Review Article

Single-row Versus Double-row Rotator Cuff Repair: Techniques and Outcomes

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Abstract

Double-row rotator cuff repair techniques incorporate a medial and lateral row of suture anchors in the repair configuration. Biomechanical studies of double-row repair have shown increased load to failure, improved contact areas and pressures, and decreased gap formation at the healing enthesis, findings that have provided impetus for clinical studies comparing single-row with double-row repair. Clinical studies, however, have not yet demonstrated a substantial improvement over single-row repair with regard to either the degree of structural healing or functional outcomes. Although double-row repair may provide an improved mechanical environment for the healing enthesis, several confounding variables have complicated attempts to establish a definitive relationship with improved rates of healing. Appropriately powered rigorous level I studies that directly compare single-row with double-row techniques in matched tear patterns are necessary to further address these questions. These studies are needed to justify the potentially increased implant costs and surgical times associated with double-row rotator cuff repair.

Improvements in surgical technique and instrumentation have made arthroscopic rotator cuff surgery commonplace. Currently, the clinical results reported with arthroscopic repairs are equivalent to those reported for both open and mini-open techniques.[1,2] Despite good to excellent outcomes in most cases, however, structural healing of the tendon to bone remains problematic. Reported healing rates based on ultrasonography and MRI range from 91% in small tears to 10% in massive tears.[3-5] With larger tears, the best clinical results are achieved in patients who experience tendon healing postoperatively.[6]

Gerber et al[7] postulated that the ideal rotator cuff repair would provide high initial fixation strength and minimize gap formation during healing. Much recent research has focused on improving tendon-to-bone healing through stronger biomechanical constructs and an improved biologic milieu.[8-11] Traditionally, arthroscopic rotator cuff repairs were performed using a single row of suture anchors, with the anchors placed in a linear fashion from anterior to posterior on the greater tuberosity.

One major advance in rotator cuff surgery is the use of double-row repair techniques, which incorporate a medial row and a lateral row of suture anchors into the repair configuration (Figure 1). In double-row repairs, a linear row of anchors is placed medially at the articular mar-

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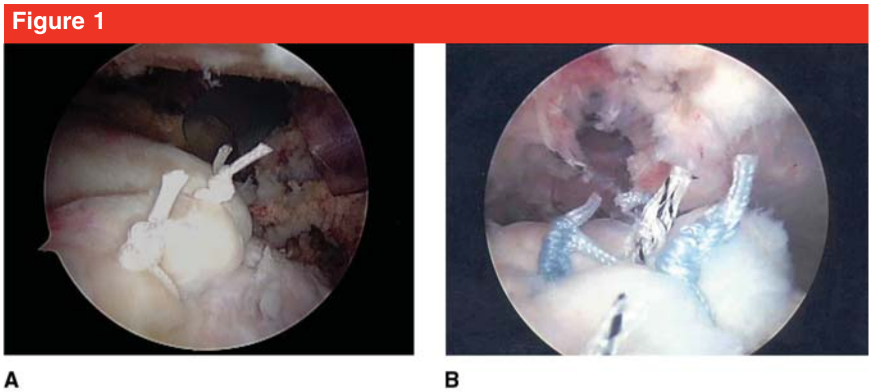
J Am Acad Orthop Surg 2010;18: 83-93

gin, and a second row is placed along the lateral aspect of the rotator cuff footprint on the tuberosity. Along with the superior biomechanical properties, this configuration better recreates the normal anatomic footprint and improves apposition between tendon and bone. Double-row repairs were designed to achieve fixation strengths comparable to those of open or mini-open transosseous repairs.

The impetus for recent clinical studies comparing single-row and double-row rotator cuff repair stems from biomechanical studies demonstrating increased load to failure, improved contact areas and pressures, and decreased gap formation at the healing enthesis with double-row constructs.[8,11-14] The clinical relevance and potential advantages of double-row rotator cuff repairs have yet to be defined. There is a paucity of level I data, in large part secondary to the rapid evolution of techniques and multiple potential causes of failure in a heterogeneous patient population.

Figure 1



Arthroscopic images of single-row (**A**) and double-row (**B**) suture anchor rotator cuff repair.

Rotator Cuff Tear Anatomy and Tendon-to-Bone Healing

The rotator cuff is composed of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles and their tendons. The tendons insert onto the humeral head into a specialized fibrocartilaginous tissue known as the enthesis. This tissue serves to minimize stress concentrations at the tendon and bone interface.[15] The enthesis is made up of four continuous zones: tendon proper, fibrocartilage, mineralized fibrocartilage, and bone.[16] The organized zones of the native enthesis are not re-created after rotator cuff repair. Repaired tendon insertions are histologically and biomechanically inferior to the normal enthesis and typically heal with a disorganized, interposed zone of fibrovascular scar tissue.

