J Shoulder Elbow Surg (2011) 20, S14-S19

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

A systematic review of the clinical outcomes of single row versus double row rotator cuff repairs

George J. Trappey IV, MD*, Gary M. Gartsman, MD

Fondren Orthopedic Group, Houston, TX, USA

Rotator cuff tears are a ubiquitous cause of shoulder pain and disability. Full thickness rotator cuff tears are present in 19-21% of the general population, and their prevalence increases with age.[39,64] The incidence of this problem is exacerbated by the ever advancing age of our patient population. Thankfully, with advances in arthroscopic rotator cuff repair, this has become a treatable problem with low morbidity, few complications, and good success. Although patients can do well in the face of a persistent or recurrent rotator cuff tear after arthroscopic repair, several studies have documented better subjective and objective results when the rotator cuff tear has been documented to heal.[3,16,18,19,27,30-33,57,58]

It is for this reason that much emphasis and many resources have been dedicated to improving the success of rotator cuff healing after arthroscopic repair. Several areas have been explored as possible solutions to this complex problem. Proposals have included improving patient factors such as smoking cessation.[38] Improving the local milieu with various growth factors and scaffolds has also been suggested.[14] However, the 1 factor that has probably received the most attention to date is improving the initial fixation strength and recreating the anatomic footprint of the rotator cuff to ameliorate this problem.

Traditional open rotator cuff repairs using tranosseous bone tunnels had the advantage of reapproximating the rotator cuff tendon solidly onto the greater tuberosity while increasing the area available for healing.[44] Unfortunately, this came at the expense of increased pain and decreased range of motion postoperatively from violating the deltoid. As arthroscopic techniques improved and suture anchors became available, single row rotator cuff repairs became fashionable due to easier rehabilitation postoperatively. Most of these techniques relied on simple sutures through the rotator cuff with less reliable compression of the rotator cuff tendon onto the tuberosity.[60] As arthroscopic techniques became more sophisticated and implants improved, it became possible for surgeons to employ double row repair techniques that afford the compression of traditional open bone tunnels through minimally invasive arthroscopic procedures.

This review article examines the currently available literature regarding single versus double row suture anchor repair for arthroscopic rotator cuff repair. Interpreting this literature, however, is fraught with difficulty. The difficulty lies in the fact that what defines a single row repair and what defines a double row repair is fairly ambiguous. For example, is a single row repair, where the anchors are placed on the lateral aspect of the footprint, the same construct as a single row repair, where the anchors are placed medial along the articular margin (Fig. 1)? Likewise, should traditional double row repairs and transosseous equivalent repairs be considered together in the same category as ''double row'' repairs (Figs. 2 and 3)?

As will be shown, there is mounting basic science biomechanical data that double row suture anchor repairs seem to offer a stronger time zero construct.[1,2,6,7,24,26,28,34-36,41-43,48,50,51,55,59,63] What is less clear is the role this plays clinically. While there is still much uncertainty surrounding rotator cuff repairs, 1 thing is certain: very few definitive scientific clinical conclusions can be drawn from the

Investigational Review Board approval was not necessary for this review article.

*Reprint requests: George J. Trappey IV, MD, Fondren Orthopedic Group, 7401 South Main Street, Houston, TX 77030.

E-mail address: j_trappey@yahoo.com (G.J. Trappey IV).

1058-2746/$ - see front matter
doi:10.1016/j.jse.2010.12.001

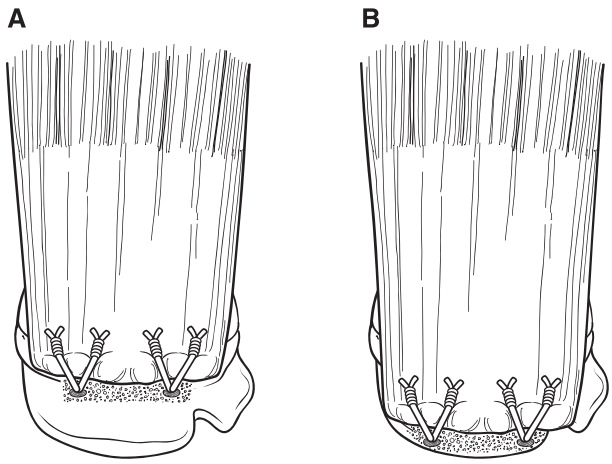

Figure 1 (A), Single row repair on the medial side of the footprint. (B), Single row repair on the lateral side of the footprint.

