Technical Note

Human Dermal Allograft Patch Augmentation of Degenerate Rotator Cuff Tendon Using a Single Lateral-Row Technique

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Abstract: The role of biological augmentation in arthroscopic rotator cuff repair surgery has increased over the years. It has shown favorable healing rates and functional outcomes. Patch augmentation is commonly applied in repairs of massively retracted cuff tears, full-thickness tears, revision repair, or open cuff surgery. There is a paucity of literature on the use of patch augmentation when dealing with a chronic degenerate tendon associated with small-sized cuff tears. In recent years, the resorbable bioinductive bovine collagen implant has gained popularity for its application in partial-thickness tears via an isolated bioinductive repair fashion, without traditional rotator cuff repair. These bioinductive implants, albeit promising in their biological properties for tendon repair, lack structural strength and do not confer similar biomechanical advantages as human dermal allograft. We share our surgical technique for an arthroscopic patch augmentation involving human dermal allograft, using a single-lateral row surgical fixation, to address a degenerate cuff tendon with small-sized rotator cuff tear. We believe that our use of a human dermal patch augmentation conferred increased biomechanical advantage and reduced costs while delivering favorable outcomes for patients in our value-driven care.

Degenerative rotator cuff disease is a leading cause of shoulder pain and dysfunction.[1,2] The pathophysiology of rotator cuff failure is a degenerative process attributed to the interactions between intrinsic, extrinsic, and environmental factors.[3,4] Propagation of this process eventually leads to lack of collagen maturation within a weakened and degenerated tendon, preluding to rotator cuff tears.[3,4]

Arthroscopic rotator cuff repair is one of the most common orthopaedic procedures performed in patients with symptomatic rotator cuff tears.[5,6] These can vary in terms of tear pattern, size, and location—from partial- to full-thickness tears or small-to-massive large tears associated with retraction.[7] Following arthroscopic rotator cuff repair, a study by Chung et al.[8] showed that severity of tendinosis was related to failure to heal.[8] Tendon quality was identified as a prognostic factor for repair integrity and should be addressed during repair surgery.[8]

With advances in biologic augmentations in recent years, patch augmentation has been used increasingly in arthroscopic rotator cuff repair to improve healing rates.[9,10] A patch interposition technique when a tear cannot be advanced to the tuberosity has been described. In instances in which a tear can be advanced only to the medial aspect of the footprint, an additional reinforcement of the repair using a patch placed on the bursal side of the tendon can be done. Patch augmentation also may improve restoration of native enthesis for tears that can be advanced to the native footprint.[10]

Surgical revision following rotator cuff repair is often a more complicated procedure due to poorer tissue quality and patient factors.[11] There have been previous

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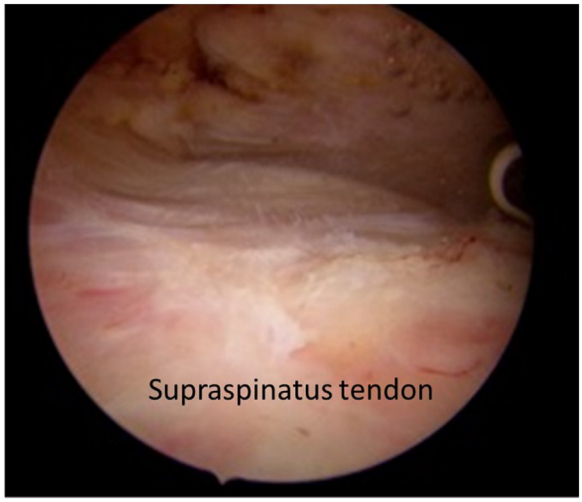

Fig 1. Arthroscopic view of right shoulder through a standard posterior viewing portal showing degenerative supraspinatus (SSP) tendon.

studies of patch augmentation used for revision repair procedures involving massive (>2 tendons) rotator cuff tears, full-thickness (>2 cm) tears, or in open revision surgery.[12-14]

To date, there is a paucity of literature on the application of patch augmentation when dealing with a chronic degenerate tendon that may be associated with presence of small-sized rotator cuff tears. In these circumstances, a sole repair of the tear could lead to high failure rates due to severity of tendinosis.

