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ORIGINAL ARTICLE • SHOULDER - ARTHROSCOPY

Do functional outcomes and cuff integrity correlate after single- versus double-row rotator cuff repair? A systematic review and meta-analysis study

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Abstract

Purpose The purpose of this study is to perform a systematic review and meta-analysis of all available level I prospective randomized controlled trials comparing arthroscopic single-row (SR) with double-row (DR) rotator cuff repairs by both clinical outcomes and radiological re-tear rates.

Methods PubMed, EMBASE, Google Scholar, and Cochrane databases search was done for level I RCTs comparing clinical and radiological outcomes after SR versus DR rotator cuff repair. Clinical outcomes included UCLA, ASES, Constant, WORC, and SANE scores; structural outcomes included MRI, MRA, or US.

Results Seven level I studies were included (5 mid-term and 2 short-term). Postoperative ASES, Constant, WORC, and SANE scores showed nonsignificant slightly better function of DR groups. Only, UCLA score showed significantly better scores with DR repair ($p = 0.007$). Full-thickness re-tear incidence was reported in 15/174 (8.6%) in DR group and 20/175 (11.4%) in SR group ($p = 0.44$). Partial-thickness re-tear rate was reported in 18/174 patients (10.3%) in DR group and 41/175 patients (23.4%) in SR group ($p = 0.009$).

Conclusion Within the domain of level I mid-term and short-term studies, DR repair showed significant better UCLA score only. (ASES, Constant, WORC, and SANE scores showed no significance.) This may correlate weakly with the significant lower partial-thickness re-tear rates of DR repairs. In contrary, long-term level III studies showed a direct correlation of both functional outcomes and cuff structural integrity, with significant superiority of DR over SR repair techniques.

Level of evidence Level 1, systematic review and meta-analysis.

Keywords Single row · Double row · Rotator cuff repair · Systematic review · Meta-analysis

Introduction

Arthroscopic rotator cuff repair (RCR) has become popular in the last decades as it avoids large skin incisions, deltoid detachment, dysfunction, and postoperative pain, and it allows the surgeon to detect and treat other associated shoulder pathologies [1].

Earlier arthroscopic single-row (SR) repair methods achieved only partial restoration of the original footprint of the tendons of the rotator cuff. Subsequently, double-row (DR) repair methods showed better restoration of the footprint area, less micro-movements, and better homogeneous compression pressure through the tendon [2].

The former biomechanical advantages aided higher healing rates with DR repair as concluded by Ma et al. [3]. These data lead to a paradigm shift in arthroscopic RCR to the DR techniques, which unfortunately failed to give better clinical results over SR repair in further studies [2, 4–7].

Many systematic reviews [8–11] and meta-analyses [1, 2, 5, 6, 12–18] were done to compare the two repair techniques. However, the inclusion of level II [1, 13, 14, 16, 17] and III [12, 19] trials or level I trials [5, 10, 15] that do not strictly rely on both functional and radiographic evaluations creates a potential source of heterogeneity that interferes with accurate analysis of the relation of the function to the cuff integrity after both techniques [20]. Consequently, their evidence supports the equivocal integrity and functional outcomes of both SR

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and DR techniques, which does not correlate with the proven biomechanical advantage of DR technique. Moreover, due to the paucity of long-term studies, most of these studies depend on short- and mid-term results, which do not give enough time for DR technique to show significant functional and structural superiority over SR repair.

The purpose of this study is to perform a meta-analysis of only level I prospective RCTs strictly studying both clinical outcomes and radiological re-tear rates of arthroscopic single-row versus double-row rotator cuff repairs until November 2017. Our hypothesis assumes that when considering the simultaneous analysis of both functional outcomes together with the structural integrity, DR repair technique gives better clinical outcomes and lower re-tear rate.

Materials and methods

Study design

This systematic review and meta-analysis were started in October 2016 according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [21] and the protocol described by Harris et al. [22]. Only level I randomized controlled clinical trials comparing both clinical and structural outcomes after arthroscopic single-row and double-row rotator cuff repairs were included. The latest date for this search was May 18, 2017.

Search technique

Electronic databases, including PubMed, EMBASE, Google scholar, and the Cochrane Central Register of Controlled Trials were searched for full-text trials from January 2000 till May 2017. The search was language unrestricted and used the following terms: (1) Rotator cuff tear, (2) rotator cuff arthroscopic repair, (3) single-row repair, (4) double-row repair, (5) structural and clinical outcomes of rotator cuff tear repair. The references of retrieved articles were further searched for potential eligible trials. When necessary, included articles' authors were contacted for further data. Two reviewers independently reviewed the titles and abstracts to identify articles meeting the eligibility criteria.

Eligibility criteria

Studies were included in meta-analysis only if met the following inclusion criteria:

Inclusion criteria

Type of studies Level I evidence prospective randomized controlled trials (RCTs), comparing both structural and clinical outcomes of SR versus DR RCR.

Type of subjects Rotator cuff tear with a thickness larger than 10 mm, of any age, gender, physical, or sports activity.

Type of surgeries Arthroscopic rotator cuff repairs using suture anchors.

Duration of follow-up Postoperative follow-up should be at least 1 year.

