5 Points on
Improving Rotator Cuff Healing

Robert Z. Tashjian, MD

Over the past 15 to 20 years, there has been a dramatic increase in interest and research on rotator cuff repairs and tendon healing. More than 1700 articles have been written on rotator cuff repairs in the past 50 years, 80% just in the last 10 years. With increased interest in cuff repairs, there has been a subsequent increase in interest of repair outcomes, and more specifically, tendon healing. Common questions include why do repairs heal, how often, what can be done to improve healing rates and finally does healing really matter. The following article will outline 5 points regarding rotator cuff healing including whether tendon healing matters, what factors affect healing and what patient and surgeon specific factors that can be modified in order to improve healing after repair.

1 Is Healing Important?

Rotator cuff healing is not necessary for a good long-term functional outcome after rotator cuff repair, although healing will likely result in improved strength and range of motion (ROM).

Rotator cuff repair was historically performed through an open technique and long-term studies have shown durable functional results after repair.[1] The emphasis on early rotator cuff repair clinical series was initially placed on improvements in functionality including pain relief, motion, and strength. Ellman and colleagues[2] reported on 50 patients at an average of 3.5 years after open rotator cuff repair. Eighty-four percent of patients were satisfied after repair with longer preoperative duration of symptoms, larger tears, worse preoperative strength, and limited preoperative active motion all correlating with worse outcomes. Rotator cuff healing was not evaluated in most early outcome studies of rotator cuff repair.

The era of rotator cuff healing began with Harryman and colleagues[3] who used ultrasound to evaluate repair status after open rotator cuff repair and correlate healing status with functional outcomes. Overall, 65% of tears healed with 80% healing of single tendon tears and 32% healing of multiple tendon tears. Older age was found to correlate with worse healing and poorer healing correlated with worse functional outcomes as determined by the Simple Shoulder Test. The investigators concluded that age and tear size affect healing and healing affects function after repair.

Despite the data from Harryman and colleagues,[3] and others suggesting that healing affects function, excellent long-term outcomes after rotator cuff repair have been reported independent of healing. Jost and colleagues[4] reported on 20 patients after open rotator cuff repair with an average of 7.6 years after rotator cuff repair and documented failure of healing. Pain, shoulder function, and strength were reasonable and determined to be stable out to 7.6 years after rotator cuff repair even though healing did not occur. While this data suggest that healing is not required for reasonable outcomes after repair, there are several problems with this argument. These problems include the assumption is based on poor retrospective literature, most studies are likely underpowered, subgroup analyses were not performed and most literature extends to 5 or 10 years postoperative with unknown outcomes or consequences at 15 to 20 years after repair failure.

According to the current literature, rotator cuff repair healing is not necessary for good long-term outcomes however if the cuff stays intact then patients are likely to have improved strength, range of motion, and possibly less long-term disability, compared with patients who do not heal.

2 Patient Factors Affecting Healing Rates

Patient factors including age, tear size, and muscle quality should be recognized to identify patients at-risk for rotator cuff repair failure who may benefit from stronger repair constructs and slower rehabilitation.

Rotator cuff healing studies have identified several patient factors associated with healing after rotator cuff repair.[3,5,6] Older age, larger tear size, and poorer muscle quality have been identified as risk factors for repair failure. Information

Dr. Tashjian is Associate Professor, Department of Orthopaedics, University of Utah School of Medicine, Salt Lake City.

Author's Disclosure Statement: The author wishes to disclose that he receives grant funding from the Department of Veteran's Affairs relevant to the treatment of rotator cuff tears.

Address correspondence to: Robert Z. Tashjian, MD, University of Utah Orthopaedic Center, 590 Wakara Way, Salt Lake City, Utah 84018, (tel, 801-587-5457; fax, 801-587-5411; email, Robert.Tashjian@hsc.utah.edu).

Am J Orthop. 2013;42(4):160-165.

