

Current Concepts in Rotator Cuff Repair Techniques

Biomechanical, Functional, and Structural Outcomes

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There is substantial evidence indicating that double-row (DR) repair restores more of the anatomic rotator cuff footprint and is biomechanically superior to single-row (SR) repair. Transosseous-equivalent (TOE) techniques have shown biomechanical advantages when compared with traditional DR, including increased contact at the rotator cuff footprint, higher pressure at the tendon-bone interface, and increased failure strength. Several meta-analyses of evidence level 1 and 2 studies have shown a lower rate of failed/incomplete healing when DR repair was compared with SR repair types. There is some limited evidence that TOE techniques improve healing rates in large and massive tears as compared with SR and DR. Overall, most level 1 and 2 studies have failed to prove a significant difference between SR and DR repairs in terms of clinical outcomes. However, most studies include only short-term follow-up, minimizing the impact that the higher rate of retears/failed healing seen with SR repairs can have in the long term. There are no high-quality clinical studies comparing different DR configurations, and there are currently not enough clinical data to determine the functional advantages of various DR technique modifications over one another. Although numerous biomechanical and clinical studies comparing different rotator cuff repair techniques have been published in the past decade, none has achieved universal acceptance. It is essential for the orthopaedic surgeon to know in detail the available literature to be able to apply the most appropriate and cost-effective technique in terms of healing and functional outcomes. This review provides a critical analysis of the comparative biomechanical and clinical studies among SR, DR, and TOE techniques reported in the literature in the past decade.

Keywords: rotator cuff repair; single row- double row; transosseous equivalent; biomechanical; structural outcomes; functional

The number of rotator cuff repairs has increased steadily in the past 2 decades.²⁰ Good to excellent outcomes have been reported in the short- and long-term follow-up in most cases.^{11,12,45,50} However, despite advances in instrumentation and surgical techniques, a risk of rerupture of 20% to 60% has been observed.^{10,14} Although

patients whose tendons fail to heal can still have pain relief, most studies have shown that patients with healed repairs achieve higher patient-reported outcome scores.^{14,57}

Biomechanical studies of double-row (DR) repair have shown increased load to failure, improved contact areas and pressures, and decreased gap formation at the healing entheses as compared with single-row (SR) repair.^{18,54} However, many clinical studies have not yet demonstrated a substantial improvement over SR repair with regard to either the degree of structural healing or functional outcomes.^{20,34,50,58} The transosseous-equivalent technique (TOE; also called “suture bridge”) was designed to improve the biomechanical repair construct in an effort to improve some limitations of conventional SR and DR repairs.³⁹ In the TOE repair, the suture limbs from the medial row of anchors are brought over the bursal side of the rotator cuff and secured to the lateral margin of the greater tuberosity footprint with a knotless anchor.³⁹

Although numerous biomechanical and clinical studies comparing different rotator cuff repair techniques have been published in the past decade, none has achieved

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universal acceptance.^{18,20} It is essential for the orthopaedic surgeon to know in detail the available literature to be able to apply the most appropriate and cost-effective technique in terms of healing and functional outcomes. Therefore, the purpose of this review is to provide a critical analysis of the comparative biomechanical and clinical studies among SR, DR, and TOE techniques reported in the literature in the past decade.

BIOMECHANICAL STUDIES

Single Row vs Double Row

After a rotator cuff repair, the structure and composition of the native tendon-bone interface are not re-formed during healing, resulting in a mechanically and structurally inferior interface.^{1,55} The repaired tendon forms fibrovascular scar tissue with a large proportion of type III collagen rather than the biomechanically superior type I collagen.^{1,55} In particular, the zone of calcified cartilage does not re-form, and this scar tissue is biomechanically weaker and more prone to failure than the native insertion.^{1,55} Therefore, to achieve an effective repair, it is essential to enhance the biomechanical conditions for healing. The ideal rotator cuff repair should provide the following: restoration of the footprint contact area, appropriate compression of the tendon on the footprint, and minimal motion at the bone-tendon interface until durable tendon-bone healing is completed.^{13,28,36}