Type of clinical outcome measures Either University of California Los Angeles (UCLA) [23], American Shoulder and Elbow Surgeons (ASES) [24], Constant [25], Western Ontario Rotator Cuff Index (WORC) [26], or Single Assessment Numerical Evaluation (SANE) [27] scores should be used as measures for clinical evaluation.

Type of structural evaluation Either MRI, MRA, or US should be used as a radiological tool for structural evaluation of healing or re-tear [8, 28–30].

Exclusion criteria

1. Non-randomized controlled trials.
2. Retrospective studies.
3. Trials that did not use arthroscopic or suture anchors techniques.
4. Trials that did not involve imaging for structural evaluation.
5. Trials that did not include both single-row and double-row repairs.
6. Trials published before the year 2000.

Data extraction

Retrieved studies methodological quality, procedures, and outcomes were reviewed independently by 2 reviewers (AHK, MRH). Disagreements were resolved by discussion until consensus was reached. If the 2 reviewers could not reach a consensus, the third author (MHS) was asked for a final opinion, resulting in a group agreement.

Data synthesis and statistical methods

Extracted data from the included studies were pooled for meta-analysis using RevMan® v5.3.5 software (Nordic Cochrane Centre, Copenhagen, Denmark). Continuous data (UCLA score, ASES score, Constant score, WORC index, and SANE score) were reported as standardized mean differences using the inverse variance statistical method and random effects analysis model. Dichotomous data (MRA/MRI/US detected re-tear rate) were reported as odds ratio using Mantel–Haenszel statistical method and random effects analysis model. Heterogeneity was determined by estimating the proportion of between-study inconsistencies due to actual differences between studies, rather than differences due to random error or chance, using the I^2 statistics. Study confidence interval (CI) was adjusted at the 95% level.

Results

Study selection

From the 3993 retrieved articles, only 747 are chosen after removal of duplicates and exclusion of non-arthroscopic studies. Only 139 studies remained after exclusion of non-comparative studies and decreased to 17 after selecting articles comparing SR versus DR repairs. With thorough review of the studies, only 7 studies met our eligibility criteria (Table 1, Fig. 1):

1. Franceschi et al [31].
2. Burks et al. [32].
3. Koh et al. [33].
4. Lapner et al. [34].
5. Carbonel et al. [35].
6. Barber [36].
7. Franceschi et al. [37].

The last two studies have never been included in any previous systematic review or meta-analysis.

Study characteristics and patients population

The seven studies included 500 patients underwent rotator cuff repairs (only 477 were available at the final follow-up), 241 with single-row technique and 236 with double-row technique (Fig. 1). All the seven RCTs compared postoperative clinical outcomes and radiological (MRA/MRI/US) re-tear rate between both techniques. Only Burks et al. [32] used all the proposed clinical outcome scores (ASES, UCLA, Constant, WORC, and SANE), two studies [33, 35] used 3 scores (ASES, Constant, and UCLA), while Lapner et al. [34] used other 3 scores (ASES, Constant, and WORC). Barber et al. [36] used other 3 scores (ASES, Constant, and SANE). Franceschi et al. [31, 37] used only the UCLA score.

All the included studies (465 out of 477 patients) used radiological assessment to detect postoperative re-tear rate, but only 5 studies [31, 33, 35–37] stratified the re-tears into partial and full-thickness tears (349 patients). Barber et al. [36] and Burks et al. [32] were short-term studies (minimum 12 months), while other included studies [31, 33–35, 37] were mid-term studies (minimum 24 months) (Table 2).

Quality assessment

The methodological quality of included studies was appraised with CONSORT (Consolidated Standards

Table 1 Included and excluded studies in the meta-analysis note that exclusions were due to lower evidence than level I RCTs, or the absence of either radiological or functional assessment in any study

Study	Year	Level	Functional	Radiologic	Results
Included					
Barber et al. [36]	2016	I	+	+	Same outcomes
Franceschi et al. [37]	2016	I	+	+	Same function/lower re-tear after DR
Lapner et al. [34]	2012	I	+	+	Same function/lower re-tear after DR
Carbonel et al. [35]	2012	I	+	+	DR has better function in tear > 3 cm/same re-tear rate
Koh et al. [33]	2011	I	+	+	Same outcomes
Burks et al. [32]	2009	I	+	+	Same outcomes
Franceschi et al. [31]	2007	I	+	+	Same function/nonsignificant lower re-tear of DR
Excluded					
Nicholas et al. [38]	2016	II	+	–	Same function
Gartsman et al. [39]	2013	I	–	+	DR has lower re-tear rate
Ma et al. [3]	2012	II	+	+	Same function and integrity (DR has better shoulder strength in 3–5 tears)
Denard et al. [40]	2012	III	+	–	DR is better in massive tears at long term
Mihata et al. [41]	2011	III	+	+	DR is better in function and integrity
Aydin et al. [42]	2010	II	+	–	Same outcomes
Grasso et al. [43]	2009	I	+	–	Same outcomes
Park et al. [44]	2008	II	+	–	DR is better in 3–5 cm tears (function and re-tear rate)
Charousset et al. [7]	2007	II	+	+	Same function/DR has lower re-tears
Sugaya et al. [45]	2005	III	+	+	Same function/DR has lower re-tears

