SCIENTIFIC ARTICLE

Arthroscopic Single-row versus Double-row Technique for Repairing Rotator Cuff Tears: a Systematic Review and Meta-analysis

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Objective: The purpose of this study was to systematically review published reports that compare the outcomes of single-row and double-row suture anchor fixation in arthroscopic rotator cuff repair.

Methods: Combined data regarding relevant patient characteristics, rotator cuff pathology, surgical techniques, postoperative rehabilitation regimens, University of California at Los Angeles (UCLA) Scores, Constant scores, American Shoulder and Elbow Society (ASES) scores, tendon healing, incidence of recurrent rotator cuff defects, shoulder muscle strength, range of motion, surgical time and patient satisfaction were assessed.

Results: Seven eligible randomized controlled studies and four prospective cohort studies were identified. There were no significant differences between the single-row and double-row groups in terms of Constant or ASES scores. However, UCLA scores, tendon healing, abduction shoulder strength index (SSI), external rotation SSI and internal rotation SSI were significantly better for double-row technique than for single-row technique. A statistically significant advantage for double-row repair according to UCLA score and external rotation SSI was found in the subgroup with tears greater than 3 cm.

Conclusion: No definite conclusion could be drawn about differences in overall outcomes of double- and single-row techniques for repairing for small to medium (<3 cm) or large to massive (>3 cm) rotator cuff tears, even though some measures of clinical outcome showed significant differences between these two techniques.

Key words: Arthroscopy; Double-row technique; Rotator cuff; Single-row technique

Introduction

Arthroscopic repair of rotator cuff tears under is becoming a common and popular procedure, having the advantages over open surgery of a minimally invasive approach, smaller skin incisions, no deltoid detachment and less soft-tissue dissection^{1,2}. Ideally, rotator cuff repair provides initial strong fixation strength and minimization of gap formation during the process of the tendon incorporating into the bone. The single-row technique for repair of torn rotator cuffs has been

standard, even though numerous studies have reported retears and incomplete tendon healing after using this technique³⁻⁹. It is estimated that as much as an average of 52.7% of the rotator cuff footprint is left uncovered after lateral-row repair alone¹⁰. One possible explanation for the high rate of repair-site failure is that the single-row technique does not completely recreate the native footprint insertion of the tendon onto the greater tuberosity, leading to incomplete anatomic healing¹¹.

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The double-row technique has been recommended as a means of increasing the contact area between the repaired rotator cuff and the native bone bed. Theoretically, this technique incorporates a medial and a lateral row of suture anchors, increasing the initial coverage of the tendon–bone junction^{12,13}. Restoring the anatomic footprint may enhance healing of the tendon–bone interface and the mechanical strength of the repaired tendons¹⁴. The double-row technique provides a greater contact area, which may contribute to developing a better environment for tendon healing¹⁵. Good clinical outcomes have been reported for arthroscopic rotator cuff repair using a double-row technique^{12,16,17}; several studies have also reported anatomic or biomechanical advantages of the double-row fixation technique^{18–20}. A cadaver study has shown that, compared with the single-row technique, the double-row technique provides superior initial fixation strength²¹. Another study demonstrated that the supraspinatus tendon footprint can be better restored to its original size by the double than the single-row technique¹³. The findings of the above studies suggest that the double-row technique provides a better tendon–bone healing environment for rotator cuff repairs than does single-row repair. However, the clinical superiority of double-row techniques has yet to be shown. A series of prospective randomized control studies have compared the two techniques clinically: most of them reported finding no statistically significant differences in clinical outcomes between double and single-row arthroscopic rotator cuff repairs^{22–26}. However, in three of these studies the subjects were separated into patients with small to medium tears (<3 cm long) and those with large to massive tears (>3 cm long). All three showed that patients with large to massive tears in whom the double-row technique was been used had better clinical outcomes than those who had undergone single-row fixation^{26–28}.

The purpose of this study was to conduct a systematic review and meta-analysis of recent studies to ascertain whether arthroscopic single-row rotator cuff repair has equivalent outcomes to the double-row technique according to postoperative University of California at Los Angeles (UCLA) Scores, Constant scores, American Shoulder and Elbow Society (ASES) scores, tendon healing, incidence of recurrence of rotator cuff defects and shoulder muscle strength. Our hypothesis was that the double-row technique achieved better clinical results in patients with large to massive tears (>3 cm) than the single-row technique.