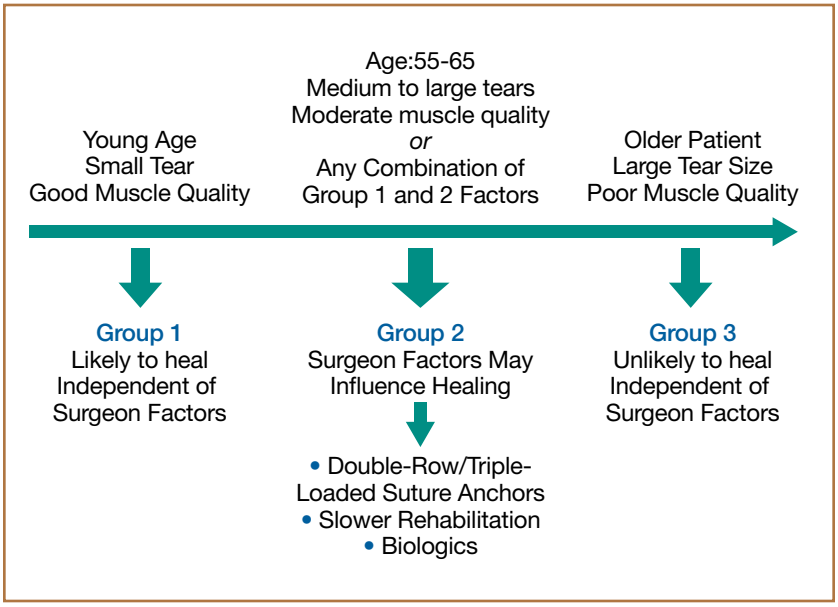

Figure 1. Continuum of rotator cuff healing from poor healers (Group 1) on the left and excellent healers (Group 3) on the right. Factors influencing healing are listed above. Group 2 patients have some limitations in healing which may be positively influenced by surgeon-related factors.

regarding healing success after rotator cuff repair may be used to identify patients in whom modification of surgeon-related factors may be utilized to improve structural success.

Older age has been identified in several studies as a risk factor for worse healing after open, single-row (SR) arthroscopic and double-row (DR)(conventional and suture-bridge) arthroscopic rotator cuff repairs.[3,5,7,8] Several studies have shown a tipping point for healing in the mid-60's with average ages of healed patients in the mid-50's and of the unhealed in the early to mid-60's.[3,5,7,8]

Tear size has also been correlated with rotator cuff tendon healing. Larger tears have been shown to have inferior healing rates after open, SR arthroscopic and DR (conventional and suture bridge) arthroscopic repairs.[3,5,9] Approximate healing rates for SR and DR repairs include 85% (SR) and 95% (DR) for small/medium sized tears and 24% (SR) and 67% (DR) for large/massive tears.[5,10,11]

Assessments of rotator cuff muscle quality, including both fatty infiltration and atrophy, have been shown that worse fatty infiltration and muscle atrophy correlate with worse healing.[6,12] Recently, Liem and colleagues[11] reported that stage 2 or higher preoperative fatty infiltration of the supraspinatus was predictive of worse postoperative tendon healing.[6]

Understanding which patient factors may negatively impact tendon healing will allow surgeons to employ various tactics to improve healing. Taking into consideration age, tears size, and muscle quality, patients can be categorized into 3 different groups on a continuum of rotator cuff healing (**Figure 1**). Healing is depicted on the horizontal bar where at the far left there is a high probability for healing and at the far right there is a very low probability for healing. Patients at the far left include young patients (<55 years) with small tears (<1 cm) and good muscle quality (Goutallier Stages 0 and 1). These can be considered Group 1 patients and will likely heal independent of surgeon-factors. Patients at the far right include older patients (>70 years) with large tears (>4 or 5 cm) and poor muscle quality (Goutallier Stages 3 and 4). These patients can be considered Group 3 patients and will likely not heal independent of surgeon-factors. In the middle are patients of middle age (55-65 years) with medium to large tears with moderate muscle quality or any patient with a combination of Group 1 and Group 3 factors. These patients constitute Group 2 and are the group where surgeon-controlled factors including stronger constructs (DR fixation, possibly SR repairs with triple-loaded anchors) and slower rehabilitation may push these patients to Group 1 and healing instead of Group 3 and repair failure.

3 The Role of Biomechanically Strong Repair Constructs

Stronger rotator cuff repair constructs (DR repairs or triple-loaded suture anchor repairs) should be considered in patients with some risk factors for impaired healing.

In the past 10 years, there has been an enormous amount of interest in improving rotator cuff repair strength. The transition from open to arthroscopic repairs coincided with concerns of the initial strength and durability of early arthroscopic anchor repairs. DR suture anchor repairs were subsequently developed to improve repair strength and potentially tendon healing and outcomes. Because of the wealth of information published on arthroscopic repairs, each SR and DR repair is far from similar making comparisons of various studies difficult. Nevertheless, some conclusions can be made regarding construct strength and the affect on repair healing and outcomes.