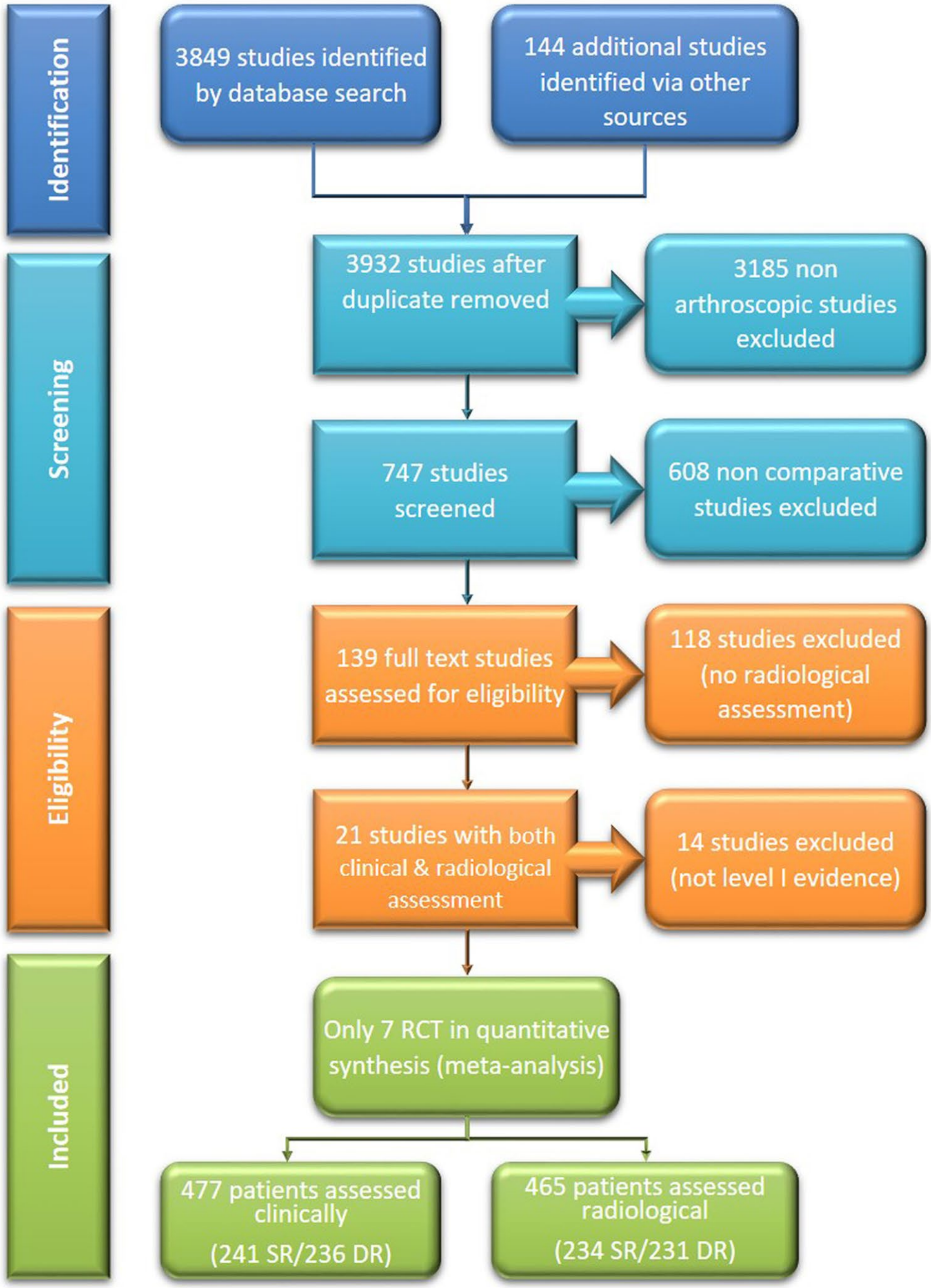

Fig. 1 Study Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the identification, selection, and population of the studies included in this meta-analysis. *SR* single row, *DR* double row

on Reporting Trials) checklist and scoring system [46]. Included studies scored between 15 and 20 points, which was consistent with excellent to good quality (Table 3).

Risk of bias

Two reviewers independently assessed each trial's risk of bias that may inhibit study interpretation using the Cochrane Collaboration's tool [47]. The bias risk of the seven studies was mainly of attritional type (71%) due to incomplete MRI/MRA/US assessments for all subjects in 2 studies [32, 34]. Other types of bias were all of low risk among included studies (Fig. 2).

Operative details

Details of surgical procedures done for every study (no of suture anchors, material and operative techniques and rehabilitation program) are shown in Table 4.

Table 2 Studies' demographic data, follow-up periods, and imaging technique, time, stratification of imaging data (into full and partial-thickness tears), and subjects number at final clinical and radiographic follow-up