We share our technique of an arthroscopic patch augmentation involving human dermal allograft, in a degenerate cuff tendon, using a single-lateral row surgical method. In our review of literature, this has not been described previously.

Surgical Technique (With Video Illustration)

Patient Evaluation, Imaging, and Indications

A detailed history should be obtained from patients presenting with symptomatic shoulder pain, with regards to the nature of symptoms, possible preceding trauma or injury, previous history of shoulder surgery, duration of symptoms, and patient's premorbid activity level. A thorough physical examination is then conducted. Upon suspecting a possible cuff tear, further investigations such as an ultrasound or magnetic resonance imaging can be obtained to evaluate the tear morphology in greater detail. Surgery can be offered in patients who do not respond to conservative measures and have persistent symptoms. For those patients who might have had a previous shoulder rotator cuff surgery and are presenting with a possible new tear, arthroscopic revision shoulder surgery may be offered with a view of possible biological augmentation upon careful preoperative planning and review of tear morphology on imaging workup.

Diagnostic Arthroscopy

A standard posterior viewing portal is created and a routine diagnostic arthroscopy is performed to evaluate the patient's intra-articular shoulder pathology and tendon quality. An anterior working portal is secondarily created. The glenohumeral joint is methodologically evaluated starting first with locating and debridement of the rotator interval.

Articular-sided assessment of the rotator cuff tendons, biceps pathology, and labrum is carried out, following which the subacromial space is entered and bursa debrided, to further evaluate the bursa-side of the tendons. Assessment of the rotator cuff tendons include evaluation of tear location, pathology, size, and quality of tendon, all of which may potentially affect repair outcomes.

Our assessment of the supraspinatus (SSP) tendon showed generalized thinning medially with no large or massive cuff tear (Fig 1). At this juncture, an additional anterolateral portal is created to aid in location of any possible discrete tears over the SSP tendon. Using an obturator as a probe, 2 small 0.5-cm tears were located over the lateral edges of the tendon (Figs 2 and 3). A second posterolateral working portal also is created for facilitation of the subsequent steps of repair.

Medial Sutures

With the camera maintained at the posterior portal, medial sutures are placed using the following stepwise method. An ACCUPASS (Smith & Nephew, Andover, MA) suture passer is placed through the anterolateral portal and is inserted through the anterior small tear, to exit in the anteromedial aspect of the tendon. A

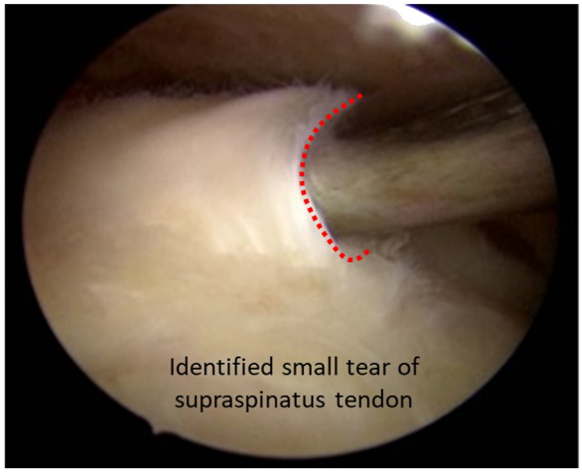

Fig 2. Arthroscopic view of right shoulder through a standard posterior viewing portal, showing lateral edge bursal-sided 0.5-cm small tear of the supraspinatus. Two of these tears were identified using an obturator as a probe.

