Revision Rotator Cuff Reconstruction for Large Tears With Retraction: A Novel Technique Using Autogenous Tendon and Autologous Marrow

Hillel D. Skoff, MD

Abstract

Revision rotator cuff reconstruction for large tears with retraction results in a high rate of recurrent cuff tearing. To try to obtain more consistent results, I conducted a study of a technique that addresses the potential factors involved.

Ten patients (7 men, 3 women) were enrolled. Mean age was 58 years. Mean follow-up was 24 months. Mean time between primary and revision cuff surgery was 36 months. The cardinal inclusion criterion was a symptomatic, full-thickness rotator cuff tear with at least 3 cm of retraction in a shoulder that previously underwent rotator cuff repair. Ultrasound was used for postoperative radiographic assessment of cuff integrity. Validated Constant, American Shoulder and Elbow Surgeons (ASES), and University of California Los Angeles (UCLA) shoulder scoring systems were used. Surgical technique included mini-open incision, adequate débridement and mobilization of remaining cuff, reconstitution of cuff defect with autogenous biceps tendon incubated in concentrated autologous bone marrow, and sewing under zero tissue tension.

Constant, ASES, and UCLA scores improved significantly (standard error at .001). Ultrasound revealed 0% incidence of full-thickness rotator cuff retearing.

In patients with large recurrent retracted rotator cuff tears the technique presented in the current study consistently yields satisfactory clinical results and promotes rotator cuff tissue healing without full-thickness retearing.

Primary rotator cuff repair is a common procedure that consistently yields favorable clinical results.[1] Revision rotator cuff repair and reconstruction yield less consistent clinical results and are associated with a significant incidence of recurrent cuff tearing.[2] Possible factors contributing to the loss of tissue continuity have included poor quality or frank loss of rotator cuff tissue, diminished biological potential of the rotator cuff tendon, and excessive mechanical stress on or strain of the reconstructive surgical construct.[3]

I conducted a pilot study involving a technique that addresses these potential factors, amalgamating several contemporary surgical methods with the addition of a novel step: an autogenous tendon graft incubated in autologous bone marrow concentrate.

Materials and Methods

Ten consecutive patients (7 men, 3 women) enrolled in this retrospective case series. Mean age at time of surgery was 58 years (range, 47-65 years). Mean follow-up was 24 months (range, 12-44 months), and no patients were lost to follow-up. Mean time between original primary repair and current reconstruction was 36 months (range, 6-120 months). Criteria for enrollment included unremitting shoulder pain, radiographs showing no significant degenerative joint disease, magnetic resonance imaging confirming a large (3-5 cm) full-thickness rotator cuff tear with retraction, and history of prior rotator cuff repair on the affected shoulder without associated biceps tenodesis. The intraoperative inclusion criterion was direct visualization of a 3- to 5-cm full-thickness rotator cuff tear with retraction of at least 3 cm. Validated Constant, American Shoulder and Elbow Surgeons (ASES), and University of California Los Angeles (UCLA) shoulder scoring systems were used to collect range-of-motion, pain, strength, daily function, and patient satisfaction data before and after surgery. Standard error was calculated. Two-sample *t* test was used for preoperative–postoperative comparisons. Postoperative integrity of the rotator cuff reconstruction was evaluated by an independent full-time academic musculoskeletal radiologist using dynamic diagnostic ultrasound (iU22 xMatrix Ultrasound System [Philips Healthcare] at L 9-3 MHz). Informed consent was obtained from each patient.