	Age mean	Sex		Tear side		Tear size (mm)		Clinical follow-up (final no.)	Imaging follow-up technique (stratification)–time (final no.)
		M	F	RT	LT	Sagittal	Coronal		
Franceschi [31]	SR: 63.5 DR: 59.6	SR:12 DR:16	SR:14 DR:10	NA	NA	NA	NA	Baseline 24 months (SR26/DR26)	MRA (*stratified*) Baseline and 24 months (SR26/DR26)
Burks [32]	SR:56 DR:57	NA	NA	NA	NA	NA	NA	Baseline 12 months (SR20/DR20)	MRI (*not stratified*) Baseline/3/12 months (SR20/DR20)
Koh et al. [33]	SR: 61.6 DR: 61.1	SR: 9 DR: 11	SR: 22 DR: 20	SR: 21 DR: 22	SR: 10 DR: 9	SR: 17.2 DR:17.5	SR: 21.0 DR:20.8	Baseline 24 months (SR31/DR31)	MRI (*stratified*) Baseline and 24 months (SR24/DR23)
Lapner [34]	SR: 56 DR: 57.8	SR: 35 (73%) DR: 29 (69%)	SR: 13 (27%) DR: 13 (31%)	SR: 37 (77%) DR: 29 (69%)	SR: 11 (23%) DR: 13 (31%)	SR: 18.9 DR: 18.9	SR: 21.4 DR: 23.8	Baseline 3/6/12/24 months (SR39/DR34)	Baseline MRI (*not stratified*) 12 months; US/MRI ($n = 65/11$) (SR39/DR37)
Carbonel [35]	SR: 55.8 DR: 55.2	SR: 35 DR: 33	SR: 45 DR: 47	NA	NA	NA	NA	Baseline 24 months (SR80/DR80)	MRI (*Stratified*) Baseline and 24 months (SR80/DR80)
Barber [36]	SR: 57 DR: 55	SR: 11 DR: 13	SR: 9 DR: 7	SR: 15 DR: 18	SR: 5 DR: 2	< 30 mm	NA	Baseline 12 months (SR20/DR20)	MRI (*Stratified*) Baseline and 12 months (SR20/DR20)
Franceschi [37]	SR: 61.8 DR: 58.9	SR: 12 DR: 15	SR: 13 DR: 10	NA	NA	< 50 mm	NA	Baseline 24 months (SR25/DR25)	MRI (*Stratified*) Baseline and 24 months (SR25/DR25)

Note that most of the studies were mid-term results, except Barber and Burks studies were short-term results

Clinical outcome scores (Fig. 3)

UCLA Score was reported in 5 of the included studies [31–33, 35, 37]. It was done on 182 patients enrolled in DR repair, and 182 enrolled in SR repair. It was the only score that showed statistically significant better scores with DR repair ($p = 0.004$).

ASES and Constant Scores were reported in 5 of the included studies [32–36]. They were reported for 185 patients enrolled in the DR, and 190 patients enrolled in the SR. Although DR scored slightly higher means for both scores, they were statistically nonsignificant ($p = 0.10$ and 0.32, respectively).

WORC Index was reported only in 2 studies [32, 34]. It was done on 54 patients enrolled in the DR, and 59 patients enrolled in the SR. Also, it showed no statistical significance between both groups ($p = 0.92$).

SANE Score was reported in 2 studies [32, 36]. It was done on 80 patients divided equally between DR and SR techniques. Also, it showed no statistical significance between both techniques ($p = 0.86$).

Radiographic outcomes (Fig. 4)

Included studies mainly used MR to assess re-tear rate; Lapner et al. [34] used 65 US/11 MRIs, while Franceschi et al. [31, 37] used MRA in two studies as the most sensitive tool to detect re-tears after RCR [28].

Overall re-tear rate including partial and full-thickness re-tears was reported in all studies. Data showed a lower re-tear rate of DR group (45/231 patients), as compared to SR group (76/234 patients). This difference was statistically significant ($p = 0.001$).

Only 5 studies stratified detected re-tears into partial and full thickness [31, 33, 35–37]. *Full-thickness re-tear* incidence was reported in 15 of the 174 patients enrolled to the DR group, and 20 of the 175 patients enrolled to the SR group, which showed no significance between both groups ($p = 0.44$).

Partial-thickness re-tear rate was reported in 18 of the 174 patients in DR group and 41 of the 175 patients in SR group. This showed a statistical significance between both groups ($p = 0.009$) (Fig. 4).

Table 3 Consolidated Standards on Reporting Trials (CONSORT) appraisal of the quality of the level I studies

Checklist Items	Franceschi [31]	Burk [32]	Koh et al. [33]	Lapner [34]	Carbonel [35]	Barber [36]	Franceschi [37]
Title and abstract	1	1	1	1	1	1	0
Introduction and background	1	1	1	1	1	1	1
Methods							
Participation	1	1	1	1	1	1	1
Intervention	1	1	1	1	1	1	1
Objectives	1	1	1	1	1	1	1
Outcomes	1	1	1	1	1	1	1
Samples size	0	1	1	1	0	0	0
Random sequence generation	1	1	1	1	1	1	1
Allocation concealment	1	1	0	1	1	1	1
Implementation	0	0	0	1	1	1	0
Blinding	0	0	0	0	0	0	0
Statistical methods	1	1	1	1	1	1	1
Participant flow	1	0	1	1	0	1	1
Results							
Implementation of intervention	1	1	1	1	1	1	1
Recruitment	1	0	0	1	1	1	1
Baseline data	1	1	1	1	1	1	1
Numbers analyzed	0	0	0	0	0	0	0
Outcomes and estimation	0	0	0	0	0	0	0
Ancillary analyses	0	0	0	1	1	0	0
Adverse events	1	1	0	1	0	0	1
Discussion							
Interpretation	1	1	1	1	1	1	1
Generalizability	1	1	1	1	0	1	1
Overall evidence	1	1	1	1	1	1	1
Total score	17	16	15	20	16	17	16