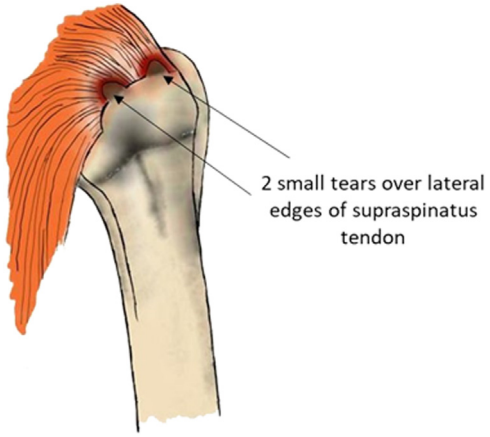

Fig 3. Schematic diagram illustrating the 2 small tears over the lateral edges of the supraspinatus tendon.

cruciate hook is used to retrieve the monofilament through the anterior portal. A loose ORTHOCORD (DePuy Mitek, Neuchatel, Switzerland) suture is loaded onto the monofilament and threaded through the anteromedial aspect of the tendon.

A second suture bite is made on the posteromedial aspect of the SSP tendon using the same method with the ACCUPASS and ORTHOCORD suture. This results in 2 ORTHOCORD sutures placed medially in an anterior and posterior position, approximately 1 cm apart. The suture limbs of both sutures at the bursal side comes out through the anterior portal, while the other ends of the suture exit through the anterolateral portal.

A mattress suture configuration is then completed medially. The ACCUPASS device is now placed through the anterior portal with an entry point on the tendon further anterior to the previous first suture entry. The

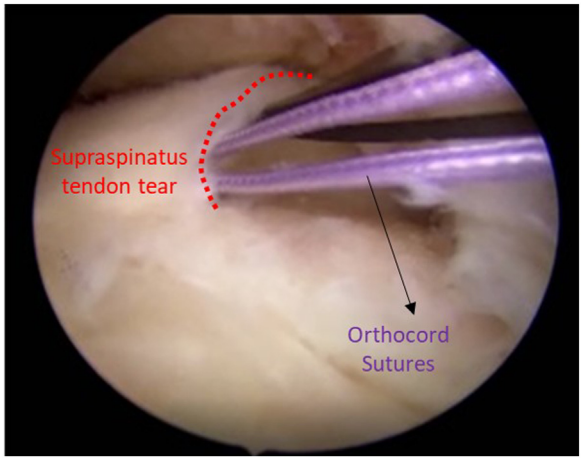

Fig 4. Arthroscopic view of right shoulder from posterior viewing portal showing the creation of medial mattress suture configurations with aid of ORTHOCORD (DePuy Mitek) sutures and ACCUPASS (Smith & Nephew) suture passer device.

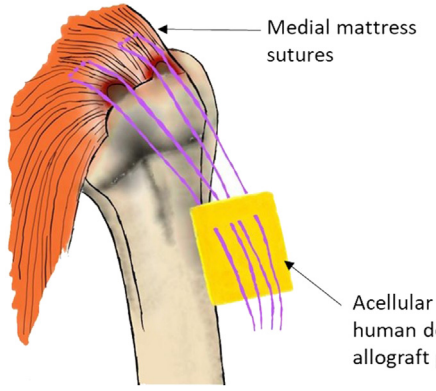

Fig 5. Schematic diagram illustrating the completion of 2 mattress sutures on the medial aspect of the tendon. The 4 suture limbs exit through the antero-lateral portal to form a relay system for the eventual delivery of the human dermal allograft.

ACCUPASS device exits through the anterior tear; the loose suture limb of the anterior ORTHOCORD suture is threaded through, completing the first mattress anteriorly (Fig 4). The second posterior mattress suture configuration is completed in the same fashion. All suture limbs are then retrieved through the anterolateral portal.

Care is taken to ensure satisfactory width of each of the mattress sutures and that each of the 4 resulting suture limbs are strategically placed to guide the eventual relay system for the subsequent patch implementation (Fig 5).