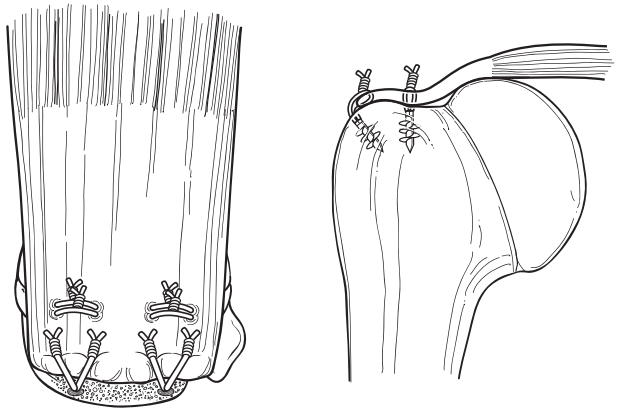

Figure 2 Traditional double row repair.

available literature due to the paucity of Level I evidence and multitude of different uncontrolled variables.

Biomechanical data

There have been a number of basic science studies comparing single and double row suture anchor repairs for rotator cuff tears.[1,2,6,7,24,28,34-36,41,42,48,50,51,54,55,59,63] These studies have included cadaveric specimens, as well as animal specimens such as rabbit, bovine, ovine, and porcine.

The majority of the available basic science data suggest that double row repairs have greater footprint coverage, improved contact area and pressure, better initial fixation strength and stiffness, decreased gap formation, and higher load to failure when compared to single row repairs.[1,2,6,7,24,28,34-36,41-43,48,50,51,55,59,63] However, there are studies to the contrary. Mazzocca et al[40] performed a cadaveric study on 20 fresh frozen shoulders. The single row repairs had similar load to failure, cyclic displacement, and gap formation when compared to double row repairs; however, double row repairs did restore a larger percentage of the anatomic footprint.[40] Mahar et al showed in 18 bovine shoulders that double row repairs did not have a biomechanical advantage over single row repairs.[37] Finally, using 6 matched pairs of ovine shoulders, Nelson et al demonstrated that although double row repairs restore a greater percentage of the anatomic footprint, the time zero biomechanical strength was not significantly different from single row repairs.[45]

Although the 3 above-referenced studies show no biomechanical advantage to using double row repairs for arthroscopic rotator cuff surgery, 2 of the studies do show better recreation of the anatomic footprint of the rotator cuff on the humerus. This greater footprint coverage alone may be advantageous for rotator cuff healing. While the 3 studies mentioned above show equivocal biomechanical results, clearly the majority of the published basic science literature supports the argument that double row repairs are stronger biomechanical constructs that better recreate the normal anatomic footprint of the rotator cuff.[17] What is more difficult to demonstrate is whether this translates into superior clinical results.

Clinical data

The majority of patients show significant improvement in shoulder functional outcomes and a high rate of patient satisfaction with both single and double row arthroscopic rotator cuff repairs.[3,9,10,16,22,27,29,31,46,57,61] So, why bother with double row repairs, knowing that double row repairs are more expensive and time consuming?[18,20] The time and money may be worthwhile, because several studies have documented better subjective and objective results after rotator cuff repairs when the tendon has been documented to heal.[3,16,18,19,27,30-33,57,58] Therefore, if double row repairs are superior to single row repairs in terms of biomechanical performance, as well as improved contact area and pressure, one would expect better healing rates and, therefore, better outcomes. Surprisingly, this has been difficult to prove clinically.

Sugaya et al[56] demonstrated that arthroscopic rotator cuff repairs yielded successful functional outcomes without a significant difference between single and double row repairs. Double row repairs did, however, excel in structural healing versus single row repairs based on MRI findings.[56] Brady et al showed intraoperatively that double row repairs offered over twice the footprint coverage yielded by single row repairs.[8] Charousset et al also found no significant difference in clinical results; but, anatomic tendon healing rates were better with the double row repairs based on computed tomographic (CT) arthrography.[13]