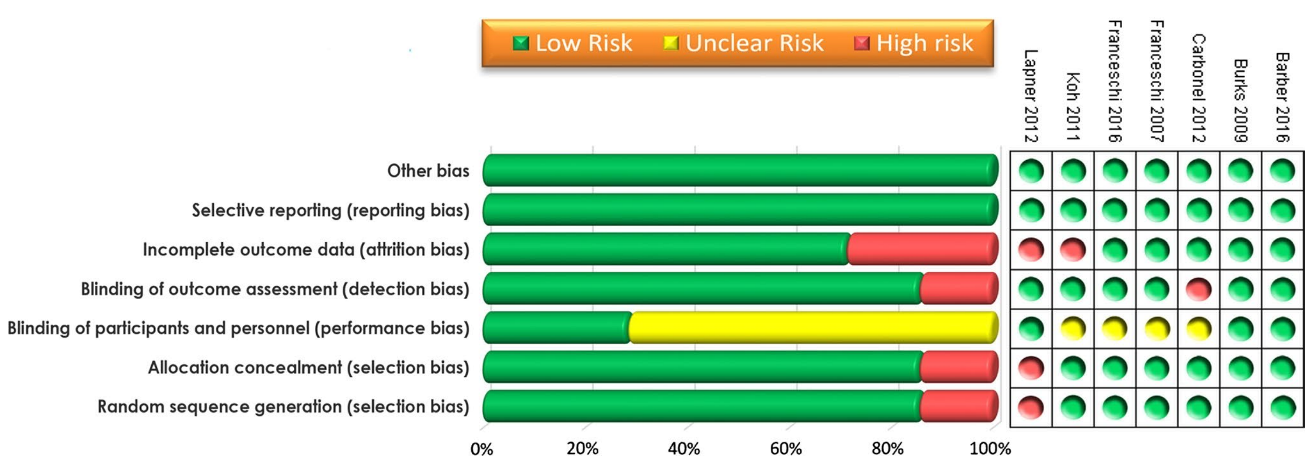

Fig. 2 Risk of bias graph: review authors' judgements about each risk of bias item across all included studies

Table 4 Number of suture anchors, material and operative techniques and rehabilitation program used in all of the included studies

	Mean number of suture anchors	Materials and technique	Rehabilitation protocol
Franceschi [31]	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 6 weeks Passive external rotation on day 1 Overhead stretching restricted for 6 weeks Sling removed 6 weeks and overhead begun Full activities at 6–10 m
Burks [32]	SR: 2.25 DR: 3.2	SR: Double-loaded No. 2 FiberWire DR: Double-loaded No. 2 FiberWire Knot type: Sliding, locking knot with half hitches	Abduction brace + PROM 4 weeks Supine AAROM at 4–6 weeks Full AROM at 6–8 weeks Strengthening at 10–12 weeks
Koh et al. [33]	SR: 2 DR: 3	SR: Double-loaded metal or bioabsorbable anchors → Simple stitches DR: Double-loaded anchors → simple stitches for lateral row and mattress sutures for medial row	Abduction brace for 3 weeks PROM at 4 weeks AROM began after full PROM Strengthening at 12 weeks
Lapner [34]	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 → Sliding, locking and half hitches; medial and lateral rows were not linked	Pendulum exercises on day 1 AAROM at 6 weeks AROM at 8–12 weeks Strengthening at 12 weeks
Carbonel [35]	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	Sling with abduction pillow 6 weeks PROM within the first week Supine AAROM at 4–6 weeks Full AROM at 6–8 weeks Strengthening at 10–12 weeks
Barber [36]	SR: ≥ 1 DR: ≥ 2	SR: Triple-loaded No. 2 OrthoCord + PRPFM* DR: Double-loaded No. 2 OrthoCord → mattress medial row linked suture bridge to lateral row + PRPFM*	Sling with abduction pillow 3 weeks Regular sling for more 3 weeks AROM (rope and pulley) at 6 weeks Strengthening 12 weeks
Franceschi [37]	SR: 1.8 (range 1–2) DR: 2.4 (range 2–4)	SR: Double-loaded No. 2 FiberWire DR: Double-loaded anchors → mattress sutures for medial row and simple stitches for lateral row	Sling with abduction pillow 4 weeks Passive external rotation on day 1 Overhead CKC stretching for 6 weeks AROM (rope and pulley) at 6 weeks Strengthening and scapular stabilizer 10–12 weeks → sport at 6 months

SR single row, *DR* double row, *PROM* passive range of motion, *AAROM* active assisted range of motion, *AROM* active range of motion, **PRPFM* platelet-rich plasma fibrin membrane, *CKC* closed kinetic chain

Discussion

Generally, there is a development of optimal RC repair evidence over time due to improvements in learning curves, arthroscopic techniques, anchors geometry, suture material, and study designs. That was reflected on the results of different systematic reviews and meta-analysis over time (Table 5). Earlier studies were of systematic review nature and of equivocal results between the two techniques, while more recent studies are of meta-analysis nature and with a tendency to show lower re-tear rate after DR repairs. Moreover, both are of short- and mid-term outcomes.

The current study provides an evidence based only on level I RCTs to avoid the possible bias associated with cohorts, and exclusively on studies which used functional and radiological evaluations together. The inclusion of studies with either evaluation creates a potential source of heterogeneity with that interferes with accurate analysis of the relationship between the cuff integrity and function.