With an aid of an arthroscopic probe that has built-in markings at 0.5-cm intervals, the anteroposterior (A-P) and mediolateral (M-L) dimensions for the potential allograft are measured. The A-P length is measured from a point of approximately 0.3 cm anterior to the first suture limb, to a point approximately 0.3 cm posterior to the fourth suture limb. This is to ensure that the first to fourth suture limbs will be safely threaded through the eventual graft, with low risk of cutting out from the edges of the graft.

The M-L dimension is measured from the medial sutures to a point lateral to the small tears of the rotator cuff tendon, to ensure that the graft is adequately sized to cover the area of degenerate tendon and the small rotator cuff tears. The A-P and M-L dimensions of our patch augment is measured to be 2 cm × 2 cm, respectively (Fig 6).

Dermal Graft Preparation

An acellular human dermal graft (RTI Surgical, Alachua, FL) is prepped according to the measured dimensions. The location of the 4 suture limbs is marked out at its corresponding intervals on the medial aspect of the graft. With the help of a spinal needle and Chia wire (DePuy Mitek), each of the 4 sutures are threaded

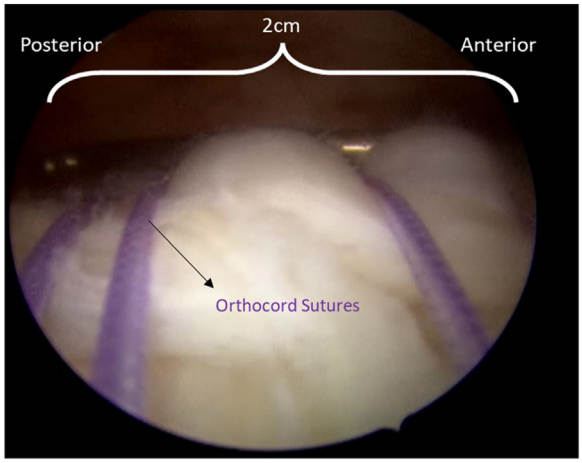

Fig 6. Arthroscopic view of the right shoulder through the lateral working portal showing the medial mattress configuration and 4 suture limbs of the ORTHOCORD sutures. The anteroposterior and mediolateral dimensions were measured using a probe. In this figure, the approximate distance from the first suture limb anteriorly to the fourth suture limb posteriorly was 2 cm.

through the graft (Fig 7). The prepped graft is then delivered into the joint through the lateral portal.

Medial Knots

Upon careful placement of the dermal patch graft and under good visualization, the medial mattress sutures are tied using sliding knots to secure down the graft

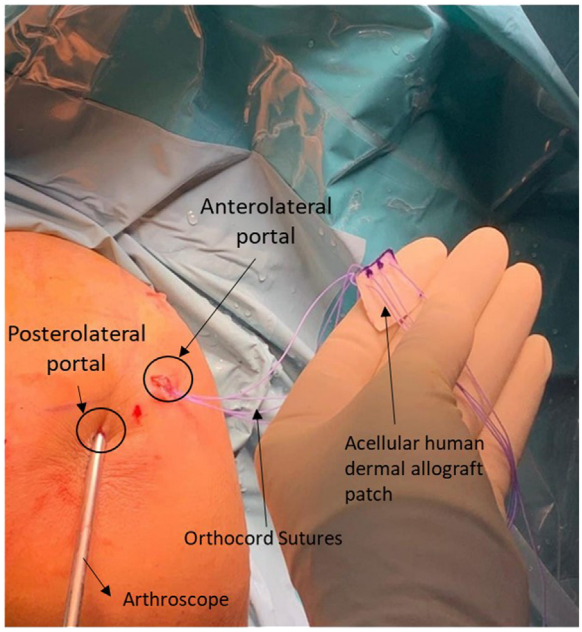

Fig 7. The 4 suture limbs of the ORTHOCORD sutures exiting out the anterolateral working portal, are threaded through the acellular human dermal graft (RTI Surgical) at its corresponding intervals. The prepped graft was then delivered into the joint through this portal.