Several others, including Aydin et al, Buess et al, Reardon et al, and Wall et al have noted equivalent clinical outcomes after comparing single and double row repairs.[4,11,52,62] Park et al made an interesting observation when comparing small to medium rotator cuff tears ($\leq$3 cm) with large to massive rotator cuff tears ($\geq$3 cm). They noted that when rotator cuff

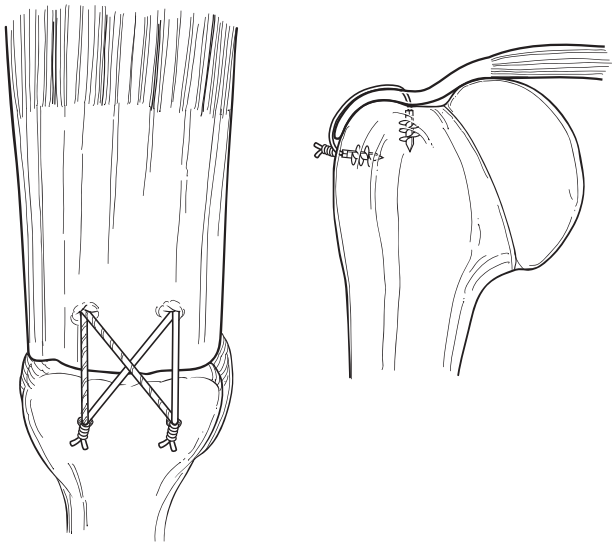

Figure 3 Transosseous equivalent or bridging repair.

tears ≥3 cm were repaired using a double row technique, they had better American Shoulder and Elbow Surgeons (ASES) and Constant scores postoperatively as compared to single row repairs. This was the first study to show a clinical difference between single and double row repairs, and it was strictly in these larger sized tears.[49]

In spite of the fact that the single versus double row question has yet to be answered definitively, researchers have already begun to compare double row constructs. The 2 most commonly studied constructs are traditional double row repairs and transosseous equivalent or bridging repairs. Traditional double row repairs do not have the potential tendon-bone interface pressure benefits demonstrated by transosseous equivalent repairs.[5,17] Park et al showed, using biomechanical comparisons between double row and transosseous equivalent repairs, that the mean ultimate load to failure was, statistically, significantly greater for the transosseous equivalent repairs.[50] Frank et al went on to demonstrate with MRI that transosseous equivalent repairs had equivalent or improved healing rates when compared to historical controls with satisfactory outcomes and excellent function at 1 year after surgery.[21]

Recently, however, Cho et al brought to light an interesting finding regarding these transosseous equivalent repairs. He noticed an unusual pattern of tendon failures at the musculotendinous junction of rotator cuffs repaired with this method.[15] Therefore, while there appears to be theoretical benefits to transosseous equivalent repairs, the significance of this medial failure is not yet known, and clearly needs to be addressed in future studies on this technique.

Review articles

Of late, several review articles have been published on the topic of single versus double row arthroscopic rotator cuff repairs. The consensus of these review articles is that while double row repairs seem to offer biomechanically sound constructs that may decrease retear rates, this leads to few advantages clinically. Duquin et al showed in their systematic review of the literature that double row repair methods lead to significantly lower retear rates, when compared with single row methods for tears greater than 1 cm.[18] Saridakis et al pointed out in another systematic review that there appears to be a benefit of structural healing when an arthroscopic rotator cuff repair is performed with double row as opposed to single row fixation. There was little evidence to support any functional differences between the 2 techniques, except possibly for patients with large or massive rotator cuff tears (≥3 cm).[53] In a review article by Dines et al, the authors noted that clinical studies have not yet demonstrated a substantial improvement when using double instead of single row repairs with regard to either the degree of structural healing or functional outcomes.[17] In the most recent systematic review, Nho et al conclude that there are no clinical differences between single and double row repair techniques for arthroscopic rotator cuff repairs.[47]

Level I evidence

Franceschi et al pointed out that single and double row repairs provide comparable clinical outcomes at 2 years. Double row repairs did appear to produce superior mechanical constructs with better restoration of the anatomic footprint on MR arthrography; however, the difference was not statistically significant. In the first randomized controlled trial on this subject, 60 patients were randomized into either a single or double row repair group. Four patients in each group did not return for final 2-year follow-up. There was no statistically significant difference at 2 years in the University of California Los Angeles (UCLA) score or range of motion between groups. Postoperative MRI at 2 years did favor the double row group with intact rotator cuffs in 18 patients, partial-thickness defects in 7, and full-thickness defects in 1. In comparison, there were 14 patients with intact rotator cuffs, 10 patients with partial-thickness defects, and 2 patients with full-thickness defects in the single row group. An interesting side note was made regarding the operative times. The mean operative time for the single row group was 42 minutes compared to 65 minutes for the double row group. This difference was statistically significant (Table).[20]