DR repairs have been shown, in general, to have superior biomechanical properties, compared with SR arthroscopic rotator cuff repairs (2 simple stitches per anchor). Meier and colleagues[13] determined that DR rotator cuff repairs restored 100% of the footprint while SR repairs restored only 46%. Mazzocca and colleagues[14] compared contact pressure between SR and DR repairs and determined that transosseous-equivalent repairs had statistically greater contact pressure and force when compared with SR repairs. Wall and colleagues[15] performed a systematic review of biomechanical

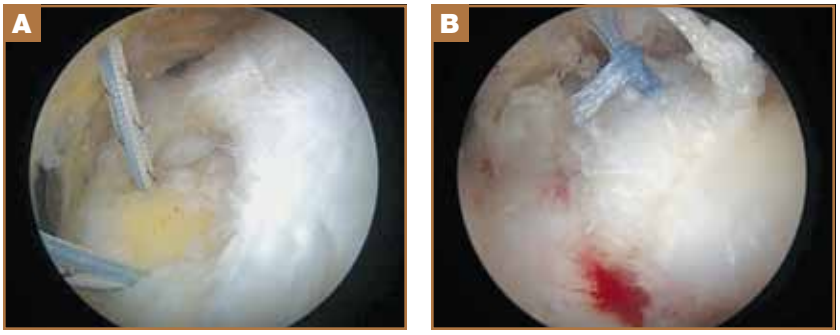

Figure 2. Single-row rotator cuff repair with triple-loaded anchors placed (A) and after cpmpleted repair with simple stitches (B).

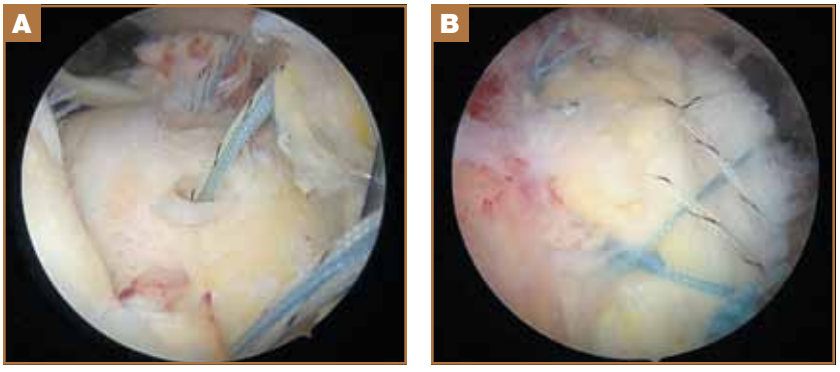

Figure 3. Transosseous equivalent double-row rotator cuff repair with medial row anchors in place (A) and after completed repair.

testing of arthroscopic repairs. They reviewed data from 12 studies and determined that 9 showed DR repairs had superior biomechanical properties when compared to single row repairs while 3 showed no difference. Based upon this data, DR repairs can be considered biomechanically superior to SR repairs using 2 sutures per anchor in a simple stitch configuration.

Recently, several biomechanical studies have been performed comparing the initial biomechanical properties of triple-loaded suture anchor repairs (simple stitches) **(Figures 2A, 2B)** with DR repairs (transosseous equivalent) (**Figures 3A, 3B**). Lorbach and colleagues[16] compared SR repairs with triple-loaded anchors and DR suture bridge repairs. The authors determined that the SR repairs have similar load to failure and cyclic displacement compared to DR suture-bridge repairs. Barber and colleagues[17] also compared SR triple loaded repairs with suture bridge repairs and reported reduced gap formation with the SR triple loaded repairs. Consequently, triple-loaded SR repairs may prove an alternate to DR repairs for patients in whom improved fixation may be desirable (Group 2) in order to push them towards healing.