Materials and Methods

Studies were eligible for inclusion if they were randomized controlled trials or cohort studies with at least 12 months follow-up that directly compared single- with double-row arthroscopic rotator cuff repair and measured some of the following primary outcomes: UCLA scores, Constant scores, ASES scores, percentage of tendon healing, incidence of recurrent rotator cuff defects, shoulder muscle strength, range of motion, surgical time and patient satisfaction. These variables were selected because at least half of the studies included each of these measures.

Although the pathology of resected tissue would have been an ideal outcome measure, this would require following large number of participants for decades. Because no such studies have been performed, various commonly used clinical scoring systems and radiologic characteristics known to be associated with clinical efficacy were used as surrogate outcomes.

Identification of Studies

The review protocol described by Spindle *et al.*²⁹ and Wright *et al.*³⁰ was employed. An electronic search of published reports was last updated on 10 April 2014. Without language restrictions, the Medline (1966 to present), Cochrane Central Register of Controlled Trials, and EMBASE (1980 to present), CINAHL (1982 to present), AMED (1985 to present) and ISI Web of science (1945 to present) were searched for the terms “‘rotator cuff repair’”, “‘single-row repair’” and “‘double-row repair.’” The three terms were searched individually and were combined with Boolean terms. No exclusions such as publication year or journal name were specified in the search strategy.

In addition, the following conference abstract issues of key journals for 2000–2013 were manually searched: The American Journal of Sports Medicine, The Journal of Bone and Joint Surgery (USA and UK versions), Arthroscopy: The Journal of Arthroscopic and Related Surgery, Clinics in Sports Medicine, Clinical Orthopaedics and Related Research and the Journal of Shoulder and Elbow Surgery. The reference lists and ISI citations of all included studies were examined. Two reviewers assessed potentially relevant articles against the inclusion criteria, which were English-language Level I (or better) evidence studies assessing single-row versus double-row rotator cuff repair. Exclusion criteria included less than 1 year of follow-up, no clinical assessment of outcome, assessment of only single-row or only double-row repair, retrospective study design and follow-up of fewer than 70% of study subjects.

Data Collection and Analysis

Each abstract and extracted required data were independently reviewed by two reviewers (Z-mY, TL). The references of each study were examined for other relevant studies. If there were any discrepancies, a third individual reviewed the articles. Changes between the two different techniques in UCLA scores, Constant scores, ASES scores, percentage of complete tendon healing, incidence of recurrent rotator cuff defects, shoulder muscle strength, range of motion, surgical time and patient satisfaction were extracted. The two reviewers independently assessed each trial's risk of bias, assessing factors such as randomization, allocation concealment, blinding, completeness of outcome assessment and selective reporting. Where necessary, authors were contacted to obtain information on primary outcome factors.

All assessed outcomes were converted to standardized mean differences, which were calculated from changes from base-line in treatment and control groups. Where clinically

useful, a benefit in units of percentage change since baseline was estimated from the standardized mean differences by estimating the pooled standard deviation from the means of the standard deviation of the outcomes in double- and single-row groups for each study, and multiplying the standardized mean differences by this³¹.

Statistical heterogeneity was calculated using the χ^2 test on N-1 degrees of freedom, with significance conservatively set at 0.10. To determine the percentage variability in effect estimates due to heterogeneity, inconsistency (I^2) was assessed using the formula $([Q-df]/Q) \times 100\%$, where Q is the χ^2 statistic and df is its degrees of freedom. A value greater than 50% was considered to denote substantial heterogeneity. For each study, relative risks (RRs) with 95% confidence intervals (CIs) and standardized or weighted mean differences with 95% CIs were calculated for dichotomous outcomes and continuous outcomes, respectively.

A fixed-effects or random-effects model was applied depending on the heterogeneity of the studies. Quality appraisal was performed according to the CONSORT 2010 checklist and the Cochrane scale was used to assess the risk of bias³². When heterogeneity was considered substantial, its causes were explored by carrying out pre-specified subgroup analyses where data were available; namely, subgroup by sex, tear size, base profiles, compliance and adequacy of allocation concealment. Where clear clinical or study methodology reasons for substantial heterogeneity between studies were not identified, meta-analysis using random effects models was performed. All analyses were carried out in Review Manager 5 (version 5.0.16). When possible, intention to treat data were used in analyses. If these were not available, in order of preference, data from available data or per protocol analyses were used. Publication bias was assessed by funnel plot.