A second randomized clinical trial was performed by Grasso et al. This study involved 80 patients randomized into either the double or single row repair group. Follow-up was 2 years, with 8 patients lost to follow-up. No significant difference in clinical outcomes was apparent between the single and double row groups at 2 years. Imaging was not used to verify the integrity of the repairs.[25]

Most recently, Burks et al published a randomized controlled trial. In this study, 40 patients were randomized

Table Level I evidence

Author	Year	Sample	Follow-up (mos)	Outcome	Imaging	Type of DR	Results
Franceschi et al[20]	2007	60	24	UCLA/ROM	MRI	Standard	Clinically no difference. MRI favored DR group
Grasso et al[25]	2008	80	24	DASH/Constant/Strength	None	Standard	Clinically no difference
Burks et al[12]	2009	40	12	UCLA/Constant/WORC/SANE/ ASES/ROM/Strength	MRI	Standard	No clinical or MRI difference
Gartsman[23]	2010	90	10	None	US	T.O.E.	DR statistically superior per US

DR, double row; *T.O.E,* tranosseous equivalent; *MRI,* magnetic resonance imaging; *US*; ultrasound; *ROM*, range of motion; *UCLA*, University of California Los Angeles; *ASES*, American Shoulder and Elbow Surgeons; *DASH*, Disabilities of the Arm, Shoulder and Hand; *WORC*, Western Ontario Rotator Cuff Index; *SANE*, Single Assessment Numeric Evaluation.

to either single or double row arthroscopic rotator cuff repairs, with no patients lost to follow-up. Patients were followed with clinical measures as well as magnetic resonance image (MRI) to 1 year postoperatively. There were no significant differences in any of the clinical parameters at 1 year. There were 2 retears at 1 year in each group, with an additional 2 cases in the double row group demonstrating severe thinning. Per MRI, there was no significant difference between the single and double row groups with regards to the structural integrity of the repairs. The conclusion from this study was that there is no clinical or MRI differences between single and double row arthroscopic rotator cuff repairs.[12]

Finally, in a prospective randomized trial that is currently in press and has been presented at both the open meeting of the ASES and Nice shoulder course, Gartsman et al used ultrasound to evaluate rotator cuff integrity at 1 year comparing single and double row arthroscopic rotator cuff repairs. This study included 90 patients randomized to either single or double row repair using the transosseous equivalent technique. Eighty-three patients had complete data to allow their inclusion in the study. Follow-up ultrasound was performed at an average of 10 months to evaluate cuff integrity. Clinical outcomes and function was not evaluated in this study. Forty of 43 patients (93%) had intact repairs in the double row repair group. Thirty-two of 40 patients (80%) had intact repairs in the single row group. This difference was found to be statistically significant.[23]

Authors' preferred approach

Although the biomechanical time zero construct strength is an important factor when repairing rotator cuff tendon tears arthroscopically, it is certainly not the only factor to consider when deciding between a single or double row repair construct. Patient factors have to be considered as well. Many of the decisions regarding the appropriate construct need to be made intraoperatively after seeing the rotator cuff tear, assessing the tissue, and feeling the tension. It is the authors' collective opinion that a low tension environment is critical for rotator cuff healing. If given the choice between an anatomically positioned double row repair under undue tension or a tension-free single row repair at the articular margin, it is our practice to choose the low tension environment preferentially.

Our treatment algorithm is subjective, but our goal is to obtain the most biomechanically sound construct in the lowest tension environment. If the patient has an easily reducible tear with reasonable tendon quality, it is our practice to perform a double row repair using the transosseous equivalent technique. If, however, the tendon only reduces to the articular margin, and the tendon quality is suspect, we prefer to perform a single row repair at the articular margin, as we believe this gives the tendon the best chance to heal.