The clinical data comparing SR and DR repairs is controversial and is clouded by the variety of repair techniques used. There is prospective data comparing SR repairs and DR repairs supporting no difference in healing rates while at the same time there is data supporting improved healing rates with DR repairs.[18-20] Numerous systematic reviews have been performed evaluating clinical studies comparing SR and DR repairs with most concluding that there is a structural advantage of improved healing rates with DR fixation but no evidence of clinical superiority with DR repairs.[21-23] A more detailed review of healing studies subdivided by tear size suggests that the differences in healing rates between SR and DR repairs is likely seen in larger tears with no differences in smaller sized tears.[24] Similarly, Park and colleagues[25] reported in a prospective study comparing SR and DR repairs that there was no functional advantage in small and medium sized tears, although there was a functional advantage in patients with large and massive tears.

Taking into account the biomechanical and clinical data regarding single- and DR cuff repairs, several conclusions can be made: (1) SR repairs with 2 sutures per anchor with simple stitches have inferior biomechanical properties, healing rates and possibly clinical outcomes (especially in larger tears) compared to DR repairs; (2) conventional DR repairs and transosseous equivalent DR repairs are likely clinically equivalent based upon healing rates and functional outcomes; (3) SR repairs with triple loaded anchors appear to have biomechanical properties similar to DR repairs and may be a viable alternative to DR repairs although clinical studies are lacking.

In general, a stronger construct—DR repair or maybe some SR variant (triple loaded anchors, MAC stitches, arthroscopic Mason-Allen stitches)—should be considered in patients with some risk factors for impaired healing (ie, older age, larger tear size, poorer muscle quality) as there is evidence suggesting some improvement in healing rates and potentially clinical outcomes.

4 Delaying Rehabilitation

Delayed rehabilitation may improve healing rates and does not affect long-term ROM after rotator cuff repair.

A variety of physical therapy regimens have been recommended during the postoperative period after rotator cuff repair. Historically, early passive motion was required after open rotator cuff surgery in order to prevent recalcitrant stiffness. With the advent of arthroscopic repairs, delayed rehabilitation has become an option as a result of less surgical trauma. A potential benefit of slower rehabilitation includes improved healing rates after arthroscopic repair as a result of less early stress on the repair.

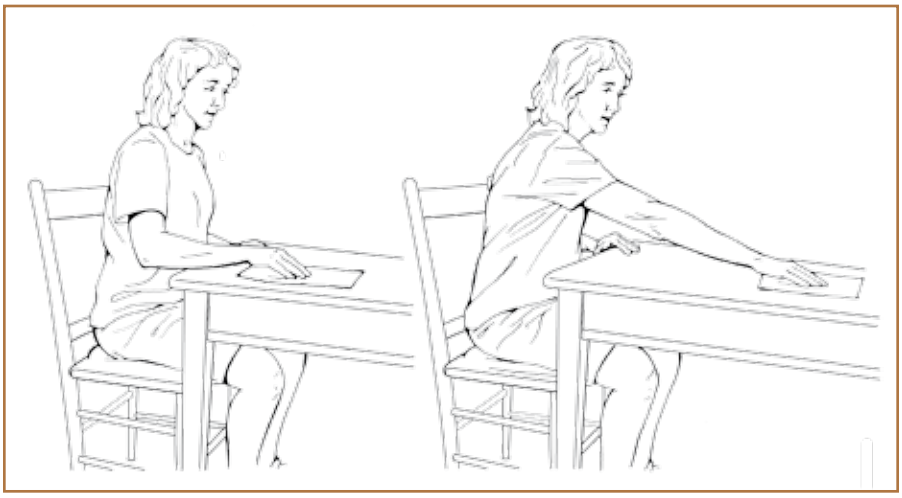

Figure 4. Table slide exercises can be instituted in patients with risk factors for the development of postoperative stiffness.

Despite arthroscopic repairs reducing the incidence of stiffness, it can still be a problem in certain patient populations. Targeting patients who may get stiff, even after arthroscopic repair, and initiating earlier rehabilitation might reduce the chances for long-term loss of motion.