Figure 1. Aspiration of iliac marrow from dorsal table with 14-gauge needle.
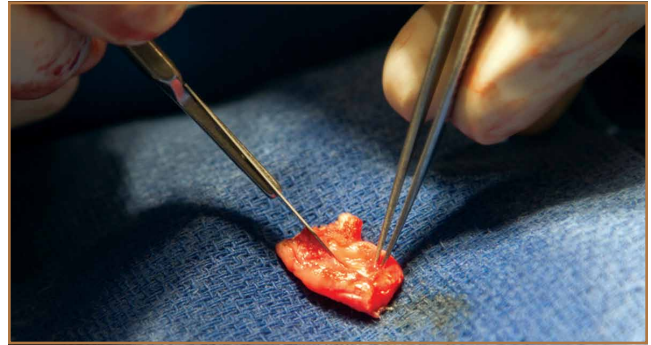

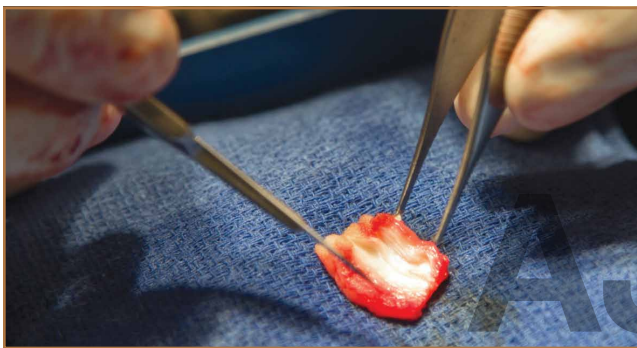Figure 2. Harvested proximal biceps tendon graft longitudinally split 50%.

Figure 3. Further splaying of biceps tendon to transform shape from cylindrical to flat.

Figure 4. Processed tendon graft immersed in concentrated marrow.

The study was approved by institutional review board.

After induction of general anesthesia, each patient was placed in the lateral decubitus position. Bone marrow (60 mL) was aspirated through a 14-gauge needle from a dorsal iliac table, just inferior to the iliac crest (**Figure 1**). The patient was then placed into the beach-chair position on a surgical shoulder table. The aspirated marrow was centrifuged at 2800 and 3800 rpm for 14 to 17 minutes (Magellan Autologous Platelet Separator; Arteriocyte Medical Systems) to yield 10 mL of a concentrated (4- to 5-fold) mixture of platelet-rich plasma (PRP) and mesenchymal stem cells. Surgery was performed through a 3-cm oblique anterior mini-open incision between the anterior corner of the acromion and the coracoid process, as I previously described.[4] The deltoid muscle was split, not detached. Acromioplasty and release of the coracoacromial ligament were performed. The rotator cuff was inspected under ×4.5 optical magnification. The cuff tissue was mobilized and débrided back to a healthy-appearing margin. The size and shape of the rotator cuff defect were then estimated. The long head of the biceps was harvested from its origin just distal to the superior glenoid labrum unto the intertubercular sulcus on the proximal humerus. The remainder of the biceps tendon was tenodesed to the surgical neck of the humerus. The biceps tendon graft was then manipulated and fashioned

Figure 5. Tendon graft with suture strands from bone anchors at greater tuberosity.

