Types of Retears After Knot-tying and Knotless Suture Bridge Rotator Cuff Repair

A Systematic Review and Meta-analysis

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Background: In conventional double-row repair for rotator cuff tears, tying the medial row of anchor sutures can strangulate the tendon. The knotless medial row technique has been recommended to improve vascularity and reduce retear rates. The researchers divided the retear pattern into 2 categories: type 1 (failure at the tendon-bone interface) and type 2 (failure at the musculotendinous junction with healed footprint).

Purpose: To compare studies on knot-tying versus knotless double-row repair for rotator cuff tears according to retear type and clinical and radiological outcomes.

Study Design: Systematic review; Level of evidence, 3.

Methods: A search of the PubMed, Embase, Scopus, and Cochrane databases was performed following the 2020 Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA) guidelines. Included were studies that directly compared the knot-tying and knotless double-row techniques and provided postoperative patient-reported outcomes and retear rates. The Methodology Index for Non-Randomized Studies (MINORS) criteria were used for methodological quality assessment of the included studies. Odds ratios (ORs) were calculated for dichotomous outcomes, and mean differences (MDs) were calculated for continuous outcomes.

Results: Included were 12 studies (n = 1411 shoulders); 1 study had level 1 evidence, 3 studies had level 2 evidence, and 8 studies had level 3 evidence. The MINORS score ranged from 15 to 19, indicating that the methodology was fair to good. There was no statistically significant difference in retear rate between techniques (OR, 0.99; 95% CI, 0.67-1.47; P = .96); however, more type 1 retears were seen in the knotless technique (OR, 0.42; 95% CI, 0.23-0.77; P = .005), and more type 2 retears were seen in the knot-tying technique (OR, 3.15; 95% CI, 1.70-5.83; P = .0003). Higher postoperative Constant scores were seen in the knot-tying technique (MD, 1.28; 95% CI, 0.03-2.53; P = .04); however, there were no significant differences between techniques regarding other postoperative outcomes.

Conclusion: There was no significant difference in overall retear rates between the knotless and knot-tying techniques, and both techniques demonstrated similar clinical outcomes. However, type 2 retear rates were significantly greater after knot-tying repair, and type 1 retear rates were significantly greater after knotless repair.

Keywords: systematic review; rotator cuff; double-row repair; suture bridge; knotless; knot-tying; knotted; clinical outcome; retear; failure

Although single-row repair for rotator cuff tears has produced favorable clinical outcomes, the retear rate is high.2,4,8 The double-row repair technique was developed to help decrease the retear rate.21 The goals of double-row repair are to increase fixation strength, decrease gap formation under cyclic loading, and improve the restoration of the anatomic footprint of the humeral head.1,17,25,26 A meta-analysis by Prasathaporn et al21 concluded that double-row rotator cuff repair can increase tendon healing, enabling patients to have greater external rotation and a significantly higher rate of tendon healing compared with single-row repair.

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Cho et al. divided the rotator cuff retear pattern on post-operative magnetic resonance imaging into 2 categories: type 1 (failure at the tendon-bone interface) and type 2 (failure at the musculotendinous junction with healed footprint). In conventional double-row repair, knot-tying of the medial row of anchor sutures can strangulate the tendon and impair vascular inflow, resulting in a type 2 retear. Recently, the knotless medial row technique has been recommended to improve vascularity and prevent type 2 failure. A systematic review of biomechanical factors (ultimate load, stiffness, gap formation, and contact area) reported that when medial knots are tied in double-row repairs, they perform significantly better than knotless medial row repairs.

Many studies have compared clinical and radiological outcomes between the knot-tying and knotless double-row repair techniques for rotator cuff tears. A meta-analysis by Kunze et al. concluded that clinical outcomes, retear rates, and location of retears after knot-tying versus knotless double-row repairs were not significantly different. Recent retrospective comparative studies confirmed no retear rate differences between both techniques. However, a recent prospective randomized controlled trial comparing clinical and radiological outcomes between knot-tying and knotless medial row techniques found type 2 failure rates to be significantly higher when using the knot-tying medial row technique.

The purpose of the present study was to compare studies on knot-tying versus knotless double-row repair of rotator cuff tears according to retear type and clinical and radiological outcomes.