Meier and Meier³⁰ used 3-dimensional mapping to determine the area of footprint re-creation with different repair techniques: transosseous simple suture, SR suture anchor, and DR suture anchor. DR fixation consistently reproduced 100% of the original supraspinatus footprint, whereas the SR suture anchor fixation and transosseous simple suture techniques reproduced only 46% and 71% of the insertion site, respectively. Brady et al⁵ also demonstrated that after an isolated lateral-row repair, 52.7% of the rotator cuff footprint remained uncovered. Park et al^{40,42} showed in several cadaveric studies that SR repairs consistently produced less pressurized contact area at the site of repair compared with DR techniques.

In addition to a wider contact area, most biomechanical studies have shown that DR repair has superior time-zero structural properties in rotator cuff repair.¹⁸ Smith et al⁴⁹ found that the DR technique demonstrated superior resistance to gap formation under static loading as compared with the SR technique. Kim et al²⁴ found that DR repair improved initial strength and stiffness and decreased gap formation and strain over the footprint when compared with an SR repair. In a human cadaveric study, Meier and Meier²⁹ demonstrated that fixation strength of the DR technique was significantly greater than that of SR suture anchor technique. In a biomechanical study, Milano et al³² compared the mechanical behavior of SR and DR rotator cuff repair with suture anchors under a cyclic loading test. They reported that the DR technique was significantly more resistant to cyclic displacement than the SR

technique, not only in repairs that were tension-free but also in those that were under tension.

Double-Row vs Transosseous-Equivalent Repairs

The biomechanical advantages of DR repairs over SR repairs have not been consistently reproduced in the clinical setting.^{20,34,50} TOE repairs were developed to address this deficiency.^{39,40,42} The theoretical advantages of the TOE technique over the conventional DR repair are as follows: (1) maximization of the pressurized contact area; (2) decreased tendon strangulation (because the lateral tendon is not penetrated); (3) preserved vascularity over the lateral tissue (owing to the absence of lateral knots); (4) avoidance of anchor overcrowding at the repair site by placing the second fixation row 1 cm lateral to the tuberosity footprint; (5) interconnection of the anchors, resulting in better load sharing and less tension mismatch on a given anchor with rotation; and (6) prevention of synovial fluid access to the rotator cuff footprint.^{35,38-42} Park et al⁴¹ showed that the ultimate load-to-failure value was significantly higher following knotted TOE repair than following DR repair. In addition, the knotted TOE technique provided significantly more pressurized contact area and overall pressure.³⁸ Hatta et al¹⁶ showed that the knotless TOE technique for medium- to large-sized tears provided a more uniform stiffness distribution across the repaired supraspinatus muscles as compared with the DR technique.

TOE repairs can be performed with various suture configurations but are generally divided between those in which the medial row is tied and all-knotless repairs. Some studies have shown that the musculotendinous junction is the primary failure point for DR and knotted TOE repairs.^{9,22} This has led to the development of knotless ("speed bridge") techniques.⁵³ The latest techniques use flattened tape sutures (rather than conventional sutures) to better distribute compressive forces on the cuff tendons, improve tissue cut-through resistance, enhance self-reinforcement, and possibly better preserve vascular flow.^{2,7}

Controversy exists regarding the contribution of the medial row knots to biomechanical properties in DR repair. On one hand, some authors have suggested that the medial row knots reduce the failure load by preventing gap formation and absorbing the energy. On a porcine cadaveric shoulder model, Pauly et al⁴³ showed that medial mattress knots increase initial biomechanical stability. In a human cadaveric study, Busfield et al⁸ randomized 6 matched pairs of shoulders to receive a TOE repair with or without medial knots. They demonstrated less gap formation and higher failure strengths with the knotted configuration. Nassos et al,³⁵ in a human cadaveric study, showed that a TOE technique with medial knots better prevented synovial fluid leakage onto the rotator cuff footprint as compared with knotless repairs. They proposed that isolating the healing zone interface from the synovial fluid could improve healing rates. On the other hand, other authors have failed to prove any advantage of the knotted TOE as compared with the knotless TOE. Spang et al⁵¹ found the