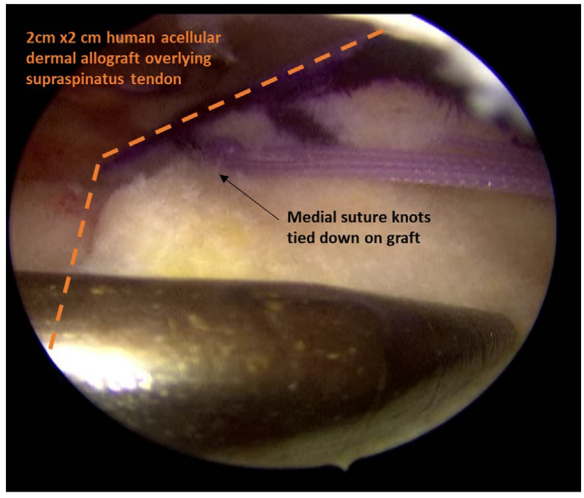

Fig 8. With the arthroscope positioned at the posterolateral portal, the medial sutures were tied to secure the graft down on to the tendon using sliding knots.

onto the tendon. A spinal needle is used to hold down the lateral edges of the graft to ensure visualization during knot-tying (Figs 8 and 9).

Lateral Row Anchor

A cannula is introduced through the lateral portal and all 4 suture limbs are retrieved through the cannula. The first and third suture limb are secured to an anterior lateral-row anchor (VERSALOK suture anchor; DePuy Mitek), whereas the second and fourth suture limb are secured to a posterior lateral row anchor (Fig 10).

This gives rise to a suture spanning configuration that aims to distribute the tension evenly through the graft and compresses the dermal graft down over the degenerate SSP tendon and over the lateral small tears (Figs 11 and 12). A balloon spacer (Conmed) is

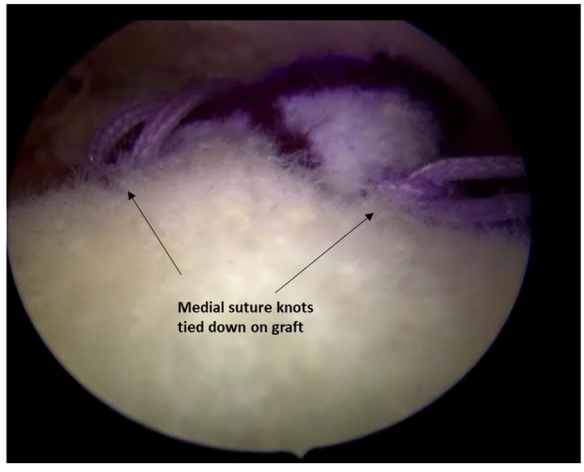

Fig 9. Arthroscopic view from lateral portal showing the graft secured down medially with 2 medial suture knots.

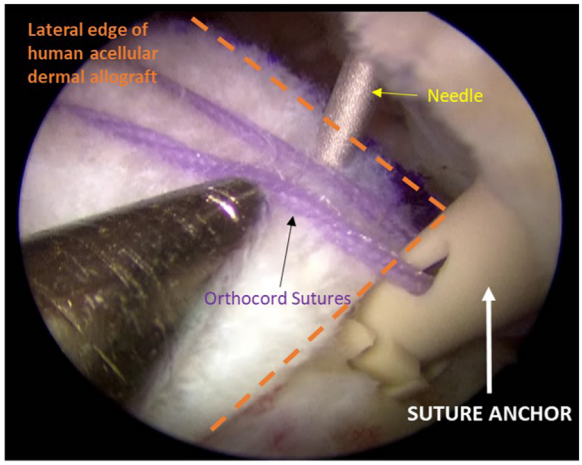

Fig 10. Arthroscopic view from posterior portal showing the first and third suture limbs being secured to an anterior lateral row suture anchor (VERSALOK suture anchor; DePuy Mitek).