Conclusion/discussion

Given the paucity of Level I evidence on this topic, it is difficult to make many definitive conclusions. Suffice it to say that the available literature indicates that arthroscopic double row suture anchor rotator cuff repairs appear to be biomechanically superior to single row repairs. This fact, however, does not appear to translate into superior functional or clinical outcomes. Proponents of arthroscopic double row rotator cuff repairs concede that current studies do not demonstrate superiority over arthroscopic single row repairs. They argue, however, that more sophisticated outcome analyses will more accurately discriminate the superiority of double row repairs. Well-designed large prospective randomized studies are needed in the future to definitively settle this debate. Until this happens, arguments can be made on either side to justify single or double row arthroscopic suture anchor rotator cuff repairs.

Disclaimer

Neither author, their immediate families, nor any research foundation with which they are affiliated

received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Ahmad CS, Kleweno C, Jacir AM, Bell JE, Gardner TR, Levine WN, et al. Biomechanical performance of rotator cuff repairs with humeral rotation: A new rotator cuff repair failure model. Am J Sports Med 2008;36:888-92. doi:10.1177/0363546508316285
2. Ahmad CS, Vorys GC, Covey A, Levine WN, Gardner TR, Bigliani LU. Rotator cuff repair fluid extravasation characteristics are influenced by repair technique. J Shoulder Elbow Surg 2009;18:976-81. doi:10.1016/j.jse.2009.01.020
3. Anderson K, Boothby M, Aschenbrener D, van Holsbeeck M. Outcome and structural integrity after arthroscopic rotator cuff repair using 2 rows of fixation: Minimum 2-year follow up. Am J Sports Med 2006;34:1899-905. doi:10.1177/0363546506290187
4. Aydin N, Kocaoglu B, Guven O. Single-row versus double-row arthroscopic rotator cuff repair in small- to medium-sized tears. J Shoulder Elbow Surg 2010;19:722-5. doi:10.1016/j.jse.2009.11.053
5. Baums MH, Buchhorn GH, Gilbert F, Spahn G, Schultz W, Klinger HM. Initial load-to-failure and failure analysis in single- and double-row repair techniques for rotator cuff repair. Arch Orthop Trauma Surg 2010;130:1193-9.
6. Baums MH, Buchhorn GH, Spahn G, Poppendieck B, Schultz W, Klinger HM. Biomechanical characteristics of single-row repair in comparison to double-row repair with consideration of the suture configuration and suture material. Knee Surg Sports Traumatol Arthrosc 2008;16:1052-60.
7. Baums MH, Spahn G, Steckel H, Fischer A, Schultz W, Klinger HM. Comparative evaluation of the tendon-bone interface contact pressure in different single- versus double-row suture anchor repair techniques. Knee Surg Sports Traumatol Arthrosc 2009;17:1466-72.
8. Brady PC, Arrigoni P, Burkhart SS. Evaluation of residual rotator cuff defects after in vivo single- versus double-row rotator cuff repairs. Arthroscopy 2006;22:1070-5. doi:10.1016/j.arthro.2006.05.007
9. Bishop J, Klepps S, Lo IK, Bird J, Gladstone JN, Flatow EL. Cuff integrity after arthroscopic versus open rotator cuff repair: A prospective study. J Shoulder Elbow Surg 2006;15:290-9. doi:10.1016/j.jse.2005.09.017
10. Boileau P, Brassart N, Watkinson DJ, Carles M, Hatzidakis AM, Krishnan SG. Arthroscopic repair of full-thickness tears of the supraspinatus: Does the tendon really heal? J Bone Joint Surg Am 2005;87:1229-40. doi:10.2106/JBJS.D.02035
11. Buess E, Waibl B, Vogel R, Seidner R. A comparative clinical evaluation of arthroscopic single-row versus double-row supraspinatus tendon repair. Acta Orthop Belg 2009;75:588-94.
12. Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuffrepair: Magnetic resonance imaging and early clinical evaluation. Am J Sports Med 2009;37:674-82. doi:10.1177/0363546508328115
13. Charousset C, Grimberg J, Duranthon LD, Bellaiche L, Petrover D. Can a double-row anchorage technique improve tendon healing in arthroscopic rotator cuff repair? A prospective, nonrandomized, comparative study of double-row and single-row anchorage techniques with computed tomographic arthrography tendon healing assessment. Am J Sports Med 2007;35:1247-53. doi:10.1177/0363546507301661