Results

The search protocol and its results are shown in Fig. 1. The search identified 657 references, 486 of which were excluded by initial independent screening of the title and abstract, with 13 disagreements. The disagreements were resolved by consensus, all 13 being excluded by screening of their abstracts. After discarding duplicate abstracts and subsequent search steps, 11 clinical studies with a level of evidence of II or better that compared the outcomes of single- and double-row repair were identified^{22–28,33–35}. Studies were excluded for the following reasons: not randomized controlled trials, no clinical comparison of arthroscopic rotator cuff repair techniques, clinical outcomes not measured, comparison of arthroscopic rotator cuff repair techniques with level III evidence or worse. Each study compared various characteristics of the two groups and reported no statistically significant differences in age, sex ratio, dominant shoulder, rotator cuff tear size, fatty degeneration and follow-up. The meta-analysis was thus performed on data from 11 studies with 807 participants that compared the outcomes of single- and double-row repair (Table 1). Relevant clinical variables and details of surgical techniques used in the included studies are listed in Tables 2

Fig. 1 Flowchart showing the steps in the search of published reports.

and 3. As shown, there were no differences between the groups of patients within each of the included studies in number of patients, tear size or number of sutures anchors used and duration of follow-up. Subgroup analysis was performed in the three studies that subdivided subjects according to the size of the rotator cuff tear, small tears being defined as less than 3 cm and large tears as 3 cm or more^{26–28}. Quality appraisal according to the CORNSORT 2010 checklist and Cochrane scale showed that the 11 studies attained good rating scores of 13–18 (Table 4).

Risk of Bias

Selection bias was minimal because seven of the included studies were randomized controlled treatment trials (level of

TABLE 1 Experimental design

Studies	Level of evidence	Randomization	Design
Franceschi <i>et al.</i> (2007) ²²	I	Yes	Prospective
Grasso <i>et al.</i> (2009) ²³	I	Yes	Prospective
Burk <i>et al.</i> (2009) ³⁴	I	Yes	Prospective
Koh <i>et al.</i> (2011) ²⁴	I	Yes	Prospective
Carbonel <i>et al.</i> (2012) ²⁶	I	Yes	Prospective
Lapner <i>et al.</i> (2012) ²⁵	I	Yes	Prospective
Gartsman <i>et al.</i> (2013) ²	I	Yes	Prospective
Aydin <i>et al.</i> (2010) ³⁵	II	No	Prospective
Charousset <i>et al.</i> (2007) ³³	II	No	Prospective
Park <i>et al.</i> (2007) ²⁷	II	No	Prospective
Ma <i>et al.</i> (2012) ²⁸	II	No	Prospective

TABLE 2 Relevant clinical variables of subjects in studies included in the meta-analysis