METHODS

Literature Search and Study Eligibility

A systematic literature search was performed in accordance with the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement by 2 authors (N.P., N.T.), who queried the PubMed, Embase, Scopus, and Cochrane databases for studies involving arthroscopic rotator cuff repair with knotless and knot-tying double-row techniques. All relevant studies were published between 2008 and 2021. The search terms used for this review were (“rotator cuff” OR “supraspinatus” OR “infraspinatus” OR “subscapularis” OR “teres minor”) AND “repair” AND (“knot” OR “knotted” OR “knotless”). Eligible studies were included based on the following criteria: (1) clinical studies with evidence level 1 to 3, (2) English-language articles, (3) studies making direct comparisons between knot-tying and knotless double-row techniques of arthroscopic rotator cuff repair, (4) studies reporting post-operative patient-reported outcomes and retear rates, and (5) full-text availability. The exclusion criteria were (1) basic science or biomechanics articles, (2) case series or case reports, (3) study reviews, (4) studies on rotator cuff repair associated with shoulder arthroplasty or trauma, and (5) overlap of patient populations when the study was conducted by the same authors or institutions.

Data Extraction and Bias Assessment

The 2 reviewers (N.P., N.T.) independently screened all titles, abstracts, and the full texts of the retrieved studies to determine study eligibility. Any disagreements were resolved by a third author (T.I.). Data extracted from the included studies were (1) article information, (2) patient characteristics, (3) surgical techniques and implants, (4) retear rate and retear location (type 1 or type 2 according to Cho classification), (5) functional outcome scores, (6) range of motion, and (7) muscle strength.

The Methodology Index for Non-Randomized Studies (MINORS) criteria were used for methodological quality assessment of the included studies.

Statistical Analysis

The retrieved data were analyzed by use of RevMan version 5.3 (The Cochrane Collaboration). For each study, odds ratios (ORs) with 95% CIs were calculated for dichotomous outcomes, and mean differences (MDs) with 95% CIs were calculated for continuous outcomes. Statistical heterogeneity was proven by the chi-square test. If the test showed $P < .1$, the included studies had statistical heterogeneity. A fixed-effects model was applied if there was no statistical and graphical evidence of heterogeneity. A random-effects model was used when there was statistical or graphical evidence of heterogeneity.

RESULTS

Included Studies

Using the identified search criteria, 698 studies were deemed eligible. After an initial screening, 416 duplicate studies were excluded. Of the remaining 282 abstracts...
screened, 249 were excluded. The final subjective synthesis included 12 articles. Figure 1 summarizes the study selection process.

The 12 articles included a total of 1411 shoulders, with tear sizes being medium in 4 studies,12,13,16,22 medium to large in 3 studies,9,28,29 small to massive in 2 studies,10,23 and not reported in 3 studies.3,11,19 One study23 was categorized as having level 1 evidence, 3 studies3,13,22 had level 2 evidence, and 8 studies9-12,16,19,28,29 had level 3 evidence. The studies had a MINORS score ranging from 15 to 19, indicating that the methodology was fair to good. Details of the included studies are shown in Table 1 and Appendix Table A1.

Retear Rate and Type

Eleven studies3,9-13,16,19,22,23,28 reported the overall retear rate of both knot-tying and knotless techniques. The overall retear rates of the knot-tying and knotless group were 20.1% and 20.4%, respectively. No statistically significant difference was found between the 2 techniques (OR, 0.99; 95% CI, 0.67-1.47; P = .96) (Figure 2). However, type 1 retear rates were significantly higher in knotless double-row rotator cuff repair (OR, 3.15; 95% CI, 1.70-5.83; P = .0003) (Figure 3), while type 2 retear rates were significantly higher in knot-tying double-row rotator cuff repair (OR, 0.42, 95% CI, 0.23-0.77; P = .005) (Figure 4).

Clinical Outcomes

For postoperative clinical outcomes, 7 studies3,9,11,13,16,23,28 reported the Constant score, 3 studies13,16,28 reported the American Shoulder and Elbow Surgeons (ASES) shoulder score, and 3 studies10,13,28 reported the University of California at Los Angeles (UCLA) shoulder rating scale. In comparison with the knotless technique, the knot-tying technique had a statistically higher postoperative Constant score (MD, 1.28; 95% CI, 0.03-2.53; P = .04). (Figure 5A) However, there was no statistically significant difference between the ASES score (MD, 0.95; 95% CI, –0.67 to 2.57; P = .25) (Figure 5B) and the UCLA score (MD, 0.18; 95% CI, –0.70 to 1.06; P = .69) (Figure 5C).