TABLE 1
Summary of Meta-analysis of Level 1 and 2 Studies Comparing Single- and Double-Row Rotator Cuff Repair^a

First Author	Year	Journal	Studies, n	Patients, n	Level of Evidence	Follow-up, Mean (Range), mo	Functional Outcomes	Retears
Perser ⁴⁴	2011	<i>Sports Health</i>	5	303	1 and 2	23 (12-40)	Scores: NSD (Constant-Murley, ASES, UCLA, WORC, DASH) ROM: NR Strength: NR	Overall: NSD
Prasathaporn ⁴⁶	2011	<i>Arthroscopy</i>	5	308	1 and 2	23 (12-40)	Scores: NSD (ASES, UCLA, WORC, DASH) ROM: Significantly more ER with DR Strength: NR	Overall: significantly > tendon retears with SR
Sheibani-Rad ⁴⁸	2013	<i>Arthroscopy</i>	5	349	1	21 (12-44)	Scores: NSD (ASES, Constant-Murley, UCLA) ROM: NR Strength: NR	NR
Zhang ⁵⁹	2013	<i>PLoS One</i>	8	619	1 and 2	26 (24-34)	Scores: tears <3 cm: NSD (ASES, Constant-Murley, UCLA); tears >3 cm: ASES and UCLA significantly > in DR ROM: NR Strength: NR	Overall: significantly > with SR Partial: significantly < with DR Complete: NSD between SR and DR
Xu ⁵⁶	2014	<i>J Shoulder Elbow Surg</i>	9	651	1 and 2	23 (12-42)	Scores: tears <3 cm: NSD (ASES, Constant-Murley, UCLA); tears >3 cm: ASES and UCLA significantly > in DR ROM: Significantly more IR with DR Strength: NR	Overall: significantly > with SR
Millett ³⁴	2014	<i>J Shoulder Elbow Surg</i>	7	567	1	21 (12-32)	Scores: tears <3 cm: NSD (ASES, Constant-Murley, UCLA); tears >3 cm: ASES and UCLA significantly > in DR ROM: NR Strength: NR	Overall: significantly > with SR
Ying ⁵⁸	2014	<i>Orthop Surg</i>	11	807	1 and 2	24 (12-36)	Scores: NSD (ASES, Constant-Murley, UCLA) ROM: NSD Strength: NR	Overall: significantly > with SR Partial: significantly < with DR Complete: NSD between SR and DR
Sobhy ⁵⁰	2018	<i>Eur J Orthop Surg Traumatol</i>	7	477	1	21 (12-32)	Scores: NSD (Constant-Murley, ASES, WORC, SANE) ROM: NR Strength: NR	Overall: significantly > with SR Partial: significantly < with DR Complete: NSD between SR and DR

^aASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder and Hand; DR, double row; IR, internal rotation; NR, not reported; NSD, no significant difference; ROM, range of motion; SANE, Single Assessment Numerical Evaluation; SR, single row; UCLA, University of California, Los Angeles; WORC, Western Ontario Rotator Cuff Index.

knotless TOE technique biomechanically similar to the conventional TOE in an ovine cadaveric study. In a human cadaveric study, Burkhart et al⁷ showed that DR footprint reconstruction with a knotless TOE system produced ultimate loads and cyclic displacements that were statistically equivalent to those of standard TOE reconstructions. In a recent biomechanical study, Tashjian et al⁵² compared the biomechanics of (1) a TOE repair with medial and lateral anchors with tape and (2) a TOE knotless tape repair with only laterally placed intraosseous anchors. They found that the TOE knotless construct with 2 lateral anchors was equivalent in biomechanical function to a traditional 4-anchor construct, reducing anchor load in the tuberosity.