Several authors have examined the influence of delayed rehabilitation after arthroscopic rotator cuff repair on postoperative motion. Parsons and colleagues[26] retrospectively reviewed patients who underwent arthroscopic cuff repair for a full-thickness tear followed by 6 weeks of sling immobilization without therapy. The authors concluded that, even in patients who developed early stiffness after conservative rehabilitation, long-term stiffness was unlikely with delayed rehabilitation. Huberty and colleagues[27] also looked at patients treated with sling immobilization and only external rotation motion (no elevation) for the first 6 weeks after an arthroscopic rotator cuff repair. They found only 5% of patients became dissatisfied with their result due to stiffness. Risk factors for the development of stiffness included preoperative adhesive capsulitis, calcific tendonitis, single tendon repairs, partial articular sided tendon avulsion repairs and any concomitant labral repair. If a patient had one identifiable risk factor, the incidence of stiffness was 13%. All unsatisfied patients elected to undergo arthroscopic release and all were satisfied after release. Schoolfield and Burkhart[28] followed-up the prior study by adding a table slide exercise to the at-risk group identified in the prior study (**Figure 4**). With the addition of the one exercise, the incidence of stiffness was reduced to 0%.

Several authors have evaluated the effect of conservative rehabilitation on the development of short-term and long-term stiffness as well as rotator cuff healing. Three prospective, randomized studies have been performed comparing delayed versus early passive motion after rotator cuff repair.[29-31] All 3 studies determined that there was no difference in final ROM or functional outcome scores between groups at one year postoperative. Cuff and colleagues,[29] Lee and colleagues,[30] and Kim and colleagues[3] all reported lower re-tear rates in the delayed rehabilitation groups, compared with the early motion groups although none of these differences were statistically significant (9% vs 15%, P = .47; 9% vs 23%, P = .11; and 12% vs 18%, P = .429, respectively).

Based on these results, slower rehabilitation does not appear to affect long-term stiffness in general. There are some groups of patients that might benefit from earlier motion in which introduction of one table slide exercise may limit the development of stiffness (**Figure 4**). While not statistically significant, there does appear to be a trend that delayed motion may improve healing rates after cuff repair. Consequently, in patients at risk for limited tendon healing (ie, large tears, older patients, poor muscle quality), slower rehabilitation can be initiated to improve healing rates with limited risk for the development of stiffness. Early passive motion may be considered in smaller tears or in patients with other risk factors for the development of stiffness.

5 Does Platelet-Rich Plasma Improve Healing and Outcomes?

Platelet-rich plasma (PRP) has a limited effect on rotator cuff repair healing and currently has a limited role in rotator cuff surgery.

At this point in time, most advances in improvements of healing after rotator cuff repair have focused on improved initial biomechanical fixation or changes in postoperative rehabilitation. Limited data exists on biologic augments to improve rotator cuff healing although this has been increasing over the past several years. At this point in time, PRP or platelet-rich fibrin matrix (PRFM) are the only augments that have been utilized clinically in an attempt to improve healing (**Figure 5**).

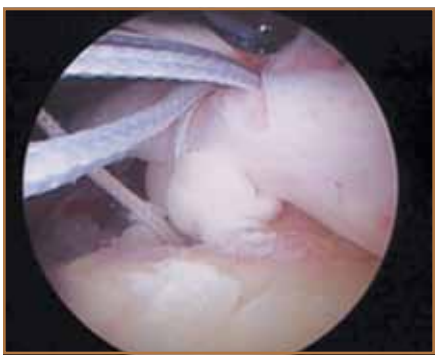

Figure 5. Platelet-rich fibrin matrix augmentation of an arthroscopic rotator cuff repair.

Currently, there have been 6 published clinical reports of the usage of PRP or PRFM as a biologic augment for rotator cuff healing. Five of the

6 studies report that PRP had no positive effect on healing after rotator cuff repair.[32-36] Randelli and colleagues,[32] Jo and colleagues,[33] and Castricini and colleagues[34] all reported that PRP had no effect on tendon healing rates. Bergeson and colleagues[35] compared repairs augmented with PRFM to those without augmentation in tears at-risk for healing and found significantly worse healing in the PRFM group (44%), compared with the non-PRFM group (62%) after arthroscopic repair. Rodeo and colleagues[36] recently reported similar findings of a negative effect of PRFM augmentation on cuff healing. Overall, these studies support that PRP or PRFM augmentation has a limited role in improving healing rates or outcomes after arthroscopic rotator cuff repair.