(by longitudinal partial-thickness incision and expansion) to fit the cuff defect (**Figures 2, 3**). The expanded graft was incubated in the concentrated marrow (10 mL) for 60 minutes (**Figure 4**). Débridement at the base of the greater tuberosity down to bleeding cancellous bone was followed by insertion of multiple bone anchors bearing several strands of No. 2 synthetic suture. These strands were then passed through
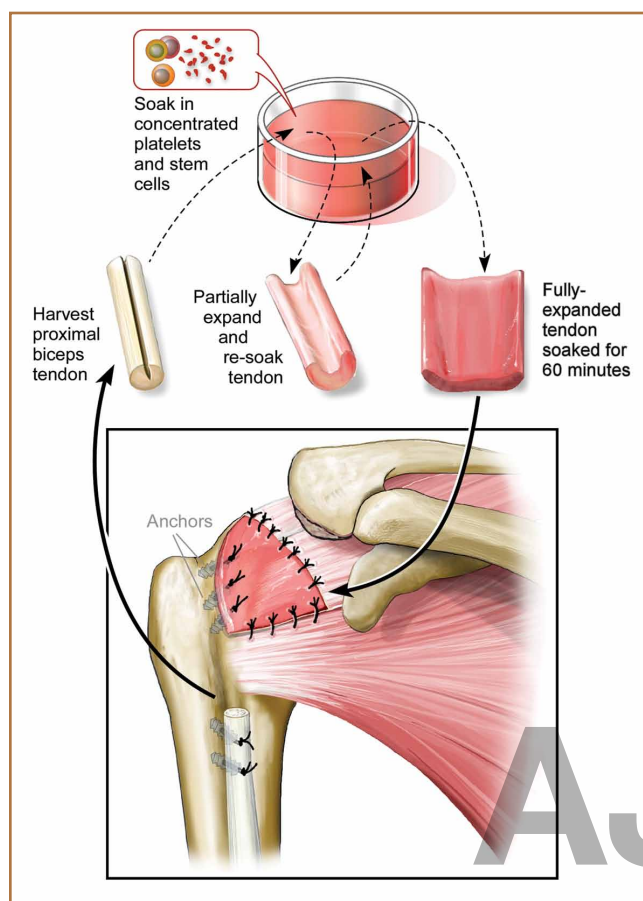
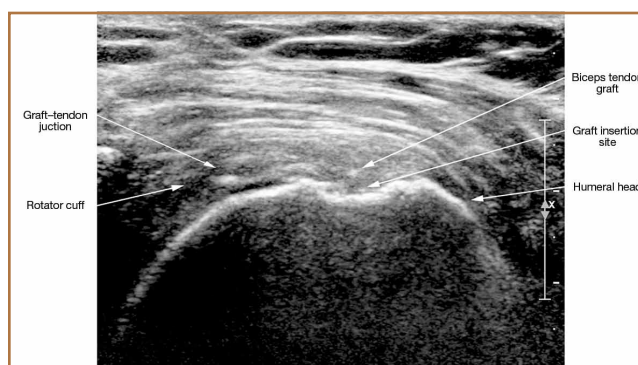**Figure 6.** Essential elements of graft processing and insertion.

Figure 7. Shoulder ultrasound at 12-month follow-up shows intact biceps graft in continuity with rotator cuff.
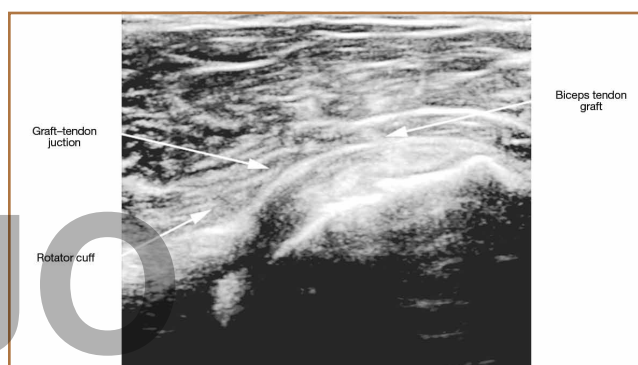

Figure 8. Shoulder ultrasound at 44-month follow-up shows excellent tissue integration of biceps graft.

the biceps tendon graft for secure fixation (**Figure 5**). The débrided end of the rotator cuff was then sewn to the biceps tendon graft using locking stitches under zero tissue tension with the arm in full adduction. The free end of the graft was sewn to the subscapularis tendon (**Figure 6**). The remaining marrow concentrate was injected both deep and superficial to the rotator cuff construct. No additional wound irrigation fluid was injected or suction drain inserted. After surgery, the patient was placed into an abduction pillow for 1 month and then engaged in passive motion for 1 month. Active-assisted motion began 3 months after surgery.

Results

Clinically, all patients improved with respect to pain, motion, strength, function, and satisfaction by virtue of the reconstructive surgery. After surgery, mean Constant score was increased, from 13 to 71 (P < .001). Mean ASES score increased from 18 to 75 (P < .001). Mean UCLA score increased from 4 to 28 (P < .001) (**Table**). Ultrasound showed 0% incidence of full-thickness retearing. Dynamic scanning during abduction showed maintained reduction of the humeral head within the glenoid socket; superior subluxation of the humeral head was not detected. The biceps tendon graft was continuous with the rotator cuff tendon, indicative of graft integration: tissue

healing at the graft–bone and graft–tendon interfaces (**Figures 7, 8**). There were no intraoperative or postoperative patient-related complications.