Anatomic studies have delineated the dimensions of the rotator cuff footprint.[17-19] Early studies showed that the supraspinatus had a trapezoidal footprint measuring 25 mm from anterior to posterior.[17] Dugas et al[18] reported the mean minimum transverse diameter across the rotator cuff insertion to be 14.7 mm. The total area of supraspinatus attachment on the greater tuberosity was approximately 350 mm^2. The footprint has been described as the maximum two-dimensional healing zone, and it has important implications for arthroscopic repair. A recent study by Mochizuki et al[19] showed that the supraspinatus footprint on the greater tuberosity is smaller than was previously thought. They believed that this difference was probably attributable to the parameters of earlier studies, which included the insertion area of the joint capsule in the measurement. Mochizuki et al[19] found the medial-to-lateral length of the footprint and capsular attachment to be similar to that reported by Dugas et al.[18] They found the infraspinatus footprint to be trapezoidal, measuring an average maximum

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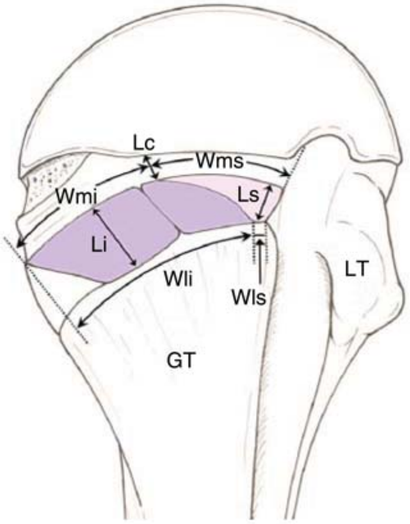
Figure 2



	Average and standard deviation (mm)
Supraspinatus	
Maximum medial-to-lateral length	6.9 ± 1.4
Anteroposterior width of medial margin	12.6 ± 2.0
Anteroposterior width of lateral margin	1.3 ± 1.4
Infraspinatus	
Maximum medial-to-lateral length	10.2 ± 1.6
Anteroposterior width of medial margin	20.2 ± 6.2
Anteroposterior width of lateral margin	32.7 ± 3.4
Articular capsule	
Medial-to-lateral length at posterior edge of supraspinatus footprint	4.5 ± 0.5

Illustration of the anatomic dimensions of the rotator cuff insertions. The average values of the dimensions are listed. GT = greater tuberosity, Lc = length of attachment of the articular capsule, Li = maximum length of the footprint of the infraspinatus, Ls = maximum length of the footprint of the supraspinatus, LT = lesser tuberosity, Wli = width of the lateral margin of the footprint of the infraspinatus, Wls = width of the lateral margin of the footprint of the supraspinatus, Wmi = width of the medial margin of the infraspinatus, Wms = width of the medial margin of the supraspinatus. (Reproduced with permission from Mochizuki T, Sugaya H, Uomizu M, et al: Humeral insertion of the supraspinatus and infraspinatus: New anatomical findings regarding the footprint of the rotator cuff. *J Bone Joint Surg Am* 2008;90:962-969.)

of 10.2 mm from medial to lateral, with a mean maximum anteroposterior width of 32.7 mm. These findings were consistent with previous reports. These authors also found that the infraspinatus tendon inserts onto a larger percentage of the greater tuberosity than does the supraspinatus tendon; this occurs because the infraspinatus extends laterally as it curves anteriorly[19] (Figure 2).

Tendon healing during rotator cuff repair begins with the formation of a fibrovascular tissue interface between the tendon and bone.[20] Bone grows into the interface tissue, and eventually, collagen fiber continuity is created between the tendon and bone.[21] Oguma at al[21] showed that the potential for woven bone formation to anchor collagen fibers at the bone-tendon interface increases as the available contact area for the fibrovascular tissue interface increases. This work provides the basis for a theoretical anatomic benefit of double-row rotator cuff repairs because techniques that provide less interface between tendon and bone theoretically offer less healing potential, with potentially higher rates of structural failure.

Normal Rotator Cuff Biomechanics

Determining the optimal repair configuration requires an understanding of the normal forces placed on the rotator cuff muscles in vivo. Juul-Kristensen et al[22] used MRI to determine the moment arm of the supraspinatus muscle and the infraspinatus muscle. The maximal force on the supraspinatus was 353 N, and the maximal force on the infraspinatus was 665 N. Hughes and An[23] measured maximal isometric contraction on the rotator cuff. Both the infraspinatus and the supraspinatus muscle exhibited their highest forces in external rotation. The supraspinatus forces measured 175 N with the arm abducted and externally rotated. In the infraspinatus, forces >900 N were noted in adduction and external rotation. Wakabayashi et al[24] corroborated the effects of abduction on the supraspinatus tendon. Using finite element analysis and MRI, the authors showed that the highest stress on the tendon occurred at the articular side near the insertion. The stress shifted laterally with abduction. These studies have important implications for rotator cuff repair in that they demonstrate that shoulder rotation and abduction can have significant biomechanical effects and can affect the integrity of the repair.

Biomechanics of Single- Versus Double-row Suture

Reasons for failure of rotator cuff healing can be grouped into four main categories: technical, biologic, anatomic, and mechanical. Improved suture materials and anchors combined with greater surgeon comfort with and adeptness at performing arthroscopic techniques have combined to make technical failure a lesser concern than in the early days of such repair. Biologic failures are those in which the healing potential of the host environment is compromised, such as in revision surgery and in patients who are physiologically older, who smoke, or who have a history of multiple cortisone injections, as well as in patients who have diabetes, poor vascularity, or fatty infiltration of the muscles.[25] Often, failure is the result of a combination of such factors. A discussion of biologic augmentation of rotator cuff healing is beyond the scope of this article.