Clinical outcomes (Fig. 3)

Although our study showed better clinical outcomes (UCLA, ASES, and Constant) of the DR over SR repairs, only UCLA score showed a statistical significance between both groups. This evidence is consistent with previous meta-analyses [1, 12, 18]. But, this DR superiority could be attributed to the large number of cases enrolled in Carbonel et al. [35] study (weight = 65.4%), which was the only study with significant higher UCLA score of the DR technique. This pushed the authors further to study the actual sample size needed to detect statistical significance for every score. To avoid a β-error for any study, it should be powered to detect a mean difference

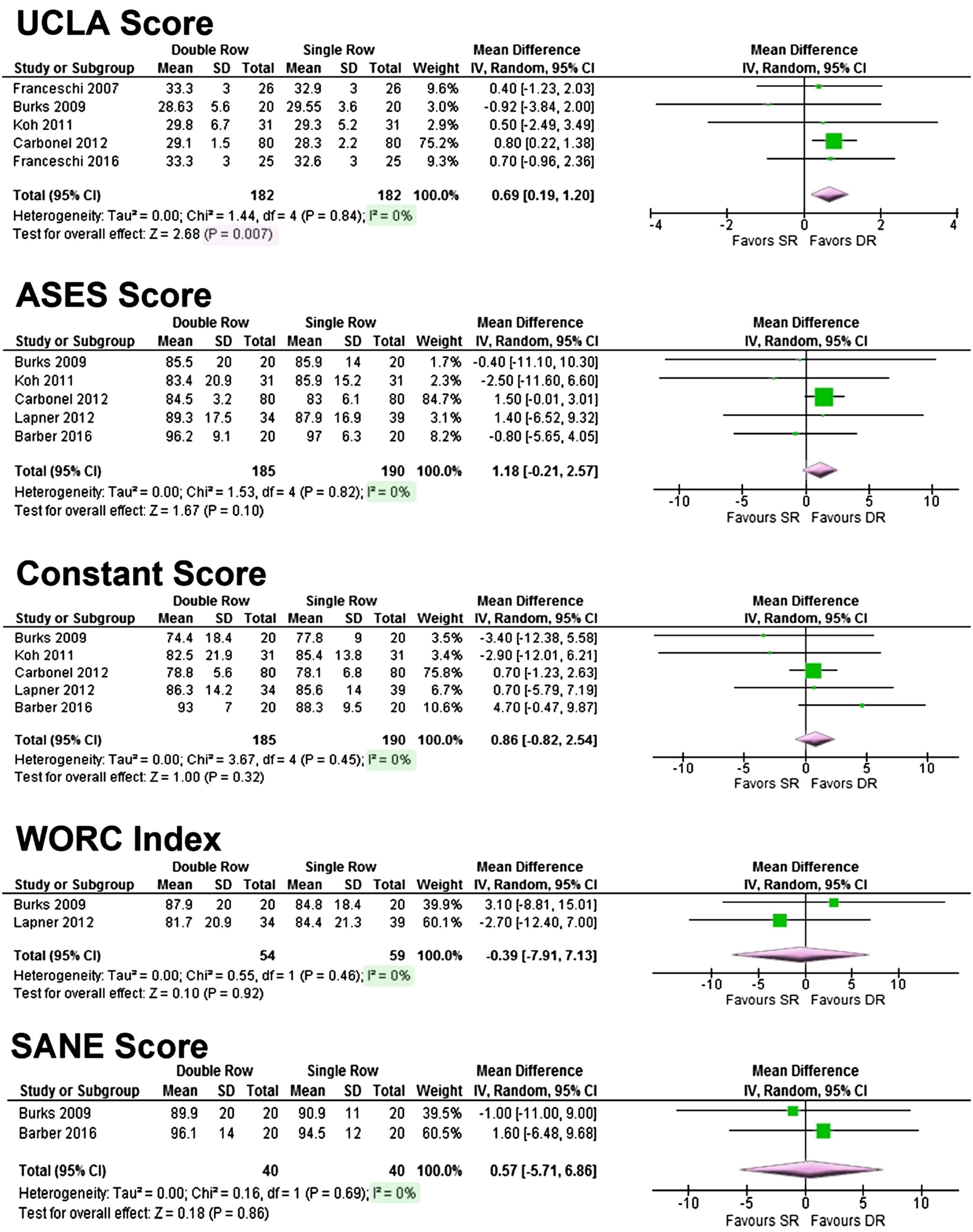

Fig. 3 The postoperative UCLA, ASES, Constant, WORC, and SANE scores mean difference analysis between SR and DR using the inverse variance statistical method with forest plots, and heterogeneity calculation. Note that only UCLA score that showed statistically significant better clinical outcome for DR repairs