Barber and colleagues[37] reported the only results that suggest a positive effect of PRP augmentation on rotator cuff healing. They stated that PRP significantly improved healing in small and medium sized tears (<3 cm) with healing rates of augmented and non-augmented repairs being 86% and 50%, respectively. There are several drawbacks of this study limiting its applicability to a majority of currently performed repairs. First, the authors used relatively poor fixation with an average of 1.4 suture anchors per repair with all being double-loaded anchors in a SR construct. Second, in the large and massive tears (accounting for 30% of all tears) the authors only used 2 double-loaded anchors per repair for a total of 4 stitches for all tears over 3 cm in anteroposterior length. In general, the initial fixation for these repairs was relatively poor limiting the ability to translate the results to surgeons using stronger initial constructs. Whatever benefits the PRP may have provided would likely have been nullified if a stronger initial construct had been utilized.

Based upon the current clinical data, there is limited evidence that PRP augmentation improves healing rates after arthroscopic rotator cuff repair therefore we do not recommend its usage at this time.

Conclusion

The treatment of rotator cuff tears has made significant advancements over the past 20 years since Harryman brought to light the importance of healing after rotator cuff repair. Despite benefits of improved strength and motion, healing after rotator cuff repair is not mandatory to achieve a good functional result. Older age, larger tear sizes, and poorer muscle quality are patient factors negatively affecting rotator cuff healing. Patients with some of these factors may benefit from stronger constructs (eg, DR repairs or single row repairs with triple loaded anchors) or slower rehabilitation. Slower rehabilitation after arthroscopic surgery does not lead to long term stiffness but may provide improved healing. PRP or PRFM augmentation of rotator cuff repairs does not appear to provide any benefit with regards to healing. In the future, the development of new biologic augments with a positive effect on tendon healing and thereby functional outcomes will be paramount in continuing the advancement of rotator cuff surgery over the next decade.

References

1. Galatz LM, Griggs S, Cameron BD, Iannotti JP. Prospective longitudinal analysis of postoperative shoulder function: a ten-year follow-up study of full-thickness rotator cuff tears. *J Bone Joint Surg Am*. 2001;83-A(7):1052-1056.
2. Ellman H, Hanker G, Bayer M. Repair of the rotator cuff. End-result study of factors influencing reconstruction. *J Bone Joint Surg Am*. 1986;68(8):1136-1144.
3. Harryman DT 2nd, Mack LA, Wang KY, Jackins SE, Richardson ML, Matsen FA 3rd. Repairs of the rotator cuff. Correlation of functional results with integrity of the cuff. *J Bone Joint Surg Am*. 1991;73(7):982-989.
4. Jost B, Zumstein M, Pfirrmann CW, Gerber C. Long-term outcome after structural failure of rotator cuff repairs. *J Bone Joint Surg Am*. 2006;88(3):472-479.
5. Cho S, Lee BG, Rhee YG. Arthroscopic rotator cuff repair using a suture bridge technique: is repair integrity actually maintained? *Am J Sports Med*. 2011;39(10):2108-2116.
6. Liem D, Lichtenberg S, Magosch P, Habermeyer P. Magnetic resonance imaging of arthroscopic supraspinatus tendon repair. *J Bone Joint Surg Am*. 2007;89(8):1770-1776.
7. 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(6):1229-1240.
8. Tashjian RZ, Hollins AM, Kim HM, et al. Factors affecting healing rates after arthroscopic double-row rotator cuff repair. *Am J Sports Med*. 2010;38(12):2435-2442.
9. Gulotta LV, Nho SJ, Dodson CC, Adler RS, Altchek DW, MacGillivray JD; Arthroscopic Rotator Cuff Registry. Prospective evaluation of arthroscopic rotator repairs at 5 years: part II – prognostic factors for clinical radiographic outcomes. *J Shoulder Elbow Surg*. 2011;20(6):941-946.
10. 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(3):290-299.
11. 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(5):953-960.
12. 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):275-283.
13. Meier SW, Meier JD. Rotator cuff repair: the effect of double-row fixation on three-dimensional repair site. *J Shoulder Elbow Surg*. 2006;15(6):691-696.
14. Mazzocca AD, Bollier MJ, Ciminiello AM, et al. Biomechanical evaluation of arthroscopic rotator cuff repairs over time. *Arthroscopy*. 2010;26(5):592-599.
15. Wall LB, Keener JD, Brophy RH. Double-row vs single-row rotator cuff repair: a review of the biomechanical evidence. *J Shoulder Elbow Surg*. 2009;18(6):933-941.
16. Lorbach O, Kieb M, Raber F, Busch LC, Kohn D, Pape D. Comparable biomechanical results for a modified single-row rotator cuff reconstruction using triple-loaded suture anchors versus a suture-bridging double-row repair. *Arthroscopy*. 2012;28(2):178-187.
17. Barber FA, Herbert MA, Schroeder FA, Aziz-Jacobo J, Mays MM, Rapley JH. Biomechanical advantages of triple-loaded suture anchors compared with double-row rotator cuff repairs. *Arthroscopy*. 2010;26(3):316-323.
18. Ma HL, Chiang ER, Wu HT, et al. Clinical outcome and imaging of arthroscopic single-row and double-row rotator cuff repair: a prospective randomized trial. *Arthroscopy*. 2012;28(1):16-24.
19. Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: magnetic resonance imaging and early clinical evaluation. *Am J Sports Med*. 2009;37(4):674-682.
20. CharoussettC, 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(8):1247-1253.
21. DeHaan AM, Axelrad TW, Kaye E, Silvestri L, Puskas B, Foster TE. Does double-row rotator cuff repair improve functional outcome of partients