Failure to recreate the normal insertional footprint can lead to anatomic failure. Repairs that do not restore the normal resting tension of the tendons are also anatomic failures. Mechanical failure occurs when repair constructs are not strong enough to overcome the normal forces on the cuff tendons during the healing phase. The timing and progression of postoperative rehabilitation protocols may be related to mechanical failure; however, no such correlation has been established in the literature.

Anatomic Failure

Apreleva et al[26] introduced the concept of footprint restoration during rotator cuff repair. They evaluated footprint contact area with single-row suture anchor repairs versus transosseous repairs and found that a 20% larger repair-site area was created with transosseous simple suture repair. Tuoheti et al[27] compared double-row, transosseous, and single-row repairs in a cadaver model. They found that double-row repairs produced a contact area 42% greater than transosseous repairs and 60% greater than single-row repairs. Mazzocca et al[28] showed that double-row repairs consistently restored a larger footprint than did single-row constructs.

Meier and Meier[14] used three-dimensional mapping to determine the area of footprint recreation with three repair techniques: transosseous simple suture, single-row suture anchor, and double-row suture anchor. Double-row suture anchor configurations consistently recreated 100% of the original tendon footprint, which was significantly larger than the footprints recreated by the transosseous technique and the single-row technique (71% and 46%, respectively) (Figure 3).

Perhaps equally important in the recreation of the normal two-dimensional anatomic footprint is the application of pressurized contact at the tendon-bone interface. Several studies have documented the effects of tendon-bone interface pressures on tendon healing.[20,29] Although most of these studies were done in anterior cruciate ligament reconstruction models, many authors have extrapolated the results to rotator cuff healing, concluding that controlled mechanical forces at the tendon-bone interface affect healing.[30] Park et al[31] have shown in several cadaver studies that single-row repairs consistently produce less pressurized contact area at the site of repair than do other techniques. They found that transosseous-equivalent repairs, in addition to covering more of the anatomic footprint than single-row repairs, significantly increased the pressurized contact area.

Mechanical Failure

Exertional force on the supraspinatus can range from 175 N to >900 N if the tear extends into the infraspinatus.[32] This is important because a significant number of rotator cuff tears have a substantial infraspinatus component. The forces on the tendons increase dramatically with internal and external rotation.[33] Gerber et al[7] found that a single-row repair with six simple sutures achieved a load-to-failure value of 273 N; this value increased to 336 N with placement of a second row of anchors.

Theoretically, initial stresses on the repaired rotator cuff are reduced in the immediate postoperative period because motion is restricted to passive movements. Nonetheless, although the subject has not been well explored, substantial forces can be generated, and patient compliance with restrictions in the absence of rigid immobilization can be a significant issue that may affect tendon healing. For this reason, a stronger mechanical construct is potentially advantageous to protect the repair during this vulnerable period.

Several biomechanical cadaver studies have compared load to failure and gap formation in double-row constructs versus single-row repairs.[11-13,28,34,35] Smith et al[12] found that gap formation during static loading was significantly greater in single-row repairs. Under cyclic loading, the double-row repairs failed at an average of 320 N, compared with 224 N for the single-row group. Kim et al[11] found that a second row of anchors increased ultimate load to failure by 48% ($P < 0.05$) and increased repair stiffness by 46%. Gap formation was significantly smaller in the double-row repair group ($P < 0.05$). Meier and Meier[13] compared the biomechanics of double-row, single-row, and transosseous repairs. They found both suture anchor repairs to be significantly stronger than the transosseous repair ($P < 0.001$) and the double-row suture anchor repair to be significantly stronger than the single-row anchor repair ($P < 0.001$).

The most recent study comparing single-row and double-row constructs was done by Milano et al,[36] who evaluated single-row tension-free repair, double-row tension-free repair, single-row tension repair, and double-row tension repair. Tension on the repair was a testing variable. The authors found single-row repair to be particularly weak when performed under tension. Double-row repairs, both tension-free and under tension, were more resistant to displacement than were single-row repairs.

Two studies reported no differences between single-row and double-row repairs. Mazzocca et al[28] found that double-row repairs consistently recreated more of the anatomic footprint. However, no differences were found with regard to load to failure, displacement with cyclic loading, and gap formation. The authors cycled the specimens 3,000 times before testing ultimate load to failure, which may have influenced the outcome. Mahar et al[34] reported similar results in a bovine cadaver model. However, there were limitations in their testing methods and conclusions, and the study was not powered appropriately for comparison between experimental groups. Furthermore, during cyclic loading, the single-row repair group had the greatest elongation.

In all of these studies, testing was done by loading the tendon in an isolated medial direction. In actuality, the supraspinatus tendon is differentially loaded in different positions of humeral rotation. Ahmad et al[33] evaluated repair strength of single- and double-row repair constructs at different positions of humeral rotation. Gapping of the rotator cuff was found to be greatest in internal rotation and least in neutral rotation. In all positions, double-row repairs had significantly less gapping than did the single-row repairs ($P = 0.0109$).