14. Cheung EV, Silverio L, Sperling JW. Strategies in biologic augmentation of rotator cuff repair: a review. Clin Orthop Relat Res 2010;468:1476-84. doi:10.1007/s11999-010-1323-7
15. Cho NS, Yi JW, Lee BG, Rhee YG. Retear patterns after arthroscopic rotator cuff repair: single-row versus suture bridge technique. Am J Sports Med 2010;38:664-71. doi:10.1177/0363546509350081
16. Cole BJ, McCarty LP III, Kang RW, Alford W, Lewis PB, Hayden JK. Arthroscopic rotator cuff repair: Prospective functional outcome and repair integrity at minimum 2-year follow-up. J Shoulder Elbow Surg 2007;16:579-85. doi:10.1016/j.jse.2006.12.011
17. Dines JS, Bedi A, ElAttrache NS, Dines DM. Single-row versus double-row rotator cuff repair: techniques and outcomes. J Am Acad Orthop Surg 2010;18:83-93.
18. Duquin TR, Buyea C, Bisson LJ. Which method of rotator cuff repair leads to the highest rate of structural healing? A systematic review. Am J Sports Med 2010;38:835-41. doi:10.1177/0363546509359679
19. Flurin PH, Landreau P, Gregory T, Boileau P, Lafosse L, Guillo S, et al. Cuff integrity after arthroscopicrotator cuff repair: correlation with clinical results in 576 cases. Arthroscopy 2007;23:340-6. doi:10.1016/j.arthro.2007.01.005
20. Franceschi F, Ruzzini L, Longo UG, Martina FM, Zobel BB, Maffulli N, et al. Equivalent results of arthroscopic single-row and double-row suture anchor repair for rotator cuff tears: A randomized controlled trial. Am J Sports Med 2007;35:1254-60. doi:10.1177/0363546507302218
21. 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;36:1496-503. doi:10.1177/0363546507313574
22. Galatz LM, Ball CM, Teefey SA, Middleton WD, Yamaguchi K. The outcome and repair integrity of completely arthroscopically repaired large and massive rotator cuff tears. J Bone Joint Surg Am 2004;86:219-24.
23. Gartsman GM, Drake G, Edwards TB, Elkousy HA, Hammerman SM, O'Connor DP. Ultrasound evaluation of arthroscopic full-thickness supraspinatus rotator cuff repair: Single-row versus double-row suture bridge (transosseous equivalent) fixation. Results of a randomized, prospective study. American Society of Shoulder and Elbow Surgeons 2010 Specialty Day. New Orleans, LA; March 2010.
24. Gerber C, Schneeberger AG, Beck M, Schlegel U. Mechanical strength of repairs of the rotator cuff. J Bone Joint Surg Br 1994;76:371-80.
25. Grasso A, Milano G, Salvatore M, Falcone G, Deriu L, Fabbriciani C. Single-row versus double-row arthroscopic rotator cuff repair: A prospective randomized clinical study. Arthroscopy 2009;25:4-12. doi:10.1016/j.arthro.2008.09.018
26. Hughes RE, An KN. Force analysis of rotator cuff muscles. Clin Orthop Relat Res 1996;330:75-83.
27. Huijsmans PE, Pritchard MP, Berghs BM, van Rooyen KS, Wallace AL, de Beer JF. Arthroscopic rotator cuff repair with double-row fixation. J Bone Joint Surg Am 2007;89:1248-57. doi:10.2106/JBJS.E.00743
28. Kim DH, ElAttrache NS, Tibone JE, Jun BJ, DeLaMora SN, Kvitne RS, et al. Biomechanical comparison of a single-row versus double-row suture anchor technique for rotator cuff repair. Am J Sports Med 2006;34:407-14. doi:10.1177/0363546505281238
29. Lafosse L, Brozska R, Toussaint B, Gobezie R. The outcome and structural integrity of arthroscopic rotator cuff repair with use of the double-row sutureanchor technique. J Bone Joint Surg Am 2007;89:1533-41. doi:10.2106/JBJS.F.00305
30. Lafosse L, Brzoska R, Toussaint B, Gobezie R. The outcome and structural integrity of arthroscopic rotator cuff repair with use of the double-row suture anchor technique. Surgical technique. J Bone Joint Surg Am 2008;90(Suppl 2 Pt 2):275-86. doi:10.2106/JBJS.H.00388
31. Lichtenberg S, Liem D, Magosch P, Habermeyer P. Influence of tendon healing after arthroscopic rotator cuff repair on clinical outcome using single-row Mason-Allen suture technique: A prospective, MRI controlled study. Knee Surg Sports Traumatol Arthrosc 2006;14:1200-6.
32. Liem D, Bartl C, Lichtenberg S, Magosch P, Habermeyer P. Clinical outcome and tendon integrity of arthroscopic versus mini-open supraspinatus tendon repair: a magnetic resonance imaging