FUNCTIONAL OUTCOMES AND HEALING RATES

Single Row vs Double Row

Several overlapping meta-analyses of evidence level 1 and 2 studies comparing functional outcomes and healing rates after SR and DR arthroscopic rotator cuff repairs have been published over the past decade, with conflicting results (Table 1). Perser et al⁴⁴ included three level 1 and two level 2 studies with 303 patients and a mean follow-up of 20 months. The authors concluded that DR rotator cuff repair did not show a statistically significant improvement in clinical outcome with short-term follow-up. They were unable to analyze healing results owing to the lack of details in the

studies. Prasathaporn et al⁴⁶ analyzed the same studies as Perser et al. The authors found no significant difference in clinical outcomes. However, DR repair showed a significantly higher rate of tendon healing and greater external rotation. Sheibani-Rad et al⁴⁸ performed a systematic meta-analysis of five level 1 studies comparing SR and DR rotator cuff repairs with 349 patients and a mean follow-up of 21 months. They found no significant differences in clinical outcomes between SR and DR. Owing to incomplete data, the rate of retears was not evaluated. Zhang et al⁵⁹ analyzed six level 1 and two level 2 studies with 619 patients with a minimum follow-up of 24 months. The authors were the first to perform a subgroup analysis according to rotator cuff tear size (tears <3 cm and ≥3 cm). The authors concluded that the DR fixation technique increased postoperative rotator cuff integrity and improved the clinical outcomes for full-thickness rotator cuff tears >3 cm. Xu et al⁵⁶ included five level 1 and four level 2 studies with 651 patients and a mean follow-up of 23 months. There was a statistically significant difference in favor of DR repair for overall American Shoulder and Elbow Surgeons (ASES) score and internal rotation range of motion. Additionally, for tears >3 cm, DR techniques produced better outcomes (ASES and University of California, Los Angeles [UCLA]) than SR techniques. Regarding retears, the pooled results showed an incidence of 23.8% in the DR repair group and 40.2% in the SR repair group (risk ratio, 0.59; 95% CI, 0.41-0.86), which was a statistically significant difference.

In other reviews, Millett et al³⁴ included only level 1 studies in their meta-analysis—specifically, 7 studies with 567 patients and a mean follow-up of 21 months. SR repairs resulted in significantly higher retear rates when compared with DR repairs, especially with regard to partial-thickness retears. The overall retear rate was 25.9% in the SR group and 14.2% in the DR group. There was a statistically significantly increased risk of sustaining an imaging-proven retear of any type in the SR group (relative risk, 1.76; 95% CI, 1.25-2.48; $P = .001$). However, there were no detectable differences in improvement in outcome scores between the techniques. Ying et al⁵⁸ included seven level 1 studies and four level 2 studies with 807 patients and a mean follow-up of 25 months. The authors concluded that given the paucity of high-quality evidence and the poor methodological quality of the included studies, no definite conclusion could be drawn about differences in overall outcomes of DR and SR techniques. In 2018, Sobhy et al⁵⁰ performed a meta-analysis of all available level 1 prospective randomized controlled trials comparing SR and DR repairs. They included 7 studies with 477 patients. Within the domain of level 1 mid- and short-term studies, DR repair showed significantly better UCLA scores only. Overall retear rate was significantly lower in the DR group. The authors also reported stratified healing rates into partial and complete retears. Full-thickness retear incidence showed no significant difference between groups. However, the partial-thickness retear rate was significantly lower in the DR group—specifically, 10.3% in the DR group and 23.4% in the SR group ($P = .009$).