Studies	No. of patients	No of patients lost to follow-up	Mean age (years)	Follow-up duration (Months)	Clinical outcome measures	Radiographic outcome measures
Franceschi <i>et al.</i> (2007) ²²	SR, 26 DR, 26	SR, 4 DR, 4	SR, 63.5 (43–76) DR, 59.6 (45–80)	22.5 (18–25)	UCLA score, FF, ER, IR	Magnetic resonance Arthrography to assess cuff integrity
Grasso <i>et al.</i> (2009) ²³	SR, 37 DR, 35	SR, 3 DR, 5	SR, 58.3 ± 10.3 DR, 55.2 ± 6.5	24.8 ± 1.4	DASH, work DASH, strength	N/R
Burk <i>et al.</i> (2009) ³⁴	SR, 20 DR, 20	0	SR, 56 (43–74) DR, 57 (41–81)	12	WORC, ASES, UCLA, SANE, ER, IR	MRI to assess footprint, thickness and signal content
Koh <i>et al.</i> (2011) ²⁴	SR, 31 DR, 31	0	SR, 61.6 ± 8.8 DR, 61.1 ± 9.1	31.0 (24–44) 32.8 (24–42)	PVAS, Constant score, ASES score, UCLA score, Range of motion, Satisfaction, Surgical time, Tendon healing, Re-rupture rate	MRI to compare full-thickness re-tears between the two groups
Carbonel <i>et al.</i> (2012) ²⁶	SR, 80 DR, 80	0	SR, 55.79 ± 6.3 DR, 55.21 ± 5.0	24	UCLA score, Constant score ASES score, ER and ER SSI, IR and IR SSI, Flexion and Flexion SSI, Abduction and Abduction SSI	MRI to identify the integrity of the rotator cuff at final follow-up
Lapner <i>et al.</i> (2012) ²⁵	SR, 39 DR, 34	SR, 9 DR, 8	SR, 56 ± 8.9 DR, 57.8 ± 7	24	Constant score, ASES score WORC, Strength	Ultrasonography and MRI to assess cuff integrity
Gartsman <i>et al.</i> (2013) ²	SR, 40 DR, 43	SR, 5 DR, 2	N/R	10 (6–12)	None	Ultrasonography to assess cuff integrity
Aydin <i>et al.</i> (2010) ³⁵	SR, 34 DR, 34	0	SR, 59 (40–69) DR, 57 (36–67)	36 (24–40)	Constant score Operation time	N/R
Charousset <i>et al.</i> (2007) ³³	SR, 35 DR, 31	SR, 2 DR, 3	SR, 58 (32–74) DR, 60 (37–62)	SR, 27.6 (24–37.7) DR, 28.7 (24–40)	Objective evaluation, subjective evaluation, time to return to work	Computed tomography, arthrography
Park <i>et al.</i> (2007) ²⁷	SR, 40 DR, 38	SR, 3 DR, 4	SR, 57 (39–78) DR, 54.4 (28–76)	25.1 (22–30)	ASES index, †SSI (abduction, IR, ER)	N/R
Ma <i>et al.</i> (2012) ²⁸	SR, 27 DR, 26	SR, 5 DR, 6	SR, 60.8 (47–80) DR, 61.6 (40–72)	33.5 (24–42)	UCLA score, ASES index Abduction strength (kg), ER strength (kg)	MRI to identify the integrity of the rotator cuff
Constant, Constant–Murley; ER, external rotation; FF, forward flexion; IR, internal rotation; SANE, Single Assessment Numeric Evaluation; WORC, Western Ontario Rotator Cuff Index.						

evidence I)^{2,22–26,34}, whereas the remaining four studies were prospective cohort studies^{27,28,33,35}. However, we thoroughly evaluated the cohorts and demonstrated no significant differences in preoperative baseline clinical characteristics. Also each study had different inclusion and exclusion criteria. Burks *et al.* excluded patients with U-shaped tears³⁴, whereas Grasso *et al.* excluded those with labral pathology²³. Koh *et al.* excluded patients with aseptic inflammatory disease of the affected shoulder (including rheumatoid arthritis)²⁴ and Lapner *et al.* excluded those with substantial shoulder comorbidity (e.g. a Bankart lesion or osteoarthritis)²⁵. Another potential performance bias is the surgeons' skill. Several studies controlled this confounding variable by one surgeon performing all procedures^{2,22,24,28,35}. All patients in the 11 studies were randomly allocated to one of the two repair techniques. However, two

or three surgeons performed the procedures in several studies^{23,25–27,33,34}, which inevitably introduces the variable of degree of skill. Nonetheless, there was little performance and selection bias between the single- and double-row groups because the exclusion criteria and surgical skill level were the same for both. Similarly, the type of postoperative imaging used to assess rotator cuff healing is another potential source of bias that is defined as detection bias. In five of the nine studies that reported radiographic outcomes, the independent observers who evaluated the imaging results were blinded to the procedure or clinical results, decreasing the likelihood that these measurements could have introduced bias into the studies^{22,24,25,33,34}. In four studies, the imaging results were evaluated by multiple physicians. In two studies, two orthopedic surgeons and two musculoskeletal radiologists interpreted

TABLE 4 Risk of bias in randomized controlled trials. “+” indicates low risk of bias, “-” indicates high risk of bias, and “?” indicates unclear risk of bias

Koh, 2011 ²⁴	+	+	+	+	+	-	?
Aydin, 2010 ³⁵	+	-	+	+	+	+	+
Burks, 2009 ³⁴	+	+	+	?	+	+	-
Grasso, 2009 ²³	+	+	+	-	+	+	+
Franceschi, 2007 ²²	+	-	+	+	+	+	+
Park, 2008 (total) ²⁷	-	-	+	+	+	+	+
Charousset, 2007 ³³	+	-	+	+	+	+	?
Gartsman, 2013 ²	+	-	+	+	+	+	+
Ma, 2012 ²⁸	+	+	+	+	+	-	+
Carbonel, 2012 ²⁶	+	+	+	+	+	-	+
Lapner, 2012 ²⁵	+	+	+	+	+	?	+