Most of the published literature supports the argument that double-row repairs are stronger biomechanical constructs that better recreate the normal anatomy of the rotator cuff insertion. However, traditional double-row suture anchor repairs do not have the potential tendon-bone interface pressure benefits demonstrated by transosseous repairs. "Suture bridge" or "transosseous-equivalent" repairs were developed to address this deficiency.[9] With this technique, the suture limbs from the medial row of anchors are brought over the bursal side of the rotator cuff and are incorporated into lateral anchors (Figure 4). Based on the original technique description, it should be possible to mobilize the rotator cuff tear more than 50% across the footprint in the lateral direction.[9] Medial anchors are placed at the articular margin, and

Figure 3

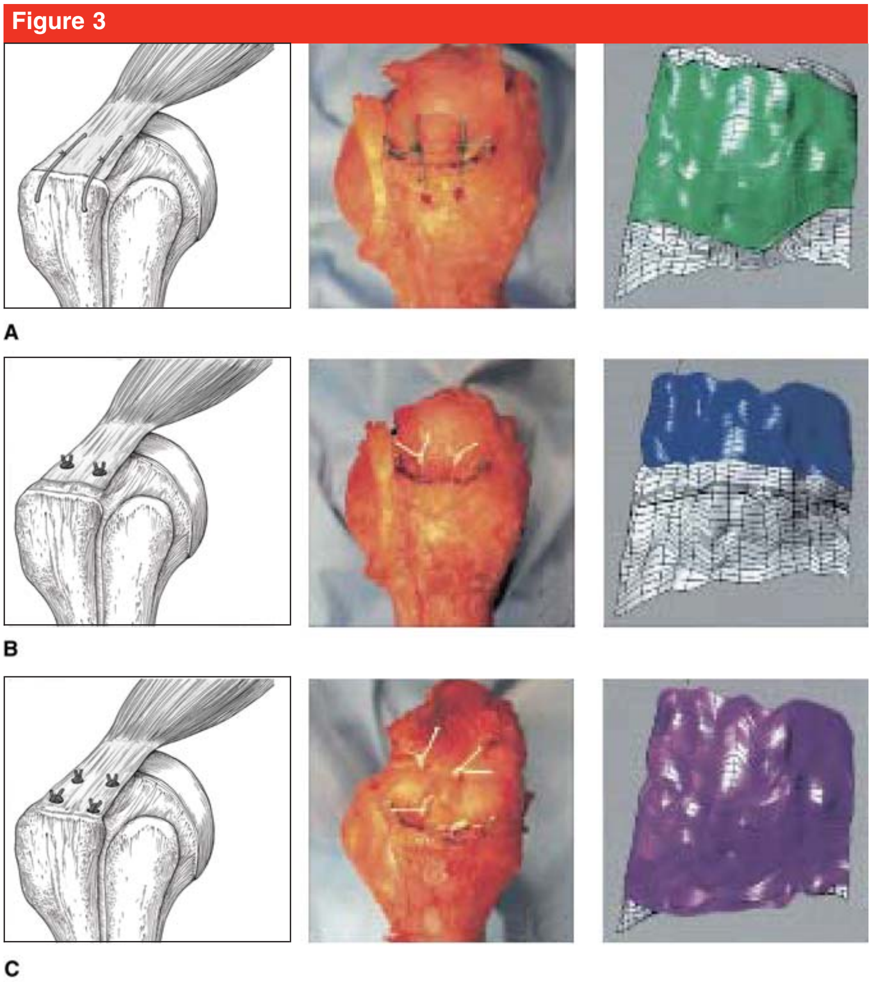
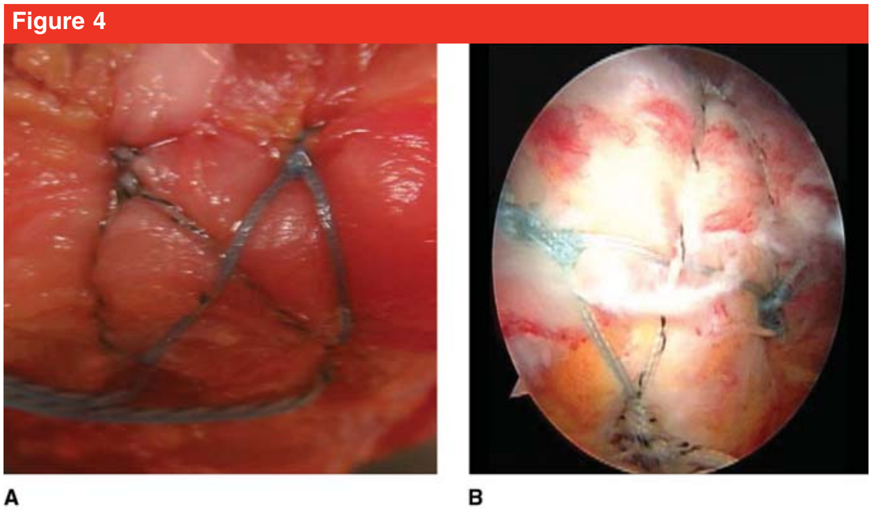