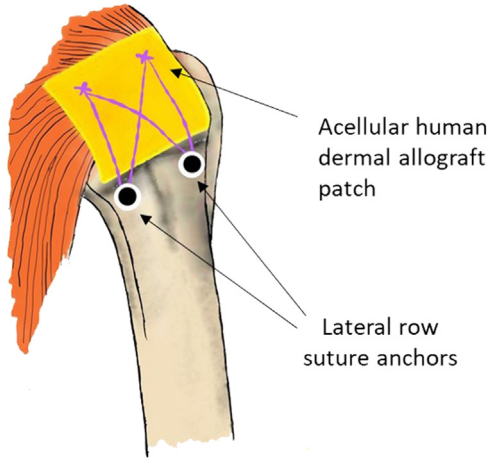

Fig 12. Schematic diagram illustrating the finalized suture spanning configuration in a single-lateral row fixation involving human dermal allograft patch augmentation.

subsequently deployed. A detailed demonstration of our surgical technique is shown in Video 1.

Rehabilitation

The patient is placed in an arm sling and started on gradual passive range of motion exercises at 2 weeks' postoperation. Postoperative magnetic resonance imaging is shown in Figure 13.

Discussion

Our surgical technique shows that isolated patch augmentation technique with human dermal allograft can be suitably applied in those with degenerate rotator cuff tendon and small-sized rotator cuff tear. Arthroscopic rotator cuff patch augmentation or interposition surgery has grown in popularity over the years, with systematic reviews and meta-analysis showing that these methods provide better shoulder scores compared with rotator cuff repair alone.[15,16] A variety of grafts are available, ranging from xenograft, synthetic grafts, autograft, and allograft.[10] Xenografts that were available included porcine dermal xenograft; however, these grafts were associated with severe inflammatory reactions, and Flury et al. in 2018 demonstrated that patients treated with xenograft had a substantial rate of recurrent tendon defect and did not show additional improvement in functional outcomes.[10,17] Polypropylene synthetic graft remains a promising alternative, with some studies showing functional improvement.[10] Autograft augmentation for rotator cuff with the long head of biceps, humeral head periosteum, or with fascia lata autograft has been described previously to provide improvements in shoulder tests, and it remains an option for cases in which allograft is culturally unacceptable.[10]

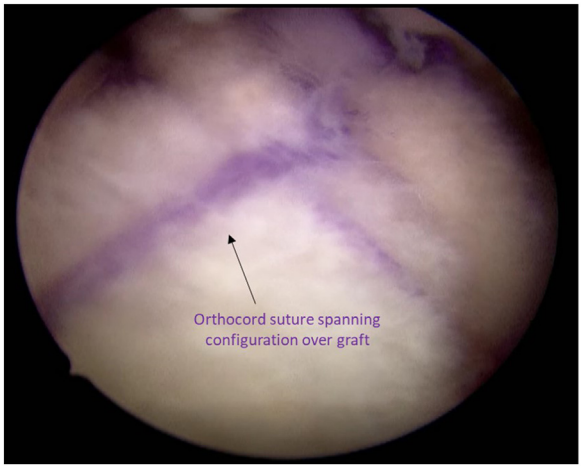

Fig 11. Arthroscopic view from the lateral portal shows the final suture spanning configuration over the graft following 2 lateral row anchors.

Human dermal allograft acts as an extracellular collagen matrix scaffold, and its surgical use is still actively evolving in the realm of orthopaedic surgery. It is biocompatible and has a wide range of size and thickness available, along with good suture retention properties and have moderate costs.[18] A systematic review by Ferguson et al.[19] in 2016 looked into graft use in augmentation of large-to-massive rotator cuff tears. Acellular human dermal allograft has shown superiority in functional and structure outcomes.[19] Kim et al.'s study[20] on rabbit models in 2017 demonstrated that bridging repair with acellular dermal matrix showed histological maturation of the tendon over time, with cellular infiltration into the graft and evidence of neotendon formation without further fatty deterioration or muscle atrophy.