controlled matched-pair analysis. Arthroscopy 2007;23:514-21. doi: 10.1016/j.arthro.2006.12.028
33. Liem D, Lichtenberg S, Magosch P, Habermeyer P. Magnetic resonance imaging of arthroscopic supraspinatus tendon repair. J Bone Joint Surg Am 2007;89:1770-6. doi:10.2106/JBJS.F.00749
34. Lo IY, Burkhart S. Double-row arthroscopic rotator cuff repair: Reestablishingthe footprint of the rotator cuff. Arthroscopy 2003;19: 1035-42. doi:10.1016/j.arthro.2003.09.036
35. Lorbach O, Bachelier F, Vees J, Kohn D, Pape D. Cyclic loading of rotator cuff reconstructions: single-row repair with modified suture configurations versus double-row repair. Am J Sports Med 2008;36: 1504-10. doi:10.1177/0363546508314424
36. Ma CB, Comerford L, Wilson J, Puttlitz CM. Biomechanical evaluation of arthroscopic rotator cuff repairs: double-row compared with single-row fixation. J Bone Joint Surg Am 2006;88:403-10. doi:10. 2106/JBJS.D.02887
37. Mahar A, Tamborlane J, Oka R, Esch J, Pedowitz RA. Single-row suture anchor repair of the rotator cuff is biomechanically equivalent to double-row repair in a bovine model. Arthroscopy 2007;23:1265-70. doi:10.1016/j.arthro.2007.07.010
38. Mallon WJ, Misamore G, Snead DS, Denton P. The impact of preoperative smoking habits on the results of rotator cuff repair. J Shoulder Elbow Surg 2004;13:129-32. doi:10.1016/j.jse.2003.11.002
39. Matava MJ, Purcell DB, Rudzki JR. Partial-thickness rotator cuff tears. Am J Sports Med 2005;33:1405-17. doi:10.1177/ 0363546505280213
40. Mazzocca AD, Millett PJ, Guanche CA, Santangelo SA, Arciero RA. Arthroscopic single-row versus double row suture anchor rotator cuff repair. Am J Sports Med 2005;33:1861-8. doi:10.1177/ 0363546505279575
41. Meier SW, Meier JD. The effect of double-row fixation on initial repairstrength in rotator cuff repair: A biomechanical study. Arthroscopy 2006;22:1168-73. doi:10.1016/j.arthro.2006.07.004
42. Meier SW, Meier JD. Rotator cuff repair: The effect of double-row fixation on three-dimensional repair site. J Shoulder Elbow Surg 2006;15:691-6. doi:10.1016/j.jse.2006.03.004
43. Milano G, Grasso A, Bareli D, Deriu L, Cello M, Fabbriciani C. Comparison between single-row and double-row rotator cuff repair: A biomechanical study. Knee Surg Sports Traumatol Arthrosc 2008;16:75-80.
44. Millett PJ, Mazzocca A, Guanche CA. Mattress double anchor footprint repair: A novel, arthroscopic rotator cuff repair technique. Arthroscopy 2004;20:875-9. doi:10.1016/j.arthro.2004.07.015
45. Nelson CO, Sileo MJ, Grossman MG, Serra-Hsu F. Single-row modified mason-allen versus double-row arthroscopic rotator cuff repair: a biomechanical and surface area comparison. Arthroscopy 2008;24:941-8. doi:10.1016/j.arthro.2008.03.011
46. Nho SJ, Brown BS, Lyman S, Adler RS, Altchek DW, MacGillivray JD. Prospective analysis of arthroscopic rotator cuff repair: Prognostic factors affecting clinical and ultrasound outcome. J Shoulder Elbow Surg 2009;18:13-20. doi:10.1016/j.jse.2008.05.045
47. Nho SJ, Slabaugh MA, Seroyer ST, Grumet RC, Wilson JB, Verma NN, et al. Does the literature support double-row suture anchor fixation for arthroscopic rotator cuff repair? A systematic review comparing double-row and single-row suture anchor configuration. Arthroscopy 2009;25:1319-28. doi:10.1016/j.arthro.2009.02.005