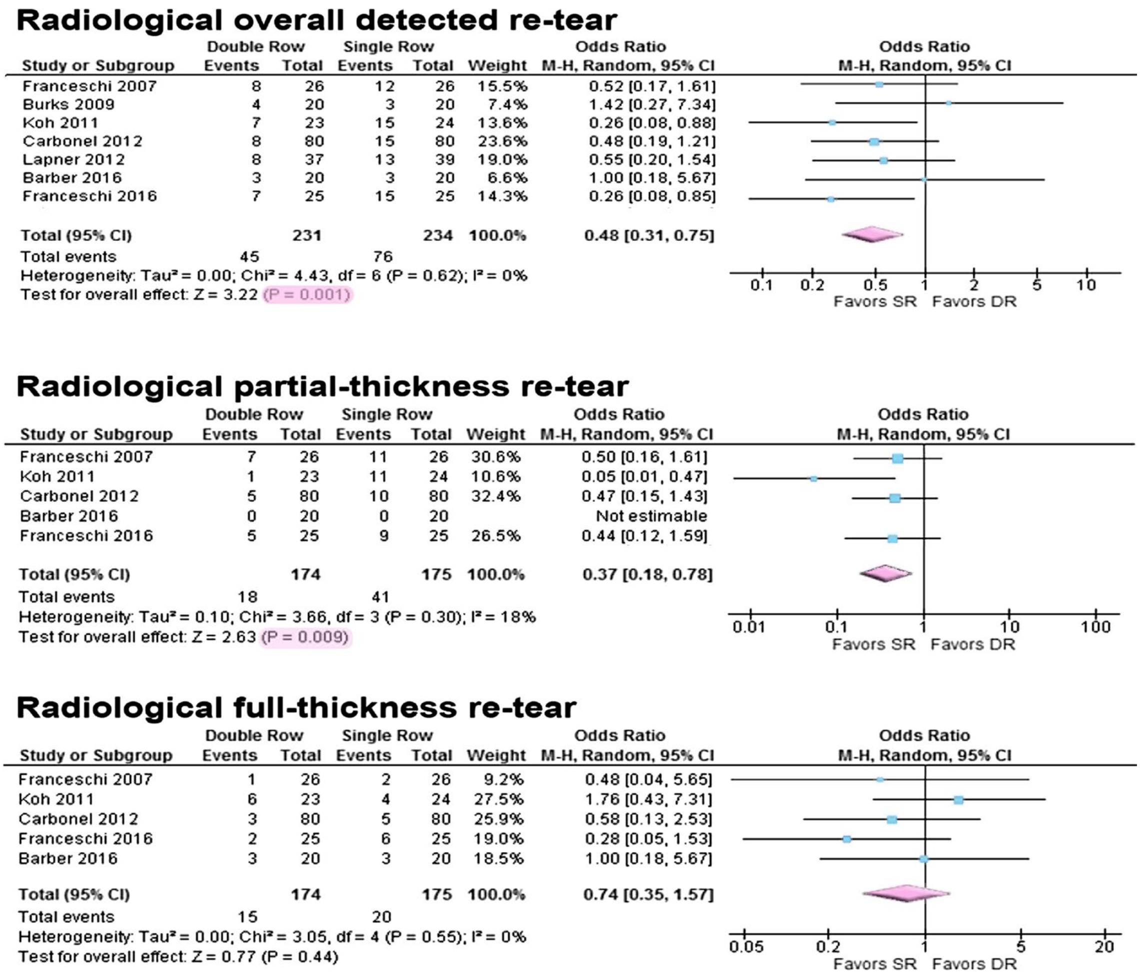

Fig. 4 Overall and stratified re-tears odds ratio between SR & DR repairs with forest plots and heterogeneity analysis using Mantel–Haenszel method. Note that significant overall re-tear risk is mainly due to partial-thickness re-tears

of 2 points for UCLA score, and 5 points for Constant and ASES scores [12, 13]. Unfortunately, only Carbonel et al. [35] who reached the needed sample size to avoid this type-II error for UCLA score only, but not for ASES nor Constant scores. Other included studies [31–34, 36, 37] did not achieve that goal either. This raises a flag that adequately calculated sample sizes may give significant functional outcome differences with other scores.

Moreover, despite the wide use of UCLA score, it has poor responsiveness, reliability, and validity [48–50]. Other scores ASES, Constant, and WORC are well validated for rotator cuff repair. Single Assessment Numeric Evaluation (SANE) is simple but not validated, and in our analysis, it was used only in 2 included studies, same for WORC score. So, the evidence of the WORC and SANE scores in our study was not enough to support any conclusion. Therefore, it is advised to study an adequate sample size with a well-validated score for rotator cuff repair to support either repair techniques.

Subgroup analysis according to tear size is a very appealing approach, as evidence showed differences between the DR and SR techniques only in large to massive tears. Park et al. [44] were the first investigators who stratified their data according to tear size and found better function and lower re-tear rates with DR technique in large tears only. Carbonel et al. [35] did the same subgroup analysis and found only better functional scores with DR repairs in tears larger than 3 cm. Ma et al. [3] found only superior shoulder strength with DR repairs in 3–5 cm tears, but could not detect any difference as regard the integrity or the functional outcomes between the two techniques. In our meta-analysis, this subgrouping was not possible, as Carbonel et al. study [35] was the only included study with such categorization according to tear size. Subsequently, we strongly recommend further RCTs studying the differences of DR and SR techniques according to tear size.