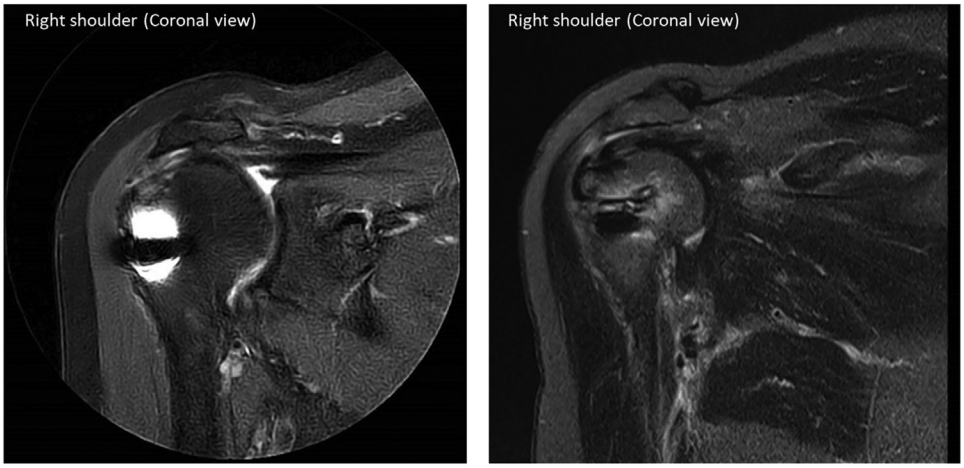

Fig 13. Postoperative magnetic resonance imaging showing the patch augmentation of the degenerate supraspinatus tendon.

Techniques commonly described in literature for patch augmentation were largely implemented in cases of complete irreparable or partially reparable large, massive retracted rotator cuff tears.[16,19] Similarly, multiple studies looking into the outcomes of these patch augmentation technique, were done in cohorts of patients with large-to-massive, retracted tears.[12,16] In terms of small-sized rotator cuff tears, the 10-year follow-up prospective randomized control study by Moosmayer et al.[21] showed surgical tendon repair to be superior to conservative physiotherapy management; there is a role for surgery in small-sized rotator cuff tears. Compared with large-to-massive tears, small- to medium-sized tears often have a greater healing rate; hence, the cost of patch augmentation may be difficult to justify in a primary arthroscopic rotator cuff repair setting.

In a revision arthroscopic shoulder procedure in an elderly patient, whereby tendons often have chronic degeneration and are weakened, this compromises the potential repair integrity of any tear size. As demonstrated earlier in a 2014 study by Chung et al.,[8] the severity of preoperative radiologically graded tendinosis is a prognostic factor of repair integrity in the setting of either small full-thickness or high-grade partial-thickness rotator cuff tears. Increasing age has been identified to be a risk factor for retears postarthroscopic rotator cuff repair, with age >70 years having an exponential increase in risk.[22,23]

In recent years, emergence of a resorbable bioinductive bovine collagen implant has increased the armamentarium of biologics available in the treatment of rotator cuff tears.[24,25] In full-thickness tears, its application as an augment to rotator cuff repair has produced favorable outcomes in medium-sized (1-3 cm) and large-sized (>3 cm) tears.[26] The implant also has been used in an isolated bioinductive repair fashion in the setting of a partial-thickness rotator cuff tear, without a traditional rotator cuff repair. This technique has showed improved early patient-reported outcomes (<6 weeks) as compared with a "take-down and repair" approach in partial-thickness tears.[27]

Biomechanical studies looking into tensile failure load have been done previously to highlight the strength of human dermal allograft in an augmented rotator cuff repair.[28-30] This is further supported by