48. Ozbaydar M, Elhassan B, Esenyel C, Atalar A, Bozdag E, Sunbuloglu E, et al. A comparison of single-versus double-row suture anchor techniques in a simulated repair of the rotator cuff: an experimental study in rabbits. J Bone Joint Surg Br 2008;90:1386-91. doi: 10.1302/0301-620X.90B10.20862
49. Park JY, Lhee SH, Choi JH, Park HK, Yu JW, Seo JB. Comparison of the clinical outcomes of single and double row repairs in rotator cuff tears. Am J Sports Med 2008;36:1310-6. doi:10.1177/ 0363546508315039
50. Park MC, ElAttrache NS, Tibone JE, Ahmad CS, Jun BJ, Lee TQ. Part I: Footprint contact characteristics for a transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique. J Shoulder Elbow Surg 2007;16:461-8. doi:10.1016/j.jse. 2006.09.010
51. 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;16:469-76. doi:10.1016/j.jse.2006.09.011
52. Reardon DJ, Maffulli N. Clinical evidence shows no difference between single- and double-row repair for rotator cuff tears. Arthroscopy 2007;23:670-3. doi:10.1016/j.arthro.2007.01.031
53. Saridakis P, Jones G. Outcomes of single-row and double-row arthroscopic rotator cuff repair: a systematic review. J Bone Joint Surg Am 2010;92:732-42. doi:10.2106/JBJS.I.01295
54. Shah AA, Milos S, Deutsch A. The strength and effects of humeral rotation on single- versus double-row repair techniques in small rotator cuff tears. Orthopedics 2010;33:22.
55. Smith CD, Alexander S, Hill AM, Huijsmans PE, Bull AMJ, Amis AA, et al. A biomechanical comparison of single and double-row fixation in arthroscopic rotator cuff repair. J Bone Joint Surg Am 2006;88:2425-31. doi:10.2106/JBJS.E.00697
56. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: Single-row versus dual-row fixation. Arthroscopy 2005;21:1307-16. doi:10. 1016/j.arthro.2005.08.011
57. Sugaya H, Maeda K, Matsuki K, Moriishi J. Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair: A prospective outcome study. J Bone Joint Surg Am 2007;89:953-60. doi:10.2106/JBJS.F.00512
58. Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res 1997;344:275-83.
59. Tuoheti Y, Itoi E, Yamamoto N, Seki N, Abe H, Minagawa H, et al. Contact area, contact pressure, and pressure patterns of the tendon-bone interface after rotator cuff repair. Am J Sports Med 2005;33: 1869-74. doi:10.1177/0363546505278256
60. Vaishnav S, Millett PJ. Arthroscopic rotator cuff repair: Scientific rationale, surgical technique, and early clinical and functional results of a knotless self-reinforcing double-row rotator cuff repair system. J Shoulder Elbow Surg 2010;19:83-90. doi:10.1016/j.jse.2009.12.012
61. Verma NN, Dunn W, Adler RS, Cordasco FA, Allen A, MacGillivray J, et al. All-arthroscopic versus mini-open rotator cuff repair: A retrospective review with minimum 2-year follow-up. Arthroscopy 2006;22:587-94. doi:10.1016/j.arthro.2006.01.019
62. Wall LB, Keener JD, Brophy RH. Clinical outcomes of double-row versus single-row rotator cuff repairs. Arthroscopy 2009;25:1312-8. doi:10.1016/j.arthro.2009.08.009
63. Waltrip RL, Zheng N, Dugas JR, Andrews JR. Rotator cuff repair. A biomechanical comparison of three techniques. Am J Sports Med 2003;31:493-7.
64. Yamamoto A, Takagishi K, Osawa T, Yanagawa T, Nakajima D, Shitara H, et al. Prevalence and risk factors of a rotator cuff tear in the general population. J Shoulder Elbow Surg 2010;19:116-20. doi:10. 1016/j.jse.2009.04.006