compared with single-row technique? A systematic review. *Am J Sports Med*. 2012;40(5):1176-1185.

22. Prasathaporn N, Kuptniratsaikul S, Kongrukgreatiyos K. Single-row repair versus double-row repair of full-thickness rotator cuff tears. *Arthroscopy*. 2011;27(7):978-985.
23. 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(3):732-742.
24. 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(4):835-841.
25. 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(7):1310-1316.
26. Parsons BO, Gruson KI, Chen DD, Harrison AK, Gladstone J, Flatow EL. Does slower rehabilitation after arthroscopic rotator cuff repair lead to long-term stiffness? *J Shoulder Elbow Surg*. 2010;19(7):1034-1039.
27. Huberty DP, Schoolfield JD, Brady PC, Vadala AP, Arrigoni P, Burkhart SS. Incidence and treatment of postoperative stiffness following arthroscopic rotator cuff repair. *Arthroscopy*. 2009;25(8):880-890.
28. Koo SS, Parsley BK, Burkhart SS, Schoolfield JD. Reduction of postoperative stiffness after arthroscopic rotator cuff repair: results of a customized physical therapy regiment based on risk factors for stiffness. *Arthroscopy*. 2011;27(2):155-160.
29. Kim YS, Chung SW, Kim JY, Ok JH, Park I, Oh JH. Is early passive motion exercise necessary after arthroscopic rotator cuff repair? *Am J Sports Med*. 2012;40(4):815-821.
30. Cuff DJ, Pupello DR. Prospective randomized study of arthroscopic rotator cuff repair using an early versus delayed postoperative physical therapy protocol. *J Shoulder Elbow Surg*. 2012;21(11):1450-1455.
31. Lee BG, Cho NS, Rhee YG. Effect of two rehabilitation protocols on range of motion and healing rates after arthroscopic rotator cuff repair: aggressive versus limited early passive exercises. *Arthroscopy*. 2012;28(1):34-42.
32. Castricini R, Longo UG, De Benedeto M, et al. Platelet-rich plasma augmentation for arthroscopic rotator cuff repair. A randomized controlled trial. *Am J Sports Med*. 2011;39(2):258-265.
33. Randelli P, Arrigoni P, Ragone V, Aliprandi A, Cabitza P. Platelet rich plasma in arthroscopic rotator cuff repair: a prospective RCT study, 2-year follow-up. *J Shoulder Elbow Surg*. 2011;20:518-528.
34. Jo CH, Kim JE, Yoon KS, et al. Platelet-rich plasma accelerate recovery after rotator cuff repair? A prospective cohort study. *Am J Sports Med*. 2011;39(10):2082-2090.
35. Bergeson AG, Tashjian RZ, Greis PE, Crim J, Stoddard GJ, Burks RT. Effects of platelet-rich fibrin matrix on repair integrity of at-risk rotator cuff tears. *Am J Sports Med*. 2012;40(2):286-293.
36. Rodeo SA, Delos D, Williams RJ, Adler RS, Pearle A, Warren RF. The effect of platelet-rich fibrin matrix on rotator cuff tendon healing: a prospective, randomized clinical study. *Am J Sports Med*. 2012;40(6):1234-1241.
37. Barber A, Hrnack SA, Snyder SJ, Hapa O. Rotator cuff repair healing influenced by platelet-rich plasma construct augmentation. *Arthroscopy*. 2011;27(8):1029-1035.