	1.03 (0.45, 2.33)
		p-value	**0.953**

Heterogeneity Testing
τ^2=0.000, Q=1.453, I^2=0% (95% CI [0, 0.903]), p=0.484

Relative Risk of Full-Thickness Re-Tears (log scale)

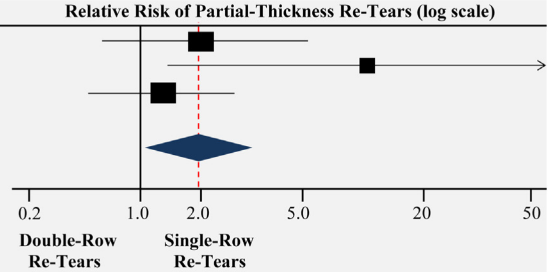


Partial-Thickness Re-Tears

Investigators	Single-Row (%)	Double-Row (%)	Relative Risk[a] (CI)[b]
Carbonel et al[10]	10 (12.5)	5 (6.3)	2.00 (0.72, 5.59)
Koh et al[24]	11 (45.8)	1 (4.3)	10.54 (1.48, 75.26)
Franceschi et al[17]	10 (38.5)	7 (26.9)	1.43 (0.64, 3.17)
Totals	31 (23.8)	13 (10.1)	1.99 (1.04, 3.82)
		p-value	**0.039***

Heterogeneity Testing
τ^2=0.039, Q=3.416, I^2=41% (95% CI [0, 0.911]), p=0.181

Relative Risk of Partial-Thickness Re-Tears (log scale)



*[a]Relative Risk: Values of less than 1.0 indicate an increased risk of re-tears in the double-row group while values of greater than 1.0 indicate an increased risk of re-tears in the single-row group; [b]CI = 95% Confidence Interval; *Statistical significance*

Limitations

This study has several limitations that should be noted. First, as with any meta-analysis, there are limitations and biases inherent to each study in this review that may have skewed our results. However, we have presented a detailed risk of bias assessment and specifically noted the important limitations of each study to decrease the risk of data misinterpretation. Second, because of the potential for publication bias and language bias in any meta-analysis, we cannot rule out the presence of relevant unpublished studies with undesirable results. Finally, although several of the included studies used the term *healing rate* to describe the proportion of shoulders with a tendon defect on postoperative imaging, we chose to use the term *re-tear rate* to describe these findings in all cases. Because it is not possible to distinguish between a *re-tear* and a *lack of healing* by imaging studies alone, it is possible that some of the "re-tears" in this study may actually represent a failure to heal rather than a true tendon re-rupture.

Conclusions

Single-row repairs resulted in a significantly higher re-tear rate compared with double-row repairs, especially with regard to partial-thickness re-tears. However, there were no statistically significant differences in outcome scores between single-row and double-row repairs. Studies that stratified their results by initial tear sizes did show differences between single-row and double-row repairs. Well-performed studies with longer follow-up are required to better understand the long-term consequences of asymptomatic imaging-diagnosed rotator cuff re-tears.

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