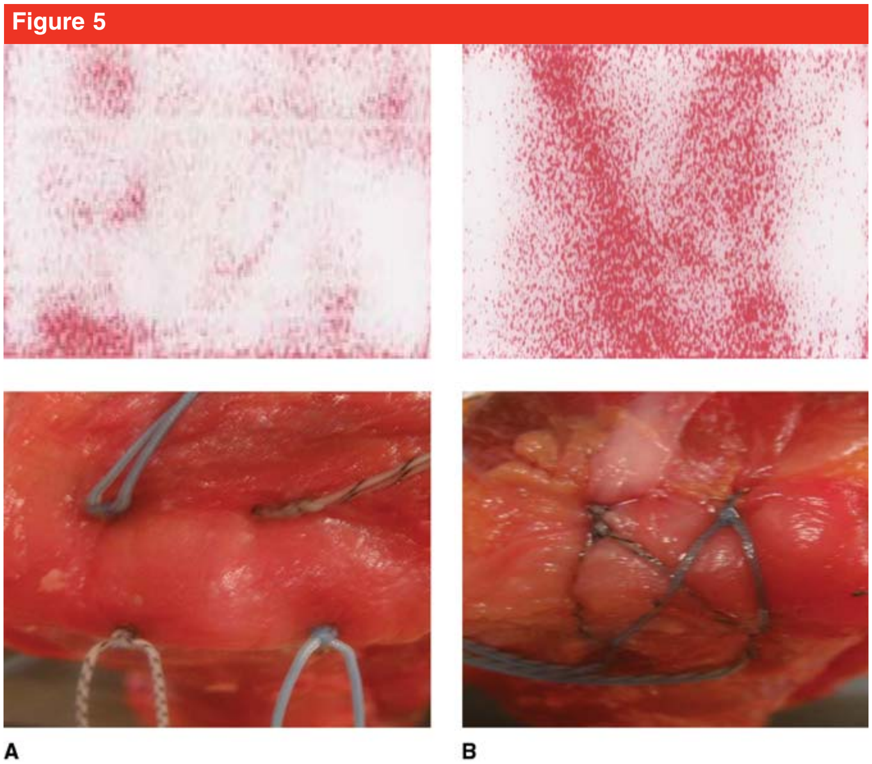
Illustration (left), anatomic representation (middle), and computer mapping (right) of footprint restoration with transosseous suture repair (**A**), single-row suture anchor repair (**B**), and double-row suture anchor repair (**C**). (Adapted with permission from Meier SW, Meier JD: Rotator cuff repair: The effect of double-row fixation on three-dimensional repair site. *J Shoulder Elbow Surg* 2006;15:691-696.)

Figure 4



Intraoperative photograph (**A**) and arthroscopic image (**B**) demonstrating transosseous-equivalent suture bridge rotator cuff repair.

Figure 5



Pressure-sensitive film representations of the double-row suture anchor technique (**A, top**) and the transosseous-equivalent suture bridge technique (**B, top**). The top of each imprint represents the medial aspect of the footprint, and the bottom represents the lateral aspect. The darker areas correlate with increased pressure across the footprint. Significantly more contact is evident in the panel demonstrating suture bridge repair (**B, top**). The bottom image in each panel is the corresponding intraoperative view. (Panels A and B, top, reproduced with permission from Park MC, ElAttrache NS, Tibone JE, Ahmad CS, Jun BJ, Lee TQ: Part I: Footprint contact characteristics for a transosseous-equivalent rotator cuff tear technique compared with a double-row repair technique. *J Shoulder Elbow Surg* 2007;16:461-468.)

sutures from these anchors are passed as medially as possible, typically about 1 cm medial to the tendon edge. The size of the tear determines the ideal anchor placement in the anteroposterior direction; the anchors are kept as far apart as possible to provide a good bone bridge between the implants while allowing for maximization of the pressurized contact area. The lateral anchors are implanted about 1 cm distal-lateral to the lateral edge of the tuberosity footprint insertion. In general, the implants are placed at the same points at which drill holes would be made for an open transosseous repair (Figure 3, A). Although initially technically demanding, new implants, such as the PushLock, Swivel Lock (Arthrex, Naples, FL), and Versalok (DePuy Mitek, Raynham, MA), have helped simplify the procedure.

In a two-part study, Park and colleagues[31,37,38] compared the transosseous-equivalent suture bridge technique with traditional double-row suture anchor repair (Figure 5). The ultimate load-to-failure value was significantly higher following suture bridge repair than following double-row repair (161.88 ± 35.09 N versus 135.17 ± 24.03 N, respectively; $P = 0.026$). In addition, the suture bridge technique provided significantly more pressurized contact area and overall pressure. Another benefit of the suture bridge construct is the interconnection of the anchors, resulting in better load sharing and less tension mismatch on a given anchor with rotation (Figure 6).