Range of Motion

For range of motion, 5 studies3,9,16,23,29 reported postoperative flexion, 2 studies23,29 reported postoperative abduction, and 3 studies16,23,29 reported postoperative external rotation. There was no statistically significant difference for postoperative flexion (MD, –1.22; 95% CI, –4.45 to 2.00; P = .46) (Figure 6A), abduction (MD, –1.01; 95% CI, –6.48 to 4.46; P = .72) (Figure 6B), and external rotation (MD, –0.48; 95% CI, –3.62 to 2.66; P = .77) (Figure 6C).

DISCUSSION

The main finding of this review was that there was no significant difference in overall retear rates between the knotless and knot-tying techniques (OR, 0.99; 95% CI, 0.67-1.47; P = .96). However, type 2 retear (failure at the musculotendinous junction) rates were significantly higher in the knot-tying technique (OR, 0.42; 95% CI, 0.23-0.77; P = .005), while type 1 retear (failure at the tendon-bone interface) rates were significantly higher in the knotless technique (OR, 3.15; 95% CI, 1.70-5.83; P = .0003). Both techniques had similar clinical results.

Double-row rotator cuff repair can improve fixation strength, footprint contact area, and tendon healing.1,17,21,25,26 The knot-tying and knotless double-row repair of rotator cuff tears is the contentious issue. Eleven of the 12 studies in the

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*References 3, 9–13, 16, 19, 22, 23, 28, 29.*
### TABLE 1
Details of the Included Studies and MINORS Score

| Lead Author (Year) | LOE | Mean Age, y | Knotless/Knot-tying Groups, n | Tear Size, cm | Imaging Modality | Mean Follow-up, mo | PROs | MINORS Score |
|-------------------|-----|-------------|-------------------------------|---------------|-----------------|-------------------|------|--------------|
| Rhee (2012)       | 2   | 61.0        | 51/59                         | 1-3           | MRI             | 21.7              | VAS  | 16           |
| Kim (2014)        | 3   | 59.9        | 61/96                         | 1-4           | MRI             | NR                | 6.2  | 15           |
| Boyer (2015)      | 2   | 58.5        | 35/38                         | NR            | MRI             | 25.2              | VAS, CS | 17         |
| Hug (2015)        | 2   | 63.3        | 22/20                         | NR            | MRI             | 24.4              | CS, WORC, SSV | 16        |
| Lee (2017)        | 3   | 59.0        | 69/59                         | Knotless: 1.76; knot-tying: 1.87 | MRI             | 38.3              | VAS, CS, ASES | 17        |
| Millett (2017)    | 3   | 59.0        | 109/39                        | NR            | MRI             | 34.8              | ASES, SF-12 PCS | 15        |
| Honda (2018)      | 3   | 63.8        | 24/29                         | NR            | MRI             | 24.0              | UCLA, JOA | 17        |
| Kim (2018)        | 3   | 59.7        | 50/50                         | 1-4           | MRI/US          | 24.0              | VAS, CS, UCLA, ASES | 19        |
| Gürpınar (2019)   | 3   | 56.7        | 57/64                         | 1-5           | MRI             | 19.0              | VAS, CS | 18           |
| Zwolak (2020)     | 3   | 61.9        | 19/64                         | 1-5           | NR              | 12.0              | QuickDASH, SPADI | 17        |
| Xu (2021)         | 3   | 63.2        | 134/158                       | 3-5           | MRI             | 15.6              | CS, UCLA, ASES | 17        |
| Şahin (2021)      | 3   | 55.1        | 53/51                         | NR            | MRI             | 24.3              | VAS, CS | 18           |

**a**ASES, American Shoulder and Elbow Surgeons shoulder score; CS, Constant score; JOA, Japanese Orthopaedic Association Score; LOE, level of evidence; MINORS, Methodological Index for Non-Randomized Studies; MRI, magnetic resonance imaging; NR, not reported; PRO, patient-reported outcome; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand Questionnaire; SP-12 PCS, 12-Item Short Form Health Survey–Physical Component Score; SPADI, Shoulder Pain and Disability Index; SSV, Subjective Shoulder Value; UCLA, University of California at Los Angeles Shoulder Scale; US, ultrasound; VAS, visual analog scale; WORC, Western Ontario Rotator Cuff Index.

