Editorial Commentary: Reflections From a Mature Arthroscopic Shoulder Surgeon on the History and Current Benefits of Augmentation for the Revision of a Massive Rotator Cuff Tear Using Acellular Human Dermal Matrix Allograft

Abstract: Acellular human dermal matrix allografts are now being used to augment and sometimes replace severely damaged rotator cuff tissue. I have been interested in this important aspect of orthopaedics for 15 years and am pleased to have the opportunity to share my personal reflections of some of the highlights in science and the literature that helped get to the point now where we can expect greater than 80% healing even in these difficult cases of revision after massive failed cuff repair. The field of tissue engineering will certainly be a critical part of our rotator cuff surgical future.

See related article on page 1752

As I read the timely and important article by Petri et al.[1] and their scientifically prolific team of researchers and surgeons at the Steadman Philippon Research Institute, I cannot help but reflect on the history regarding the use of human dermal allograft to augment the degenerative rotator cuff tendon. The importance of a healed rotator cuff tendon that can stabilize the shoulder, improve function, and decrease pain is indisputable. Who among us (or our patients) would not prefer a biologically repaired cuff rather than a shoulder prosthesis or a large open tendon transfer operation just because the initial repair failed?

Of course, my concern has always been to avoid that initial failure (i.e., protect the blood supply, avoid excessive tension, and most important of all, open the bone marrow space to allow stem cells and growth factors to form a bone marrow clot or crimson duvet). Given the fact that "failures do happen," we as shoulder surgeons need to evaluate all the facts available to determine what we can offer our patients when the cuff does not heal.[2,3]

In 1992 Dr. Scott Steinmann introduced me to a product called GraftJacket (Wright Medical Technology, Memphis, TN). This was an early form of the now well-recognized acellular human dermal matrix allograft (AHDMA). The initial product was less than 1.0 mm thick, was very friable, and could not add significant support for tendon repair—much less resist suture cutout. We developed an arthroscopic technique to implant this allograft in a young construction worker in whom a previous open repair had failed and who could not work. It proved to be a difficult 5-hour operation, but it was successful. Since that first case, we have improved our techniques and routinely perform graft augmentation cases in less than 2 hours.[4]

Soon thereafter, it was proved in an animal model and laboratory research that this allograft material had unique favorable properties when compared with xenograft or with other early synthetic materials. AHDMA had the propensity to attract and bind mesenchymal stem cells and also contained important growth factors that facilitated cell recruitment and neotendon proliferation. In addition, there was no immunologic rejection.[5-8]

Of course, "regeneration" of the tendon was the ideal result, but it was often difficult to achieve. It was a challenge for any repair or reconstruction to succeed because the remaining residual cuff stump, muscles, and tuberosity were often extensively degenerative and distorted with scar, residual anchors, and suture debris.[9]

The pioneering work of Richard Steadman, Lanny Johnson, and Hans Uhthoff in the 1980s opened our eyes to the potential of recruiting the nearby bone marrow elements for healing and regeneration. Not only are these critical healing components available for no additional cost, but they can foster an ideal environment for tendon repair when using the allograft augmentation for its structural support.[10,11] When bone

0749-8063/16537/$36.00
http://dx.doi.org/10.1016/j.arthro.2016.06.006

marrow streams from the microfractures in the tuberosity, a clot forms, covering the bone and allograft, and provides a continuous fibrous meshwork to which the stem cells can adhere. The platelet granules are then present and available to release their essential growth factors in the precise manner and amount that suit nature's exacting requirements, much like a healing and maturing fracture callus.[12]

Over the years, orthopaedic biologic allograft suppliers have "seen the light." There are now at least 6 AHDMAs available for clinical use. The new offerings are much more robust, with thicknesses of 2.5 to 3.0 mm, thus greatly improving suture retention and initial structural load sharing. The literature now reflects the benefits of using AHDMA for augmenting these weakened, non-repairable tendons. In addition, the human dermal allograft, along with a bone marrow clot, has been shown to have the potential to replace completely absent tendon segments when no other repair is possible. This is being performed with success both as a bridging technique and as a superior capsule reconstruction.[4,13-19]

For 13 years, our shoulder team at Southern California Orthopedic Institute has been performing "bridging repairs" and has followed up more than 230 patients with magnetic resonance imaging (Fig 1). We have documented that we can achieve greater than 75% healing of the allograft even when there is a sizable gap between the stump of the tendon and the tuberosity. At our institution, we commonly offer an AHDMA augment in revision rotator cuff cases and have found greater than 80% healing in a series of 13 patients. Of course, our preference is to have some native cuff tissue to repair and then overlay it with the graft, but this is not always possible, especially when there has been a Cho type 2 failure.[20] This occurs when the rotator cuff is retorn medial to the muscle-tendon junction, leaving very little tissue to reattach to bone when performing a revision operation.