the images^{24,34}, whereas in the study by Charousset *et al.*³³ two radiologists and two surgeons evaluated the images. It has been demonstrated that intraobserver and interobserver reliability in characterizing rotator cuff tears regarding the size of the tear, degree of atrophy and/or fatty infiltration as seen on MRI and arthroscopy is relatively low among fellowship-trained shoulder surgeons^{36,37}. As for attrition bias, nine of the eleven studies had acceptable rates of loss to follow-up (<15% of patients being lost to follow-up with intention-to treat analysis, range 0–13.3%)^{2,22–24,26,27,34,35}. The study by Franceschi *et al.* reported a 13.3% rate of loss to follow-up reported, four patients being lost to follow-up in each group. No patients were lost to follow-up in the following studies:^{22,24,26,28,34,35}. However, in the studies of Ma *et al.*²⁸ and Lapner *et al.*²⁵, the rate of follow-up was 18.75%, which is above the acceptable 15% rate of attrition. Another recognized potential bias in our review is publication bias, which occurs because positive studies are more likely to be published.

Postoperative Outcome Measurements

The UCLA scores at final follow-up was reported by five studies^{22,24,26,28,34} (Fig. 2), all of which reported statistically significant differences between the repair techniques (mean difference, 0.66; 95% CI, 0.20 to 1.13; $P = 0.005$). However, this difference is not considered clinically significant because it does not indicate an improvement in shoulder function.

Eight studies evaluated differences in postoperative Constant scores between the two techniques^{23–27,33–35} (Fig. 3). Each of these studies reported no significant difference between repair techniques ($P > 0.05$) and meta-analysis also did not demonstrate statistically significant differences between the groups (mean difference, 0.92; 95% CI, -0.39 to 2.22; $P = 0.17$).

Six studies evaluated American Shoulder and Elbow Surgeons scores at final postoperative follow-up^{24–26,28,34}. All reported no statistically significant differences between the groups (mean difference, 0.83; 95% CI, 0.02 to 1.65; $P = 0.05$) (Fig. 4).

Fig. 2 UCLA scores.

Fig. 3 Constant scores.

Eight studies compared tendon healing between the groups^{2,22,24–26,28,33,34}. Charousset *et al.*³³ assessed tendon healing by CT arthrography whereas Gartsman *et al.*² and Lapner *et al.*²⁵ evaluated it by ultrasound. The remaining five studies assessed tendon healing by MRI. Meta-analysis showed a statistically significant difference regarding tendon healing and incidence of tear recurrence between the two groups (tendon healing: OR 1.79; 95% CI, 1.19 to 2.68; P = 0.005; incidence of recurrence: OR 0.56; 95% CI, 0.37 to 0.84; P = 0.005) (Fig. 5).

Various methods of muscle strength measurement were described in three of the reviewed studies. Burks *et al.* measured muscle strength by the Lafayette manual muscle test system³⁴ whereas Grasso *et al.* used a digital dynamometer to measure the muscle strength of the affected side (in pounds)²³. One study used the Shoulder Strength Index to compare muscle strengths between the affected and contralateral sides²⁷. Because one study used T₉ and T₈ to represent the double- and single-row groups, respectively²⁴, we could not extract the relevant data and were therefore unable to include it in our meta-analysis. We used the standardized mean difference to compare these different scales for measuring the same outcome.

Two studies reported abduction, external rotation and internal rotation strength at final follow-up^{26,27}. Our meta-analysis showed no statistically significant differences between

the groups (abduction shoulder strength index [SSI]: standardized mean difference, 0.02; 95% CI, 0.01 to 0.04; P = 0.002; external rotation SSI: standardized mean difference, 0.01; 95% CI, 0.00 to 0.02; P = 0.04; internal rotation SSI: standardized mean difference, 0.02; 95% CI, 0.01 to 0.03; P = 0.0006) (Fig. 6).

Three studies reported the operative time of the two surgical techniques^{22,24,35}. Meta-analysis showed this was significantly longer for double- than for single-row repair (standardized mean difference, 17.65; 95% CI, 8.89 to 26.42, P < 0.05).