According to these studies, double-row suture anchor constructs confer a biomechanical advantage. The benefits of such repair are further elucidated in arthroscopic transosseous-equivalent constructs, which are the most resistant to shear and rotational forces and which closely recreate the anatomic footprint. However,

Figure 6

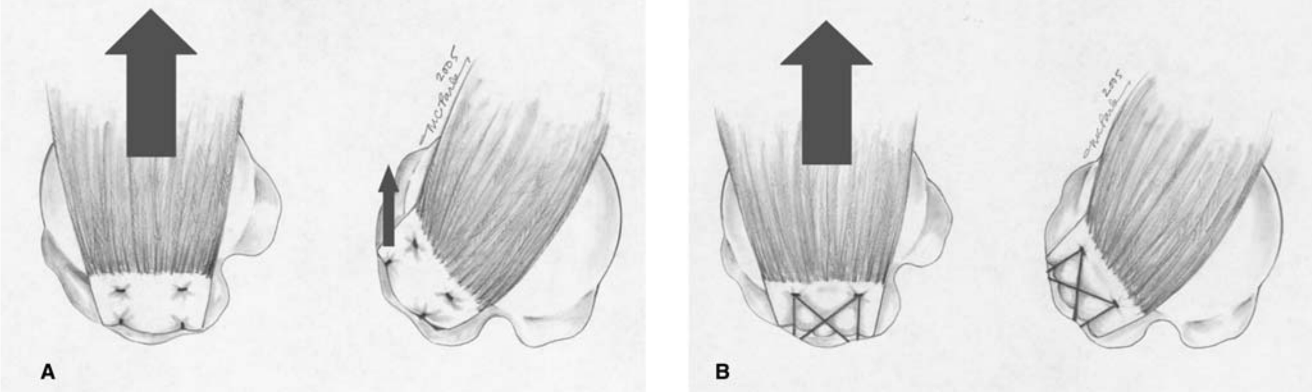


Illustration of the double-row suture technique (**A, left**) and the transosseous-equivalent suture bridge technique (**B, left**) for rotator cuff repair. The suture bridge construct provides superior interconnectivity and better load sharing than does the double-row suture construct when under rotational forces (**B, right**, and **A, right**, respectively). The large arrows indicate the supraspinatus force vector. The small arrow in panel A represents the force vector experienced by the posterolateral suture anchor. With rotation, load sharing is diminished and may predispose this suture anchor to premature failure. (Reproduced with permission from Park MC, Tibone JE, ElAttrache NS, Ahmad CS, Jun BJ, Lee TQ: Part II: Biomechanical assessment for a footprint-restoring transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique. *J Shoulder Elbow Surg* 2007;16:469-476.)

biomechanical cadaver studies only provide information from the time of repair; they fail to provide information on the integrity of the construct during the healing process. Critics of suture bridge constructs question whether the vascular supply to the tendon is compromised by the increased pressure over the top of the tendon. Other concerns include increased time in the operating room, increased cost, tuberosity crowding with regard to implants, and potentially more difficult revision surgery. Although no reports exist in the literature, there is a theoretic risk of iatrogenic tuberosity fracture if the anchors are not spaced appropriately. The presence of abundant previously placed anchors will complicate revision surgery. Increasing the number of anchors increases the amount of operating room time needed as well as the overall cost of treatment. Clinical studies are necessary to confirm whether the theoretic benefits seen in the laboratory translate to improved rotator cuff surgery outcomes and whether the additional cost is worthwhile.

Clinical Results

A summary of the studies to date evaluating the clinical and structural outcomes of single-row and double-row rotator cuff repair are provided in Table 1. Franceschi et al[39] completed one of the only level I randomized controlled studies evaluating single-row versus double-row repair. Sixty patients with unretracted mobile full-thickness rotator cuff tear that was amenable to arthroscopic repair were randomized to single-row or double-row suture anchor fixation. Two years postoperatively, patients were evaluated for functional outcome with a modified University of California, Los Angeles (UCLA) shoulder assessment and for structural outcome with magnetic resonance arthrography. Patient demographics and tear sizes were comparable in both groups. A medial mattress suture pattern and lateral simple suture fixation technique was employed in the double-row group. No significant differences were found in functional outcomes, postoperative range of motion, or structural rates of healing as assessed on magnetic resonance arthrography. The authors concluded that the mechanical advantage of double-row fixation may not translate into superior clinical performance.

Burks et al[40] performed a prospective randomized clinical trial comparing arthroscopic single-row and double-row rotator cuff repairs. Forty patients were randomized to either single-row or double-row rotator cuff repair, and outcomes were assessed with clinical measures and three postoperative MRI studies. MRI measurements showed no significant differences in footprint coverage, tendon thickness, or tendon signal. Postoperative measures of strength and motion were also similar. The authors concluded that at 1 year postoperatively, there were no

Table 1

Summary of Studies Assessing Clinical and/or Structural Outcomes Following Double-row Rotator Cuff Repair