Very few studies have compared different DR repair techniques (Table 2). Kim et al²⁵ compared conventional DR repair with the TOE technique among tears sized 1 to 4 cm. The authors found no difference in terms of functional outcomes and retear rates between these techniques at the end of 2 years of follow-up. Park et al³⁷ compared 174 patients—55 with the conventional DR repair and 119 with the knot-tying TOE repair—for medium- to large-sized rotator cuff tears. At a mean follow-up of 25 months, no significant differences were found between the groups in either the functional results or the rerupture rate. Lee et al²⁷ retrospectively compared the clinical and radiologic outcomes of patients who underwent arthroscopic rotator cuff repairs by the TOE ($n = 37$) and DR modified Mason-Allen ($n = 39$) techniques. The patients who underwent DR modified Mason-Allen repair had comparable shoulder functional outcomes and a comparable retear rate with those who underwent TOE repairs. Hashiguchi et al¹⁵ compared clinical outcomes and retear rate between 52 patients who underwent arthroscopic DR and 63 who underwent knotted TOE repair for medium-sized rotator cuff tears. There was no significant difference in Constant score between the groups. Postoperative MRI revealed that retear rate in the knotted TOE group was significantly lower than the DR group. This was the first study to find a significant difference in healing rates between conventional DR repair and TOE.

Only a few clinical studies have compared different TOE techniques. Rhee et al⁴⁷ compared the clinical results and repair integrity of arthroscopic rotator cuff repair between a knotless TOE (51 shoulders) and a conventional knot-tying TOE (59 shoulders) for patients with medium-sized full-thickness rotator cuff tears. The authors found no significant difference in functional outcomes between the groups. However, the knotless group had a significantly lower retear rate when compared with the conventional knot-tying group. Moreover, retears occurred at the musculotendinous junction in 72.7% of patients in the knotted group, while no medial cuff failure occurred with the knotless technique. Boyer et al⁴ also compared the clinical results and repair integrity of arthroscopic rotator cuff repair between a knotless TOE (35 shoulders) and a conventional knot-tying TOE (38 shoulders). At a mean follow-up of 29 months, no significant differences were found between the groups in either the functional results or the retear rate. Hug et al¹⁹ reported the results of a consecutive treatment cohort (knotted TOE vs knotless tape bridging) and found no significant differences in functional outcome scores and retears between treatment groups at the 2-year follow-up. Millett et al³³ compared the clinical results and repair integrity of arthroscopic rotator cuff repair between a knotless TOE (102 shoulders) and a conventional knot-tying TOE (35 shoulders) for patients with full-thickness rotator cuff tears. The authors found no significant differences in clinical outcomes between groups at a mean follow-up of 3 years. However, patients with a knotted medial row were significantly more likely to have an MRI-diagnosed full-thickness rotator cuff retear. Kim et al²⁶ prospectively evaluated 100 consecutive patients with full-thickness rotator cuff tears treated with the arthroscopic

TABLE 2
Summary of Studies Comparing Double-Row Rotator Cuff Repair Techniques^a

First Author	Year	Journal	Patients or Shoulders, n	Level of Evidence	Follow-up, Mean \pm SD (Range), mo	Repair Technique	Functional Outcomes	Retears
Kim ²⁵	2012	<i>Am J Sports Med</i>	52	2	37 (24-54)	DR: 26. Knot-tying TOE: 26	NSD (UCLA, ASES, Constant-Murley)	NSD in retears
Rhee ⁴⁷	2012	<i>Am J Sports Med</i>	110	2	21 (12-34)	Knotless TOE: 51. Knot-tying TOE: 59	NSD (UCLA, Constant-Murley)	Retears significantly < in knotless TOE. Knot-tying TOE significantly > retears at the musculotendinous junction
Boyer ⁴	2015	<i>Knee Surg Sports Traumatol Arthrosc</i>	73	3	29 (23-32)	Knot-tying TOE: 38. Knotless TOE: 35	NSD (Constant-Murley, ROM, strength)	NSD in retears
Park ³⁷	2013	<i>Arch Orthop Trauma Surg</i>	169	3	25 (24-40)	DR: 50. Knot-tying TOE: 119	NSD (ASES, VAS, Constant-Murley, strength)	NR
Hug ¹⁹	2015	<i>Knee Surg Sports Traumatol Arthrosc</i>	40	4	24 \pm 4.7	Knot-tying TOE: 20. Knotless TOE: 20	NSD (WORC, SSV, Constant-Murley)	NSD in retears
Millet ³³	2017	<i>Arch Orthop Trauma Surg</i>	137	3	33 (24-64)	Knotless TOE: 114. Knot-tying TOE: 41	NSD (ASES, SF-12)	Retears significantly < in knotless TOE
Lee ²⁷	2018	<i>J Shoulder Elbow Surg</i>	76	3	TOE: 36 \pm 7. DR: 34 \pm 7	Knot-tying TOE: 37. DR: 39	NSD (VAS, UCLA, ASES, Constant-Murley, ROM)	NSD in retears
Kim ²⁶	2018	<i>J Orthop Surg Res</i>	100	2	24	Knotless TOE: 114. Knot-tying TOE: 41	NSD (UCLA, ASES, Constant-Murley, VAS)	NSD in retears
Hashiguchi ¹⁵	2018	<i>J Orthop</i>	115	4	37 (24-88)	Knot-tying TOE: 37. DR: 39	NSD (Constant-Murley)	Retears significantly < in knot-tying TOE