Two studies reported subjective evaluation of patients^{24,33}. One of these reported subjective results were excellent or good in 96.4% of the double-row patients and 96.9% of the single-row group patients³³, whereas in the other study excellent or good satisfaction was achieved in 87.1% of double-row patients and 80.6% of single-row patients²⁴. The differences between the groups were not statistically significant (mean difference, 1.43; 95% CI, 0.42 to 4.90; P = 0.57) (Fig. 7).

Subgroup Analysis

Three studies included in our review compared outcomes between single- and double-row repairs for rotator cuff tear sizes less than 3 cm or greater than 3 cm^{26–28}. According to UCLA scores and external rotation SSI (mean difference, 1.17;

Fig. 4 ASES scores.

Fig. 5 Tendon healing and tear recurrence.

95% CI, 0.33 to 2.01; $P = 0.006$; mean difference, 0.02; 95% CI, 0.00 to 0.04; $P = 0.03$, respectively), there was a statistically significant difference between single- and double-row repair in the subgroup with tears greater than 3 cm long. However, there was no statistically significant difference between single- and double-row repair in the subgroup with tears less than 3 cm. A statistically significant difference in internal rotation SSI was found between the double- and single-row repair technique regardless of tear sizes (<3 cm: mean difference, 0.02; 95% CI, 0.00 to 0.04; $P = 0.02$; ≥ 3 cm: mean difference, 0.03; 95% CI, 0.01 to 0.04; $P = 0.01$). Regardless of tear sizes, no statistically significant differences were found between double- and single-row repair technique for Constant scores, ASES or abduction SSI (Figs 8–13).

Discussion

In this systematic review, we performed a meta-analysis of relevant recent evidence to determine whether arthroscopic double-row fixation is superior to single-row fixation in terms of clinical outcomes and the structural integrity of the repair. Both techniques achieve significant clinical improvement; however, we identified no overall statistically significant clinical differences between them. We found these two surgical techniques to be equivalent in terms of UCLA, Constant and ASES scores, incidence of recurrent rotator cuff

defects, shoulder muscle strength, range of motion and patient satisfaction. The results are consistent with most other published meta-analysis studies, with two exceptions^{38,39}. These two studies reported a statistically significant difference benefit for double-row repair according to ASES and UCLA scores in the subgroup with tears greater than 3 cm long. Although the number of included studies is comparatively small, they comprised seven randomized controlled trials and four prospective cohort studies, thus representing a relatively high level of evidence. Quality appraisal was performed according to the CONSORT 2010 checklist and Cochrane scale was used to assess the risk of bias. The 11 studies achieved good rating scores of 13–18 according to the CORNSORT 2010 checklist. Overall, the randomized controlled trials included in this meta-analysis had a fairly low risk of bias (Fig. 2).

There was a statistically significant difference between the two repair techniques for tendon healing, tear recurrence, abduction SSI, external rotation SSI and internal rotation SSI. We found that double-row techniques have a higher rate of tendon healing, lower rate of tear recurrence and greater muscle strength than the single-row technique. In our subgroup analysis, we found no statistically significant difference between the single- and double-row repair methods in patients whose rotator cuff tears were smaller than 3 cm. However,

Fig. 6 Abduction, external rotation SSI, internal rotation SSI.

there was a statistically significant difference between the two groups for larger tears (longer than 3 cm).

Our meta-analysis shown increased complete tendon healing and muscle strength in patients who had undergone the double-row technique, this benefit being confined to patients with large rotator cuff tears (>3 cm). However, no clinically significant differences in postoperative shoulder

evaluations were identified between the two repair methods. Thus, the superiority of the double-row technique did not translate into improved clinical function. Firstly, long-term follow-up has shown that the morphological characteristics of intact rotator cuff do not reflect histological features and biochemical aspects of tendons. The mean load to failure was significantly higher in the double-than the single-row group at

Fig. 7 Surgical time and patients' satisfaction.

Fig. 8 Subgroup analysis of UCLA scores.

6 and 12 weeks; however, at 26 weeks the differences were not statistically significant. These authors concluded that double-row rotator cuff repair provides greater mechanical strength, especially during the early recovery stage, and therefore may be translated to improved clinical outcome⁴⁰. Secondly, the degree of rotator cuff healing after repair does not necessarily affect clinical outcome. Studies have shown that improved pain and shoulder function does not always correlate with repair integrity. However, patients with better tendon healing are generally more likely to experience improved clinical outcomes⁴¹. Tendon healing can be also affected by other factors, such as age, activity and education level, osteoporosis and concomitant conditions in the affected shoulder.