Study	Level of Evidence	Type of Suture Fixation (No. of Patients)	Mean Follow-up (mo)	Clinical Outcomes	Structural Outcomes
Franceschi et al[39]	I	Suture fixation for unretractable mobile tear: single row (30), double row (30)	24	UCLA shoulder score: 11.5 preop to 32.9 postop (single), 10.1 preop to 33.3 postop (double)	Defect evident on MR arthrography in 12/16 (single) and 8/26 (double)
Burks et al[40]	I	Single-row suture anchor fixation (20), double-row suture anchor fixation (20)	12	No significant differences found based on UCLA shoulder, ASES, Constant, WORC, and SANE scores	Re-tear noted on MRI in 2 patients in each group. No difference noted between groups in tendon thickness or footprint coverage.
Grasso et al[41]	I	Single-row suture anchor fixation (40), double-row suture anchor fixation (40)	25	No significant difference between groups according to the DASH and Work-DASH questionnaires, Constant score, and muscle strength testing	—
Charousset et al[42]	II	Panalok anchors (DePuy Mitek, Raynham, MA), single row (35); Cuff Tack (Mitek) and Panalok anchors, double row (31)	28	Constant score: 56.6 preop to 80.7 postop (single), 53.6 preop to 82.7 postop (double)	At 6 mo, CT arthrography demonstrated a defect in 21/35 patients (single) and 12/31 patients (double)
Sugaya et al[43]	III	Single-row (39), double-row (41)	35	UCLA score: 14.8 preop to 32.4 postop (single), 14.4 preop to 33.1 postop (double)	Defect evident on MRI at 14 mo in 22/39 (single) and 11/41 (double)
Sugaya et al[44]	IV	Double-row suture anchor fixation of full-thickness rotator cuff tear (106)	31	UCLA score: 14.5 preop to 32.9 postop	Defect evident in 28/86 patients on MRI at 14 mo
Lafosse et al[4]	IV	Arthroscopic double-row repair of supraspinatus only or supraspinatus and infraspinatus (105)	23	Mean Constant score: 43.2 preop to 80.1 postop	Defect evident on CT arthrography or MR arthrography in 12/105
Park et al[45]	II	Single-row (40), double-row (38)	24	Constant score: 41.6 preop to 76.7 postop (single), 44.2 preop to 79.7 postop (double)	None
Anderson et al[46]	IV	Double-row in 52 shoulders (48)	30	L'Insalata shoulder score: 42 preop to 93 postop	Defect shown on ultrasonography in 9 shoulders
Huijsmans et al[47]	IV	Double-row suture anchor fixation in 242 shoulders (238)	22	Constant score: 54.9 preop to 80.0 postop	20/210 exhibited a defect on ultrasonography 93% of small and medium tears (≤3 cm) and 47% of massive tears (>5 cm) healed
Frank et al[5]	IV	Double-row transosseous-equivalent suture bridge (25)	—	None	MRI revealed defect in 3 at minimum 12-month follow-up

ASES = American Shoulder and Elbow Surgeons; DASH = Disabilities of the Arm, Shoulder, and Hand; MR = magnetic resonance; SANE = Single Assessment Numeric Evaluation; UCLA = University of California, Los Angeles; WORC = Western Ontario Rotator Cuff Index

clinical differences between single-row and double-row repairs.

In a recent level I study, Grasso et al[41] randomized 80 patients to either single-row or double-row repair. Their findings were similar to those of Burks et al.[40] At 2-year follow-up, no significant difference was found between treatment groups based on Disabilities of the Arm, Shoulder, and Hand (DASH) and Work-DASH questionnaires, normalized Constant score, or muscle strength measurement. Imaging studies were not done postoperatively.

Charousset et al[42] performed a nonrandomized comparative study of single-row and double-row fixation. Thirty-one patients who underwent double-row fixation with a medial Cuff Tack anchor (Mitek) and lateral Panalok anchor (DePuy Mitek) were compared with 35 patients who had single-row fixation with Panalok anchors alone. No significant differences in clinical results as assessed by Constant score were detected at a mean follow-up of approximately 28 months. Although no significant differences in the incidence of complete or partial healing of the rotator cuff were detected by CT arthrography between groups, the incidence of anatomic healing was noted to be significantly higher with the double-row repair technique. The applicability of these results is limited, however, because of lack of randomization and the antiquated use of the Cuff Tack as a medial row fixation device.

Sugaya et al[43] retrospectively compared functional and structural outcomes after single-row and double-row fixation of rotator cuff tears. Thirty-nine patients were treated with single-row fixation, and 41 were treated with double-row fixation. At a mean follow-up of 35 months, no significant difference in subjective functional results was observed. However, postoperative MRI demonstrated a statistically improved rate of structural healing with the double-row technique ($P < 0.01$).

In 2007, the same authors published the results of a prospective outcome study of 106 patients who underwent double-row suture anchor repair of full-thickness rotator cuff tears.[44] In 86 patients with sufficient postoperative follow-up, functional results were assessed with the UCLA and American Shoulder and Elbow Society (ASES) tools at a mean of 31 months. Structural integrity of the repair was evaluated at a mean of 14 months postoperatively. Significant improvement in clinical outcome scores was noted at final follow-up ($P < 0.01$). The overall retear rate was 17%, with a predominance occurring in patients with large and massive tears (40% recurrence). Correspondingly inferior functional strength and overall outcome scores were observed in the subgroup with large tear (3 to 5 cm) or massive tear (>5 cm).