**Figure 2.** Forest plot comparing the overall retear rate between techniques. M-H, Mantel-Haenszel.
current review assessed the overall retear rate and found no significant differences. In their series of 110 patients, Rhee et al. found that knotless double-row repair had a statistically lower retear rate (5.9%) than knot-tying double-row repair (18.6%). Similarly, Millett et al. reported that knotless double-row repairs had a statistically lower retear rate (7.5%) than knot-tying double-row repairs (33.3%). A review by Kunze et al. found no difference in the location of the retear between knotless and knot-tying double-row repairs. In the present systematic review, we analyzed studies by Gürpınar et al., Xu et al., and Şahin et al. The level 1 study by Şahin et al. suggested that knot-tying repair causes more type 2 failures.

Although we found significantly higher Constant scores after knot-tying versus knotless repair, this does not indicate a clinical difference. In patients with rotator cuff tears, the minimal clinically significant difference for the
Constant score is 10.4 points. In addition, there were no significant differences between techniques in the postoperative ASES score, UCLA score, or range of motion.

The knot-tying repair technique may not be suitable in cases that have a higher risk of musculotendinous junction failure, such as a short tendon stump. Meanwhile, it may be reasonable to consider not using a knotless repair technique in those patient conditions in which there is a high risk of failure at the tendon-bone interface, such as osteoporosis, hypovitaminosis D, diabetes, and smoking.

Limitations

This study has several limitations. First, as with any systematic review, some studies may have been missed by the search criteria used, and the inherent biases of each included study may have affected the results. Second, the included studies vary in terms of surgical techniques, surgical implants, patient data, follow-up periods, and imaging protocols. Third, the study heterogeneity in terms of other operations undertaken (eg, biceps tenotomy, tenodesis, acromioplasty, or distal clavicle excision) may influence outcomes. Fourth, retrospective studies are included in this study, meaning there is a potential for reporting and publication bias. There was no assessment of the publication bias. The majority of the included studies were level 3, indicating a poor level of evidence. Only one of the included studies was a level 1 randomized controlled trial. Finally, the clinical outcome scores used were variable, which complicates making comparisons between studies.

Figure 5. Forest plot comparing the (A) Constant score, (B) American Shoulder and Elbow Surgeons shoulder score (ASES), and (C) University of California at Los Angeles (UCLA) shoulder rating scale between techniques. IV, inverse variance.
CONCLUSION

From the reviewed studies, there was no significant difference in overall retear rates between knotless and knot-tying techniques. Furthermore, both techniques demonstrated similar clinical outcomes. However, the type 2 failure rate is significantly higher in knot-tying repair, and the type 1 failure rate is significantly higher in knotless repair.

ACKNOWLEDGMENT

The authors thank Mr. David James Sims for language editing.

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Figure 6. Forest plot comparing postoperative range of motion between techniques: (A) flexion, (B) abduction, and (C) external rotation. IV, inverse variance.

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### APPENDIX

#### TABLE A1
Details of the Included Studies: Retears, Inclusion/Exclusion Criteria, and Surgical Technique

| Lead Author (Year) | Retears, Knotless/Tying, n | Inclusion Criteria | Exclusion Criteria | Surgical Technique | Suture Type Used | Footprint Preparation |
|--------------------|-----------------------------|--------------------|-------------------|--------------------|------------------|----------------------|
| Rhee (2012)\(^{22}\) | 3/11 | Primary, medium-sized tear that could be repaired without undue tension with a suture bridge repair technique based on arthroscopic findings | SLAP lesion, distal clavicle resection, osteoarthritis, workers' compensation, biceps procedure, revision surgery | Conventional suture bridge and knotless suture bridge | FiberWire suture (Arthrex) | Using a shaver to decorticcate the footprint |
| Kim (2014)\(^{12}\) | 22/22 | Full-thickness rotator cuff tear, tear size 1-4 cm | Subscapularis tear, revision surgery, severe tendon retraction, poor tendon quality, neurological involvement | Conventional suture bridge and knotless suture bridge | NR | Using a bur to decorticcate the footprint |
| Boyer (2015)\(^{3}\) | 6/9 | Full-thickness supraspinatus tendon tear, minimum follow-up of 12 mo, Goutallier stage <2, repair by a suture bridging technique | Shoulder stiffness, arthropy, subscapularis tear | Knotted suture bridge and knotless bridge taping | FiberWire suture (Arthrex) | Using a bur to decorticcate the footprint |
| Hug (2015)\(^{11}\) | 5/5 | Repairable rotator cuff tear of the supraspinatus tendon, crescent-shaped concerning Bateman grade 2-3, Patte stage 1-2 | Shoulder stiffness, osteoarthritis, traumatic tears, and revision surgery | Knotless-anchor speed bridge and modified suture bridge knot-tying | FiberTape (Arthrex) | Using a bur to decorticcate the footprint |
| Lee (2017)\(^{16}\) | 13/8 | Full-thickness rotator cuff tear, repair of the tear using either knotted suture bridge or modified knotless tension band, follow-up MRI at 6 mo, minimum follow-up period of 24 mo, no history of fractures or surgeries on the affected shoulder, adherence to postoperative rehabilitation protocol | Subscapularis tear, osteoarthritis, revision surgery | Knotted suture bridge and modified knotless tension band | NR | NR |
| Millett (2017)\(^{19}\) | 3/4 | Full-thickness rotator cuff tear, age >18 y, repair of the tear using either knotted suture bridge or knotless bridge taping | Conversion to an open surgery, used a patch to augment the repair, subscapularis tear, labral repair, microfracture, fracture fixation | Knotted suture bridge and knotless bridge taping | Knot-tying: suture; knotless: TAPE | NR |