Discussion

Primary rotator cuff surgery is beneficial.[5] Irrespective of technique, open versus arthroscopic,[6] single- versus double-row repair,[7] the clinical results have been satisfactory.[8] Nevertheless, the "tissue failure" rate of rotator cuff surgery (full-thickness discontinuity of rotator cuff) has been as high as 31% in primary repairs.[9] In revision rotator cuff repair and reconstruction, the radiographic tissue failure rate has been even higher, particularly in the setting of chronic large tears with retraction, with tissue failure rates up to 91%.[10] Although small to medium full-thickness tears and retears are well tolerated by patients with reduced activity levels,[11] and pain symptoms do not necessarily correlate with rotator cuff tear size,[12] large retracted full-thickness tears in active patients seldom result in optimal clinical outcomes or patient satisfaction.[13,14] In addition, although recurrent tearing does not preclude a satisfactory clinical result, maintenance of cuff tissue integrity tends to produce a better objective clinical score and a more desirable clinical outcome.[2]

Few evidence-based restorative solutions exist for large

recurrent rotator cuff tears with retraction in active non-geriatric patients.[15] The no-treatment option in this context may result in gradual enlargement of the tear, chronic pain, weakness, and progressive degeneration of the glenohumeral joint and acromiohumeral confluence—so-called rotator cuff arthropathy, for which reverse total shoulder arthroplasty is required.[16,17] Partial repair of a large rotator cuff tear by margin convergence, interval slide, split deltoid flap, or nonanatomical reinsertion may improve clinical outcome scores but may not alter or prevent the progressive degenerative changes associated with rotator cuff arthropathy.[18,19] Synthetic scaffolds with and without biological enhancement have been used with varying degrees of success, particularly pain improvement and tissue integration.[20] Nevertheless, the failure rate has been reported to be 17% to 51%,[21] and no evidence exists that allograft augmentation improves functional outcomes.[22] Tendon transfer using the latissimus dorsi has also proved to be a surgical alternative in younger, active patients.[23] However, dissection in this procedure is a major undertaking for both surgeon and patient—compared with the minimally invasive technique used in the present study.[24]

I selected a cohort of active, symptomatic patients for application of a synthesis of accepted surgical techniques through a mini-open incision in order to improve the reliability of the surgical construct while minimizing surgical morbidity. Débridement of marginal tissue, safe mobilization of remaining cuff, and tension-free suture line using locking sutures maximized the mechanical strength of the construct.[25,26] Biological enhancement with autogenous tissue (the patient's own biceps tendon) as graft material (scaffolding), as well as autologous concentrated marrow delivering viable responding cells and chemokine/cytokine biofactors, increased the probability of reparative activity at the graft site.[27] The net effect was consistent tissue healing at a biologically challenging locus. Nonenhanced biceps tendon grafting in the setting of "irreparable" primary rotator cuff repair has had a 40-year history of orthopedic utility and an excellent record of clinical success.[28] Nevertheless, the retear rate has been 7% to 30%.[29] There are no previous reports of biologically enhanced autogenous biceps tendon grafting for reconstruction of a torn rotator cuff, either primary or in the setting of chronic revision surgery.

Previous well-designed PRP enhancement studies in the context of primary rotator cuff repair failed to demonstrate a consistent benefit with concentrated platelet-only augmentation.[30,31] The shared experimental design of these published studies used intra-articular injection as the sole delivery method without guarantee that the injected platelets would migrate, adhere to, and persist at the intended destination, the healing edge of the rotator cuff. In the present study, extended exposure of the splayed tendon graft by incubation in concentrated marrow was specifically designed to increase the probability that biologically active components would settle at the desired location by cellular seeding and plasmatic imbibition.[32] Furthermore, use of PRP for growth factor (platelet-derived, PDGF; basic fibroblast, bFGF; transforming, TGF-β; epidermal, EGF; vascular endothelial, VEGF; connective tissue, CTGF) therapy, in addition to pluripotential mesenchymal cells for marrow-derived stem cell therapy, is in theory biologically superior to use of PRP alone.[33,34]