Rotator cuff defect bridging and superior capsule reconstruction are both still considered off-label by the Food and Drug Administration when the gap is greater than 1 cm. Undoubtedly, with continued proven success, I believe AHDMA cuff augmentation and replacement will become a standard treatment for these complex revision cases.

My hope is that the efforts to develop a synthetic product that has similar properties to AHDMA will eventually be successful. I have no doubt that polymer

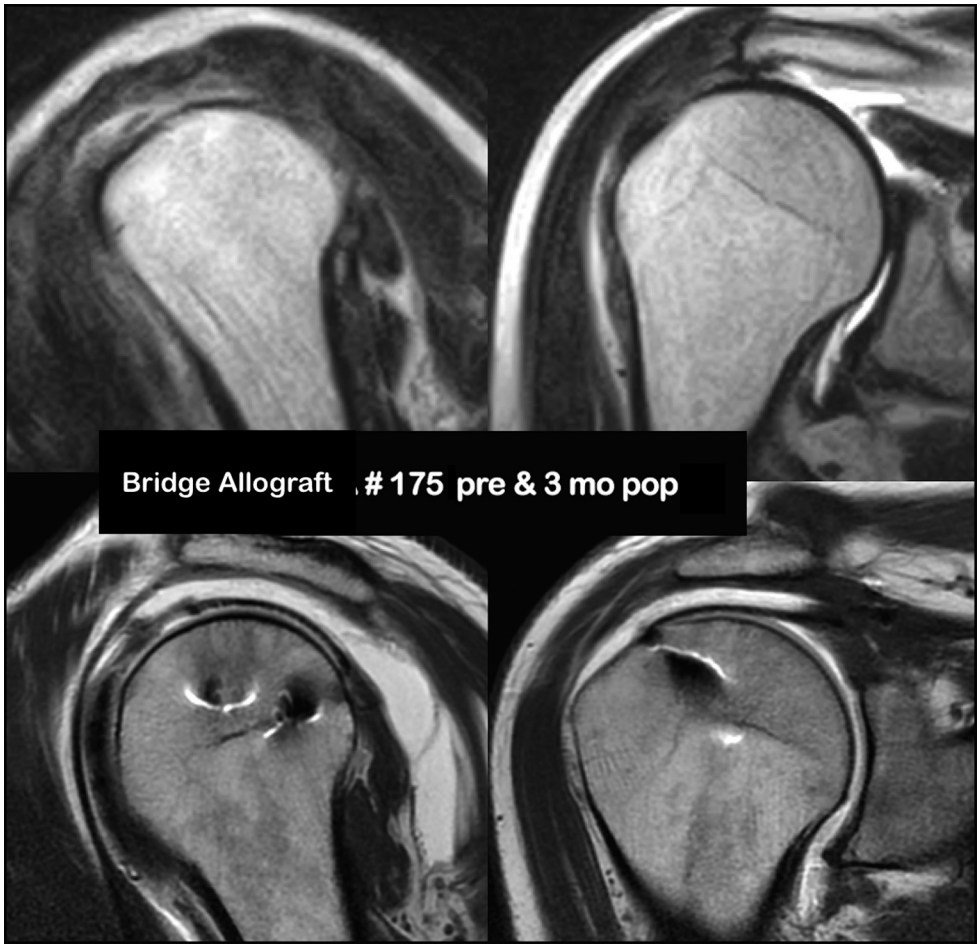

Fig 1. Magnetic resonance imaging of a bridge allograft, preoperative (pre) and 3 months postoperative (pop).

and biologic scientists will someday produce a safe, strong, and cost-effective off-the-shelf biologic augmentation material that will replace the acellular human dermal allograft. Until that happens, AHDMA seems to be the best option.