Meta-analysis of the findings of the three studies that stratified their subjects into two independent studies on the basis of tear size^{26–28} showed that rotator cuff tears repaired by double-row fixation had significantly better outcomes according to ASES and UCLA scores than those repaired by the single-row technique. None of the other studies stratified results on the basis of rotator cuff tear size.

Four of the eleven studies in our analysis included radiographic assessment of tendon healing. Two of these studies showed no significant difference between single- and double-row fixation in terms of the structural integrity of the repairs according to MRI and MRI arthrography, respectively^{22,34}. Another study utilized CT arthrography to assess for leakage of contrast medium across any full thickness defects and found no difference between patients with double- and single-row repairs in terms of the percentage of repairs that were water-tight and healed³³. However, anatomic healing with reestablishment of the footprint was seen in a significantly higher percentage of double- than single-row repairs. A study that used ultrasound to evaluate tendon healing found that arthroscopic double-row suture bridge repair of isolated supraspinatus rotator cuff tears resulted in a significantly higher rate of tendon healing than arthroscopic single-row repair². None of those studies provided separate results according to tear size. Despite differences in radiographic healing rates of the tendons^{11,33}, there were no significant differences between the two repair methods in terms of functional outcomes.

Fig. 9 Subgroup analysis of Constant scores.

Fig. 10 Subgroup analysis of ASES.

Despite the double-row repair method having superior results in terms of tendon healing and Constant and ASES scores in studies that stratified outcomes on the basis of rotator cuff tear size, there are several potential limitations to applying this technique in all patients. First, the single-row technique uses one to four anchors, whereas the double-row technique requires two to seven, which makes it more costly^{22,23,27,33}. Furthermore, the double-row repair method demands more surgical experience and takes longer than the single-row technique. The pooled effect from the three studies by Aydin *et al.*³⁵, Franceschi *et al.*²² and Koh *et al.*²⁴ showed that the double-row repair technique takes statistically longer to perform than the single-row technique (mean difference, 17.65; 95% CI, 8.89–26.42, $P < 0.0001$). Finally, from a surgical perspective, neovascularization is more severely compromised because multiple strands and more anchors are used for double-row repair.

Most surgeons focus attention on the technical issues of rotator cuff repair. Certainly, relevant patient characteristics should be considered when deciding which repair method to employ. Age, preoperative activity level, occupation, clinical outcome expected and insurance coverage should be taken into consideration. One study showed that a low tension environment is crucial to rotator cuff healing⁴². These authors preferred to repair articular margin rotator cuff tears using a tension-free single row technique rather than the double-row technique, which is associated with undue tension.

Limitations of this Study

Our study is limited by the quality of the included studies and the various biases within each study. Bias was minimal because as seven of the included studies were randomized controlled studies and four prospective cohort studies. The number of included studies contributing substantial data to the

Fig. 11 Subgroup analysis of abduction SSI.

Fig. 12 Subgroup analysis of internal rotation SSI.

meta-analysis may not have been large enough to show significant differences (a type-II error). Only two studies performed a power analysis to calculate the minimum number of patients needed to obtain sufficient power^{23,34}. Another limitation is the duration of follow-up, which differed between the studies. However, the duration of follow-up was equivalent between the single- and double-row techniques in ten of the studies, whereas in one study it was different for the two repair techniques³⁵. Clinical outcomes have the potential to improve with time because the rate of tendon-bone junction healing can increase with time.

Conclusions

Given the paucity of high-quality evidence on this issue and the poor methodological quality of the included studies, it is difficult to reach definitive conclusions. Data from the

available published studies indicates that double-row repair potentially results in more anatomic and structurally sound restoration of the rotator cuff footprint according to radiographic assessment. However, this does not mean that double-row repair has superior clinical outcomes for all sizes of rotator cuff tears. Subgroup analysis showed, according to some clinical outcomes (UCLA scores, external rotation SSI), the double-row technique may achieve better results with large to massive rotator cuff tears (>3 cm). No definite conclusions can be drawn concerning whether the double-row technique is superior to the single-row technique for repairing rotator cuff tears regardless of size, even though some clinical outcomes were significantly different for these two methods. Well-designed, large, prospective, randomized studies are needed to further investigate whether the double-row technique truly has an advantage in terms of tendon-healing rates and clinical outcomes.

Fig. 13 Subgroup analysis of external rotation SSI.

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