The recent expansion of information about biologics has generated much interest in augmentation of soft-tissue healing. Unfortunately, the optimal technique of using cellular processing to upregulate stem-cell capacity at the graft interface is yet to be defined.[35] Clinical studies using PRP and related products

Table. Patient Data and Results

Pt	Age, y	Sex	Follow-Up,[a] mo	Time 1-2,[b] mo	MRI Before Revision	Constant Pre/Post, 0-100	UCLA Pre/Post, 0-35	ASES Pre/Post, 0-100	Ultrasound After Revision
						Score			
1	64	F	24	21	No FA	4/64	2/26	13/67	No FTT
2	59	M	38	12	No FA	7/60	0/21	37/74	No FTT
3	52	M	44	120	No FA	14/65	0/23	8/50	No FTT
4	62	M	19	28	Mild FA IS	21/63	3/28	12/68	No FTT
5	65	M	13	72	Mild FA SS	23/80	6/33	28/92	No FTT
6	48	M	27	6	No FA	10/78	5/27	16/80	No FTT
7	64	F	21	20	No FA	17/83	10/33	26/90	No FTT
8	64	M	19	50	FA	14/78	7/34	21/91	No FTT
9	57	F	12	6	No FA	8/71	2/26	3/68	No FTT
10	47	M	25	25	No FA	12/65	4/27	19/72	No FTT

Abbreviations: ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; FA, fatty atrophy of rotator cuff muscles; FTT, full-thickness tear of rotator cuff tendons; IS, infraspinatus; MRI, magnetic resonance imaging; SS, supraspinatus; UCLA, University of California Los Angeles Shoulder Rating Scale.
[a]Time between revision surgery and study.
[b]Time between first and second rotator cuff procedures.

to promote tendon healing have been both inconsistent and contradictory with respect to benefit of outcome. As we have been unable to harness the biological potential of this medium, application of biologics in contemporary clinical orthopedics remains narrow, random, and infrequent. The technique presented in this clinical series appears to be a small advancement in a positive direction. The described construct provides a starting point for study, combining mechanical as well as biological steps to promote rotator cuff healing. The consistency of the outcome in a clinical model in which retearing is an expectation rather than an exception is noteworthy. The zero tissue failure rate at 1 to 4 years, compared with the literature values in similar patient cohorts, is very promising.[36] The clinical outcome as measured by validated shoulder scores is also comparable to literature outcome values.[19] Also noteworthy is the dynamic stability the construct gives to the glenohumeral joint. Ideally, the reconstructed rotator cuff provides active force coupling with the deltoid, simulating normal shoulder biomechanics. At a minimum, the reconstructed cuff provides a viable passive barrier to superior migration of the humeral head—thus supporting the mechanical efficiency of the deltoid and preventing rotator cuff arthropathy.

This study's small sample (10 patients) puts its conclusions at risk for type I statistical error, in that too few patients were examined over a long enough period to demonstrate failure. Nevertheless, retears typically occur within 6 months of repair.[37,38] Therefore, minimum follow-up of 1 year was deemed sufficient. None of the 10 patients had diabetes or another chronic comorbidity. Nine of the 10 had either no or only mild preoperative fatty atrophy of the rotator cuff muscles. Eight of the 10 were nonsmokers. These factors, which suggest optimal surgical candidates, may prove to be significant as the clinical series expands over time. Incubation of the autogenous biceps graft in concentrated marrow for 60 minutes was arbitrarily chosen. In future in vitro examination, marrow cell viability as a function of incubation time will be assessed.

Conclusion

In active, middle-aged patients with chronic recurrent large retracted rotator cuff tears, the technique presented here, using autogenous biceps tendon and autologous concentrated marrow containing PRP and mesenchymal cells, consistently yielded satisfactory clinical results and promoted rotator cuff tissue healing without full-thickness retearing.

. . . .