Table 5 Previous systematic reviews and meta-analyses and their results over time

Study	Year	Type	Level	Number of Studies			Results	
				Total	Func	Rad	Functional Outcomes	Re-tear rate
Brown et al. [6]	2015	MetaAn	IV	13	0	13	–	No difference
Xu et al. [1]	2014	MetaAn	II	9	9	5	DR is better in tears > 3 cm[a]	DR had lower re-tear rate in tears > 3 cm
Millett et al. [5]	2014	MetaAn	I	7	6	6	Same	DR had lower partial-thickness re-tear rate
Shen et al. [16]	2014	MetaAn	II	6	6	6	Same	DR had lower partial-thickness re-tear rate
Ying et al. [17]	2014	MetaAn	II	11	10	8	Same	Same
Chen et al. [12]	2013	MetaAn	III	12	12	9	DR is better in tears > 3 cm[b]	DR had lower re-tear rate in tears > 3 cm
Zhang et al. [18]	2013	MetaAn	II	8	8	6	DR is better in tears > 3 cm[b]	DR had lower re-tear rate in tears > 3 cm
Sheibani et al. [15]	2013	MetaAn	I	5	5	0	Same	–
DeHaan et al. [2]	2012	MetaAn	II	7	7	4	Same	Same
Prasathaporn et al. [14]	2011	MetaAn	II	5	5	3	Same	DR had lower re-tears
Perser et al. [13]	2011	MetaAn	II	5	5	3	Same	Same
Duquin et al. [8]	2010	S.Rev	IV	23	0	23	–	DR had lower re-tear rate
Trappey et al. [10]	2011	S.Rev	I	4	3	3	Same	Same
Saridakis et al. [9]	2010	S.Rev	III	6	4	4	Same	Same (DR may be better)
Wall et al. [11]	2009	S.Rev	II	5	5	0	Same	–

Early systematic reviews favoured equivocal results, while later meta-analyses generally favoured DR repairs for their lower re-tear rates

MetaAn meta-analysis, *S.Rev* systematic review, *DR* double row

[a]Function was assessed using ASES score

[b]Function was assessed using ASES and UCLA scores

Imaging outcomes (Fig. 4)

The radiographic results of our meta-analysis showed statistical significance between DR and SR in the overall and partial-thickness re-tear incidence. While, full-thickness re-tear incidence results showed no statistical significance between both techniques, indicating that the overall re-tear incidence is mainly due to partial-thickness type which occurs more after SR repairs. This was consistent with the results of Millet et al. [5]. and Chen et al. [12] , but they concluded that cuff integrity does not correlate with shoulder function. In our meta-analysis, DR repairs showed better cuff integrity that correlated with better functional outcomes that was significant only with UCLA score.

The relation between clinical and imaging outcomes

The relationship between cuff integrity and function is complex [20], and when we analyzed all the studies with the whole spectrum of follow-up periods, we found that this relation follows a tri-phasic pattern over time. While short-term studies [32, 36] tend to give equivocal results for both techniques, mid-term studies [31, 33–35, 37] tend to give the same function but lower re-tear rate with DR technique. However, long-term level III studies [40, 51–53] show a direct correlation between function and integrity with significant superiority of DR repairs. Moreover, partial re-tears after SR repairs eventually would turn into full-thickness tears over time with a dramatic deterioration of shoulder function. Unfortunately, these studies are not included in our meta-analysis due its lower level of evidence, but, it is the strongest available evidence with the longest follow-up periods. Consequently, the phrase of "cuff integrity does not correlate with shoulder function" turns invalid over time and should be abandoned.

Limitations

There were many limitations encountered during making this study.

First limitation was the paucity of RCTs that met our inclusion criteria, with the consequent relative decreased effect size. But the strong construct, level of evidence, and the thoroughly scrutinized included studies gave the current study a strong consistency.

Second was the unavoidable lack of standard measures used in all studies like the different operative techniques, no. of anchors, knot types, follow-up periods, and rehabilitation protocols created an unavoidable performance bias that could affect the final results.

Third, we tried to include more clinical outcomes like ROM and strength, but that was not applicable due to the heterogeneous classification systems used in every study to assess these aspects.

Fourth, the heterogeneous radiographic modalities of different studies raise a potential source of assessment bias.

Finally, we also were unable to stratify the results of our meta-analysis according to the initial tear size, due to the paucity of the studies comparing single-row and double-row according to tear sizes. Up till now, to our knowledge, only Carbonel randomized controlled trial is the only level I study comparing the clinical and imaging results between SR and DR arthroscopic techniques, according to the tear size [35].

Recommendations

Future more powered and high-level trials and meta-analyses should be directed to be more consistent with the procedures and assessments, and to be with longer follow-ups, and to study the following variables effects;

- Initial tear size.
- Muscle atrophy or fatty infiltration.
- Other repair methods: suture bridge, transosseous, speed fix, etc.
- Anchor type: metal, PEEK, biodegradable, vented, etc.
- Number of sutures per anchor.
- Suture type: high-tensile sutures and suture tapes.
- Suture technique: sliding versus half hitches, or simple, mattress, and modified Mason Alan.
- Immobilization and rehabilitation technique.

Conclusion

Within the domain of level I mid-term and short-term studies, DR repair showed significant better UCLA score only. (ASES, Constant, WORC, and SANE scores showed no significance.) This may correlate weakly with the significant lower partial-thickness re-tear rates of DR repairs. In contrary, long-term level III studies showed a direct correlation of both functional outcomes and cuff structural integrity, with significant superiority of DR over SR repair techniques.

Compliance with ethical standards

Conflict of interest All the authors have nothing to disclose.

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