^aASES, American Shoulder and Elbow Surgeons; DR, double row; NR, not reported; NSD, no significant difference; ROM, range of motion; SF-12, 12-Item Short Form Health Survey; SSV, Subjective Shoulder Value; TOE, transosseous equivalent; UCLA, University of California, Los Angeles; VAS, visual analog scale; WORC, Western Ontario Rotator Cuff Index.

conventional (n = 50) or knotless (n = 50) TOE technique. The knotless TOE technique showed comparable functional outcomes and retears rates with those of conventional knotted TOE techniques in medium to large full-thickness rotator cuff tears at short-term follow-up.

DISCUSSION

From a biomechanical point of view, most studies favored DR repair as compared with SR repair with regard to tensile strength, construct failure, gap formation, and footprint coverage.^{18,20} With regard to comparative biomechanical studies for different DR configurations, TOE techniques have shown some promising features when compared with conventional DR configurations, which could have a positive impact in tendon healing. Nevertheless, biomechanical studies comparing different TOE techniques are scarce and still controversial. More comparative biomechanical studies are needed to better define if the benefit of additional construct strength observed with knotted TOE techniques may be lost without tying of medial row sutures.

General consideration of all the included meta-analyses shows significant improvement in overall functional outcomes for both DR and SR repairs as compared with preoperative values.^{34,44,46,48,50,56,58,59} Moreover, 3 meta-

analyses found that in comparison with SR repairs, DR repairs had better functional scores or increased range of motion overall and especially for tears measuring >3 cm.^{56,58,59} Despite the innovations and documented benefits in the laboratory setting, postoperative functional outcomes with newer TOE techniques, at short- to medium-term follow-up, have been equivocal. From the 9 evaluated studies comparing different DR configurations, none of the techniques showed a significant superiority over the others regarding clinical outcomes (Table 2).

The relation between clinical outcomes and retears is controversial. Overall, although a significant increase in imaging-diagnosed retear rates after SR repair was demonstrated, this difference did not always correlate with inferior outcome scores. However, it is important to highlight that most retears of the included meta-analyses comparing SR and DR were partial thickness, and most had a short mean follow-up (range, 21-26 months), with a maximum follow-up of only 44 months (Table 1). Keener et al²³ prospectively evaluated 224 patients with asymptomatic rotator cuff tears. They showed that at a median follow-up of 5 years, tear progression was seen in 49% of the shoulders, and 49% of patients developed new pain. Thus, it is possible that the gradual progression of partial- to full-thickness retears and subsequent clinical symptoms may require

more time to become clinically apparent. Jeon et al²¹ compared clinical outcomes between patients with healed and nonhealed tendons after rotator cuff repairs and found that patients with healed repairs had significantly improved ASES and Constant scores and greater strength. Yang et al⁵⁷ conducted a meta-analysis in 2017 comparing clinical outcomes between intact and return rotator cuffs after arthroscopic repair, including 2611 patients with a mean follow-up of 25 months. They concluded that patients with a full-thickness rotator cuff re-tear exhibited significantly lower clinical outcome scores and strength when compared with patients with an intact or partially torn rotator cuff.