Stephen J. Snyder, M.D.
Van Nuys, California

References

1. Petri M, Warth R, Horan M, Greenspoon J, Millett P. Outcomes after open revision repair of massive rotator cuff tears with biologic patch augmentation. *Arthroscopy* 2016;32:1752-1760.
2. 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;86:219-224.
3. Kim SH, Kim J, Young E, Lee H-R. Healing disturbance with suture bridge configuration repair in rabbit rotator cuff tear. *J Shoulder Elbow Surg* 2016;25:478-486.
4. Snyder S, Burns J. Rotator cuff healing and the bone marrow "crimson duvet." From clinical observations to science. *Tech Shoulder Elbow Surg* 2009;10:130-137.
5. Adams JE, Zobitz ME, Reach JS Jr, An KN, Steinmann SP. Rotator cuff repair using an acellular dermal matrix graft: An in vivo study in a canine model. *Arthroscopy* 2006;22:700-709.
6. Barber FA, Herbert MA, Coons DA. Tendon augmentation grafts: Biomechanical failure loads and failure patterns. *Arthroscopy* 2006;22:534-538.
7. Blum B, Hughes K, Miller L, Burgess A. Native growth factors in acellularized human dermis. Presented at the 30th Annual Meeting of the Society for Biomaterials, Memphis, TN, April 27-30, 2005.
8. Derwin KA, Badylak SF, Steinmann SP, Iannotti JP. Extracellular matrix scaffold devices for rotator cuff repair. *J Shoulder Elbow Surg* 2010;19:467-476.
9. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. *J Bone Joint Surg Am* 2000;82:505-515.
10. Uhthoff HK, Sano H, Trudel G, et al. Early reactions after reimplantation of the tendon of supraspinatus into bone. *J Bone Joint Surg Br* 2000;82:1072-1076.
11. Steadman RJ, Rodkey WG, Singleton SB, et al. Microfracture technique for full thickness chondral defects: Technique and clinical results. *Oper Tech Orthop* 1997;7:300-305.
12. Kida Y, Morihara T, Matsuda K, et al. Bone marrow-derived cells from the footprint infiltrate into the repaired rotator cuff. *J Shoulder Elbow Surg* 2015;24:960-966.
13. Bond JL, Dopirak RM, Higgins J, Burns J, Snyder SJ. Arthroscopic replacement of massive, irreparable rotator cuff tears using a Graft-Jacket allograft: Technique and preliminary results. *Arthroscopy* 2008;24:403-409.
14. Burkhead WZ Jr, Schiffern SC, Krishnan SG. Use of GraftJacket for augmentation of massive rotator cuff tears. *Semin Arthroplasty* 2007;18:11-18.
15. Snyder SJ, Arnoczky SP, Bond JL, Dopirak R. Histologic evaluation of a biopsy specimen obtained 3 months after rotator cuff augmentation with GraftJacket Matrix. *Arthroscopy* 2009;25:329-333.
16. Wong I, Burns J, Snyder SJ. Arthroscopic GraftJacket repair of rotator cuff tears. *J Shoulder Elbow Surg* 2010;19:104-109.
17. Gilot GJ, Alvarez-Pinzon AM, Barcksdale L, Westerdahl D, Krill M, Peck E. Outcome of large to massive rotator cuff tears repaired with and without extracellular matrix augmentation: A prospective comparative study. *Arthroscopy* 2015;31:1459-1465.
18. Gupta AK, Hug K, Goggess B, Gavigan M, Toth AP. Massive or 2-tendon rotator cuff tears in active patients with minimal glenohumeral arthritis: Clinical and radiographic outcomes of reconstruction using dermal tissue matrix xenograft. *Am J Sports Med* 2013;41:872-879.
19. Mihata T, Lee TQ, Watanabe C, et al. Clinical results of arthroscopic superior capsule reconstruction for irreparable rotator cuff tears. *Arthroscopy* 2013;29:459-470.
20. Cho N, Yi J, Rhee Y. Retear patterns after arthroscopic rotator cuff repair: Single row versus suture bridge techniques. *Am J Sports Med* 2010;38:664-671.