(continued)
| Lead Author (Year) | Retears, Knotless/ Knot-Tying, n | Inclusion Criteria | Exclusion Criteria | Surgical Technique | Suture Type Used | Footprint Preparation |
|-------------------|----------------------------------|-------------------|-------------------|-------------------|-----------------|----------------------|
| Honda (2018)10    | 14/18                            | Retear, Knotless/ Knot-Tying, n | Partial repair, open repair, revision surgery, fracture, osteoarthritis, rheumatic condition, neurological involvement | Conventional suture bridge and knotless suture bridge | FiberWire suture (Arthrex) | Using a bur to decorticate the footprint |
| Kim (2018)13      | 14/8                             | Full-thickness rotator cuff tear, tear size 1-4 cm | Tear < 1 cm, tear > 4 cm, subscapularis tear, neurological involvement, revision surgery, partial-thickness rotator cuff tear, osteoarthritis | Conventional suture bridge and knotless suture bridge | FiberWire suture (Arthrex) | NR |
| Gürpinar (2019)9  | 5/7                              | Rotator cuff tear diagnosed by MRI, tear size 1-5 cm, Patte stage 1-2 | Patte stage 3, small tear (< 1 cm), massive tear (> 5 cm), subscapularis tear, traumatic tear, revision surgery, age > 75 y, osteoarthritis, Goutallier stage > 2 | Conventional suture bridge and knotless suture bridge | NR | NR |
| Zwolak (2022)29   | NR                              | Full-thickness rotator cuff tear, repair of the tear using either conventional suture bridge or knotless-anchor speed bridge, completed 12-mo follow-up, adherence to postoperative rehabilitation protocol | Failure to adhere to postoperative rehabilitation protocol, missed one of the follow-up appointments, follow-up < 12 mo, Bankart lesion, osteoarthritis, previous surgery, shoulder instability | Conventional suture bridge and knotless-anchor speed bridge | Knot-tying: Orthocord (DuPuy Mitek); knotless: Ultratape and Ultrabraid (Smith & Nephew) | NR |
| Xu (2021)28       | 20/27                            | Full-thickness rotator cuff tear, size 3-5 cm, persistent symptoms > 3 mo after adequate nonoperative treatment, adherence to postoperative rehabilitation protocol | Follow-up < 12 mo, subscapularis tear, labral tear, Hill-Sachs lesion, fracture, Goutallier stage > 2 | Knot-tying: modified double-pulley suture bridge; knotless: modified double-pulley suture bridge | Orthocord (DuPuy Mitek) | The footprint was prepared |
| Şahin (2021)23    | 13/8                             | Full-thickness rotator cuff tear, repair of the tear using either knot-tying or knotless suture bridge | Age < 18 y, partial-thickness rotator cuff tear, subscapularis tear, osteoarthritis, previous surgery, neurological disease, rheumatic condition, revision surgery | Conventional suture bridge and knotless suture bridge | Knot-tying: Ultrabraid (Smith & Nephew); knotless: Ultratape and Ultrabraid (Smith & Nephew) | Using a shaver and bur to decorticate the footprint |

*MRI, magnetic resonance imaging; NR, not reported; SLAP, superior labrum from anterior to posterior.*