References

1. Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National trends in rotator cuff repair. *J Bone Joint Surg Am*. 2012;94(3):227-233.
2. Kim HM, Caldwell JM, Buza JA, et al. Factors affecting satisfaction and shoulder function in patients with a recurrent rotator cuff tear. *J Bone Joint Surg Am*. 2014;96(2):106-112.
3. George MS, Khazzam M. Current concepts review: revision rotator cuff repair. *J Shoulder Elbow Surg*. 2012;21(4):431-440.
4. Skoff HD. Conservative open acromioplasty. *J Bone Joint Surg Br*. 1995;77(6):933-936.
5. Mather RC 3rd, Koenig L, Acevedo D, et al. The societal and economic value of rotator cuff repair. *J Bone Joint Surg Am*. 2013;95(22):1993-2000.
6. Sauerbrey AM, Getz CL, Piancastelli M, Iannotti JP, Ramsey ML, Williams GR. Arthroscopic versus mini-open rotator cuff repair: a comparison of clinical outcome. *Arthroscopy*. 2005;21(12):1415-1420.
7. Koh KH, Kang KC, Lim TK, Shon MS, Yoo JC. Prospective randomized clinical trial of single- versus double-row suture anchor repair in 2- to 4-cm rotator cuff tears: clinical and magnetic resonance imaging results. *Arthroscopy*. 2011;27(4):453-462.
8. Galatz LM, Griggs S, Cameron BD, Iannotti JP. Prospective longitudinal analysis of post-operative shoulder function: a ten-year follow-up study of full thickness rotator cuff tears. *J Bone Joint Surg Am*. 2001;83(7):1052-1056.
9. Oh JH, Kim SH, Kang JY, Oh CH, Gong HS. Effect of age on functional and structural outcome after rotator cuff repair. *Am J Sports Med*. 2010;38(4):672-678.
10. Kim JH, Kim SH, Lee SK, Seo JW, Chun YMC. Arthroscopic repair of massive contracted rotator cuff tears: aggressive release with anterior and posterior interval slides do not improve cuff healing and integrity. *J Bone Joint Surg Am*. 2014;95(16):1482-1488.
11. Moosmayer S, Lund G, Seljom US, et al. Tendon repair compared with physiotherapy in the treatment of rotator cuff tears. *J Bone Joint Surg Am*. 2014;96(18):1504-1514.
12. Dunn WR, Kuhn JE, Sanders R, et al. Symptoms of pain do not correlate with rotator cuff tear severity. *J Bone Joint Surg Am*. 2014;96(10):793-800.
13. Lubiatowski P, Kaczmarek P, Dzianach M, et al. Clinical and biomechanical performance of patients with failed rotator cuff repair. *Int Orthop*. 2013;37(12):2395-2401.
14. Holtby R, Razmjou H. Relationship between clinical and surgical findings and reparability of large and massive rotator cuff tears: a longitudinal study. *BMC Musculoskelet Disord*. 2014;15:180.
15. Nho SJ, Delos D, Yadav H, et al. Biomechanical and biological augmentation for the treatment of massive rotator cuff tears. *Am J Sports Med*. 2010;38(3):619-629.
16. Moosmayer S, Tariq R, Stiris M, Smith HJ. The natural history of asymptomatic rotator cuff tears: a three-year follow-up of fifty cases. *J Bone Joint Surg Am*. 2013;95(14):1249-1255.
17. Neer CS 2nd, Craig EV, Fukuda H. Cuff-tear arthropathy. *J Bone Joint Surg Am*. 1983;65(9):1232-1244.
18. Bartl C, Louloumentas P, Konstantin H, et al. Long-term outcome and structural integrity following open repair of massive rotator cuff tears. *Int J Shoulder Surg*. 2012;6(1):1-8.
19. Paxton ES, Teefey SA, Dahiya N, Keener JD, Yamaguchi K, Galatz LM. Clinical and radiographic outcomes of failed repairs of large or massive rotator cuff tears: minimum ten-year follow-up. *J Bone Joint Surg Am*. 2013;95(7):627-632.
20. Longo UG, Lamberti A, Maffulli N, Denaro V. Tendon augmentation grafts: a systematic review. *Br Med Bull*. 2010;94:165-188.
21. Ciampi P, Scotti C, Nonis A, et al. The benefit of synthetic versus biological patch augmentation in the repair of posterosuperior massive rotator cuff tears: a 3-year follow-up study. *Am J Sports Med*. 2014;42(5):1169-1175.
22. Murhi AM. Rotator cuff tears and cuff tear arthropathy. In: Boyer MI, ed. *AAOS Comprehensive Orthopedic Review*. Vol 2. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2014:921-929.
23. Namdari S, Voleti P, Baldwin K, Glaser D, Huffman GR. Latissimus dorsi tendon transfer for irreparable rotator cuff tears: a systematic review. *J Bone Joint Surg Am*. 2012;94(10):891-898.
24. Gerber C, Rahm SA, Catanzaro S, Farshad M, Moor BK. Latissimus dorsi tendon transfer for treatment of irreparable posterosuperior rotator cuff tears: long-term results at a minimum follow-up of ten years. *J Bone Joint Surg Am*. 2013;95(21):1920-1926.
25. Wagner JP, Krushall RJ, Masqueloet A, Gerber C. Anatomy and relationships of the suprascapular nerve: anatomical constraints to mobilization of the suprascapular and infraspinatus muscles in the management of massive rotator cuff tears. *J Bone Joint Surg Am*. 1992;74(1):36-45.