Lafosse et al[4] prospectively evaluated 105 patients who underwent arthroscopic double-row repair of one or two tendon tears, reporting favorable functional and structural results. The mean Constant score improved from 43.2 ± 15.1 preoperatively to 80.1 ± 11.1 at a mean follow-up of 23 months. Evaluation with CT arthrography or magnetic resonance arthrography revealed only 12 failures (11%), a significantly lower rate of recurrence than that previously reported with arthroscopic techniques for compatible tear sizes and patterns. A trend toward superior clinical outcomes was observed in shoulders with a structurally intact repair; pain score was the only category in which a statistically significant difference was found ($P < 0.0001$).

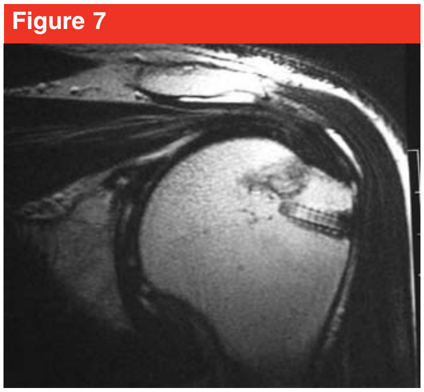
Park et al[45] recently compared clinical outcomes of single-row versus double-row rotator cuff repair. Forty consecutive patients underwent single-row repair, and the next consecutive 38 patients underwent double-row fixation. At 2 years postoperatively, ASES, Constant, and Shoulder Strength Index outcome scores were significantly improved in both groups, but no significant difference was found between the groups. When the comparison was subdivided based on tear size, functional outcome scores were significantly better with double-row fixation for large or massive tears (>3 cm) ($P < 0.05$). The authors concluded that double-row repair configurations may have a clinically relevant role in the treatment of large to massive rotator cuff tears. However, the conclusions are limited by small experimental groups, lack of randomization, lack of a standardized surgical protocol for single-row repair, and absence of structural evaluation of the repair integrity in the experimental design.

Anderson et al[46] published a case series of 48 patients (52 shoulders) who underwent double-row suture anchor repair of full-thickness rotator cuff tears. The average tear size was 2.47 cm. Postoperative evaluation included functional assessment, clinical examination, strength testing, and ultrasonography. At a mean follow-up of 30 months, ultrasonography revealed a 17% rate of re-tear or persistent defect. L'Insalata score ($P < 0.001$), motion ($P < 0.001$), and strength (elevation, $P < 0.001$; external rotation, $P < 0.001$; internal rotation, $P = 0.033$) were significantly improved compared with preoperative values. Patients with intact repairs had significantly improved strength in elevation ($P = 0.006$) and external rotation ($P = 0.001$).

Huijsmans et al[47] presented the results of double-row rotator cuff repair using a modified interlocking suture technique in 264 patients, 238 of whom were available for follow-up. At final follow-up, 90% of patients had good to excellent functional outcomes, and 82.9% had an intact repair as assessed on ultrasonography. Brady et al[48] demonstrated improved intraoperative coverage of the footprint with double-row repair compared with single-row repair in 26 patients. They reported an uncovered area of 52.7% ± 9.2% of the greater tuberosity footprint after single-row repair compared with 100% coverage after double-row repair.

Frank et al[5] were the first to clini-

Figure 7



Coronal magnetic resonance image of a healed rotator cuff 1 year after transosseous-equivalent suture bridge repair of a full-thickness tear. (Reproduced with permission from Frank JB, ElAttrache NS, Dines JS, Blackburn A, Crues J, Tibone JE: Repair site integrity after arthroscopic transosseous-equivalent suture bridge rotator cuff repair. *Am J Sports Med* 2008;36:1496-1498.)

cally evaluate the transosseous-equivalent suture bridge technique. Postoperative magnetic resonance images were obtained for the first 25 patients who underwent arthroscopic repair with the technique (Figure 7). Overall healing was 88% at a minimum of 1 year after surgery. Larger tears that involved the supraspinatus and part or all of the infraspinatus healed in 86% of patients (6 of 7), which compared favorably with tears isolated to the supraspinatus (89% [16 of 18 patients]). This study was nonrandomized and was designed solely to assess repair site integrity; however, the healing rates compare favorably with historical data.

The data seem to support predictable healing with either single-row or double-row repairs for small and medium-sized tears. The potential benefit of double-row repairs may lie in improved outcomes with large and massive tears. Larger prospective randomized studies that include clinical assessments and that take tear size into account are necessary to determine the true efficacy of transosseous-equivalent and other double-row repair techniques.

Summary

Double-row and modified double-row repair configurations for rotator cuff tears provide a superior biomechanical construct and improved footprint coverage. However, clinical studies are needed to determine whether double-row repair provides substantially better structural healing or functional outcomes than does single-row repair. Although double-row repair configurations may provide an improved mechanical environment for the healing enthesis, it is difficult to establish a definitive relationship with improved rates of healing. Appropriately powered rigorous level I studies that directly compare single-row with double-row techniques in matched tear patterns are necessary to further address these questions and to help in determining whether the results justify the increased surgical time and expense of double-row repair.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 39-41 are level I studies. References 42 and 45 are level II studies. References 2 and 43 are level III studies. Level IV studies include references 1, 3-5, 44, 46, and 47.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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