Tendon healing outcomes among studies comparing types of DR repairs are heterogeneous. In 2015, Brown et al⁶ performed a meta-analysis comparing conventional DR repair with TOE configuration and found no significant difference in re-tear rate independent of the tear size. However, other authors have demonstrated a significantly reduced rate of re-ruptures in large and massive tears with TOE repair as compared with DR. Mihata et al³¹ evaluated healing rates at a mean follow-up of 38 months according to tear size. In the large and massive tear subgroup, the re-tear rate was 7.5% in the TOE repair group but 41.7% in the DR repair group. Only a few studies directly compared DR with knotted TOE (Table 2).

Results regarding re-tears in studies directly comparing knotless and knot-tying TOE are also conflicting. Boyer et al,⁴ Kim et al,²⁶ and Hug et al¹⁹ compared healing rates in TOE rotator cuff repairs with and without tying the medial row. The overall re-tear rates among the studies varied from 23% to 25% for the knot-tying TOE and from 17% to 22% in the knotless group. None of the authors found a statistically significant difference in re-tear rates between groups. Conversely, Rhee et al⁴⁷ and Millett et al³³ found significantly lower re-tears with the knotless TOE technique. Rhee et al found that the re-tear rate was significantly lower in the knot-tying group (5.9%) than in the knotless group (18.6%; $P = .001$). Similarly, Millett et al³³ found significantly lower re-tears with the knotless TOE technique. In their study, the re-tear rate was 33.3% in shoulders with knotted suture-bridging repair and 7.5% in shoulders with knotless tape-bridging repair.

Finally, concern exists about the high percentages of rupture at the myotendinous junction reported in some studies with DR and knotting TOE.^{9,17} Tendinous strangulation at the medial knot of the tendon-bone fixation could disrupt tendinous microcirculation and lead to insufficiency with re-tears.⁹ Cho et al⁹ described 2 patterns of re-tears, in which type 1 is failure at the tendon-bone interface and type 2 is medial cuff failure with remnant cuff attached to the greater tuberosity. Type 2 re-tears are more challenging to repair and could hinder a revision surgery. Bedeir et al³ recently performed a systematic review of the literature on patterns of re-tear, comparing SR, DR, TOE, and knotless TOE. The estimated incidence rate of type 2 re-tear was 24% with SR, 43% with DR, 62% with TOE, and 38% with knotless TOE. The authors concluded that the DR and TOE techniques significantly increase the risk of medial cuff failure. However, some recent

comparative studies did not find significant differences in the rate of type 2 re-tears when comparing knotted and knotless TOE configurations.^{26,33}

CONCLUSION

There is substantial evidence indicating that DR repair restores more of the anatomic rotator cuff footprint and is biomechanically superior to SR repair. Moreover, DR repairs result in better functional outcomes and fewer re-tears than SR repairs, especially for tears >3 cm. TOE techniques have shown promising benefits in the laboratory setting as compared with traditional DR repairs, which could improve the healing environment. The important advantages include increased contact at the rotator cuff footprint, higher pressure at the tendon-bone interface, and increased failure strength in comparison with conventional DR repair. Nevertheless, there are no high-quality clinical studies comparing different DR configurations, and many of the theoretical advantages of TOE techniques over conventional DR techniques have yet to be proven. There is some limited evidence that knotted and knotless TOE techniques improve healing rates and functional outcomes in large and massive tears as compared with SR and DR. However, for small and medium tears, most of the studies showed similar results, and there are currently not enough clinical data to determine the functional advantages of various DR technique modifications.

Appropriately powered rigorous level 1 studies that directly compare DR techniques with knotted and knotless TOE techniques in matched tear patterns are necessary to further address these questions.

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