26. Ponce BA, Hosemann CD, Reghava P, Tate JP, Sheppard ED, Ebenhardt AW. A biomechanical analysis of controllable intraoperative variables affecting the strength of rotator cuff repairs at the suture–tendon interface. *Am J Sports Med*. 2013;41(10):2256-2261.

27. Thomopoulos S. Tendon and ligaments. In: Boyer MI, ed. *AAOS Comprehensive Orthopedic Review*. Vol 2. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2014:105-111.

28. Sano H, Mineta M, Kitz A, Itoi E. Tendon patch grafting using the long head of the biceps for irreparable massive rotator cuff tears. *J Orthop Sci*. 2010;15(3):310-316.

29. Rhee YG, Cho NS, Lim CT, Yi JW, Vishvanathan T. Bridging the gap in immobile massive rotator cuff tears: augmentation using the tenotomized biceps. *Am J Sports Med*. 2008;36(8):1511-1518.

30. Castricini R, Longo UG, De Benedetto 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.

31. Rodeo SA, Delos, D, Williams, RJ, Adler RS, Pearle A, Warren RF. The effects of platelet-rich fibrin matrix on rotator cuff tendon healing: a prospective, randomized clinical study. *Am J Sports Med*. 2012;40(6):1234-1241.

32. Beitzel K, McCarthy MB, Cote MP, et al. Properties of biologic scaffolds and their response to mesenchymal stem cells. *Arthroscopy*. 2014;30(3): 289-298.

33. Anz AW, Hackel JG, Nilssen ED, Andrews JR. Application of biologics in the treatment of rotator cuff, meniscus, cartilage and osteoarthritis. *J Am Acad Orthop Surg*. 2014;22(2):68-79.

34. Hernigou P, Flouzat Lachaniette CH, Delambre J, et al. Biologic augmentation of rotator cuff repair with mesenchymal stem cells during arthroscopy improves healing and prevents further tears: a case-controlled study. *Int Orthop*. 2014;38(9):1811-1818.

35. Hsu WK, Mishra A, Rodeo SR, et al. Platelet-rich plasma in orthopaedic applications: evidence-based recommendations for treatment. *J Am Acad Orthop Surg*. 2013;21(12):739-748.

36. Kowalsky MS, Keener JD. Revision arthroscopic rotator cuff repair: repair integrity and clinical outcome: surgical technique. *J Bone Joint Surg Am*. 2011;93(suppl 1):62-74.

37. Iannotti JP, Deutsch A, Green A, et al. Time to failure after rotator cuff repair: a prospective imaging study. *J Bone Joint Surg Am*. 2013;95(11):965-971.

38. Le BT, Wu XL, Lam PH, Murrell GA. Factors predicting rotator cuff retears: an analysis of 1000 consecutive rotator cuff repairs. *Am J Sports Med*. 2014;42(5):1134-1142.