Table 1. Advantages and Risks/Limitations

Advantages
• Human dermal allograft confers biological advantages in tendon repair and healing. In addition, it possesses good suture retention properties
• Our technique uses medial mattress sutures and lateral-row suture anchors for fixation of the dermal allograft over the degenerate tendon and small rotator cuff tears.
• Formation of a suture configuration construct that covers the graft sufficiently and ensures adequate compression of the graft with equal tension distribution across the tendon repair contributes to its biomechanical benefit
• A balloon spacer is used to further protect our graft augmentation integrity
• Use of human dermal allograft may present as a cost-effective option in comparison with alternative bioinductive implants. Further research can be done to study the long-term cost–benefit analysis between different biological adjuncts
Risks/limitations
• Risk of infection, inflammation, implant failure

Table 2. Surgical Pearls and Pitfalls

	Surgical Pearls	Surgical Pitfalls
Assessment of cuff pathology	• Thoroughly assess rotator cuff tear configuration and tendon quality during diagnostic arthroscopy. • Use of a probe may aid in identification of small subcentimeter tears	• Both articular- and bursal-sided assessment of rotator cuff tendons has to be adequately carried out to ensure no small-sized rotator cuff tendon tears are overlooked, which may potentially affect repair outcomes
Planning of medial mattress sutures	• Ensure adequate and appropriate width between medial mattress sutures on the tendon as this determines the eventual graft fixation points	• Unequal placement of medial mattress sutures, either too far apart or too near each other, may result in unequal distribution of tension in graft fixation
Measurement of graft	• Use of a probe as to accurately note the measurement landmarks of the medial sutures on the tendon, so as to correspond them to the eventual placement of the threaded suture limbs on the dermal patch graft • The graft size must be large enough to cover the entire degenerate area of the tendon and any small tears	• Inadequately sized graft will lead to unsatisfactory coverage of the degenerate tendon and cuff tears
Graft delivery	• Use of a spinal needle to hold down the lateral edge of the graft could aid in good visualization during graft delivery and placement	• Upon entry of the graft into the shoulder, the edges of the graft may impede on visualization for the final suture anchoring steps
Suture anchor placement	• Use of knotless anchors in the lateral row to hold down the graft • Placement of the lateral row suture anchors must be carefully planned to give rise to a biomechanically superior suture configuration construct over the graft	• Care must be taken to ensure good visualization before any preparation of anchors to avoid poor anchor placement

histologic studies in animal models that show native cell infiltration and neotendon development within 6 weeks.[20,31] In contrast, bioinductive implants may be promising due to their ability to induce new tendon-like tissue in repairs; however, they lack structural strength and may not confer similar biomechanical advantages. In our institution, bioinductive implant costs were approximately at least 5 times the cost of human dermal allograft. The use of human dermal allograft could potentially have an improved cost–benefit outcomes. Further research also can be done to look into the long-term cost-benefit analysis in comparing the various different adjuncts available.

Upon consideration of all the aforementioned factors, an arthroscopic isolated patch augmentation of a degenerate supraspinatus tendon using human dermal allograft, without traditional rotator cuff repair, was opted as the treatment for our patient.

Our technique provides both biological and biomechanical benefits. Using the human dermal allograft to augment the tendon increases the healing capabilities with potential for neovascularization, neotendon development and active graft remodeling.[32] Biomechanically, such allografts further increase the strength of the repair, as demonstrated in previous studies.[28-30]

The medial mattress sutures were placed at appropriate widths apart that eventually aided our allograft delivery and formed our allograft fixation points medially. Application of medial mattress sutures and the final suture anchors over the single lateral row gives rise to a suture bridge configuration construct that crisscross effectively and as widely as possible over the graft, ensuring equal tension distribution across the tendon and adequate compression of the graft. This further adds to its biomechanical advantage.

Balloon spacers have been used as a protective implant for rotator cuff repair, with clinically effective outcomes shown in previous studies.[33,34] Our use of the spacer was to further protect our graft augmentation integrity. These factors all aim to decrease the rate of retears and improve functional outcomes. Lastly, as compared with bioinductive implants and their associated greater cost, our technique may potentially provide a cost-effective option for patients.

Limitations of our technique include common risks of rotator cuff repair, such as infection, inflammation, and implant failure. These benefits and limitations are further summarized in Table 1. In Table 2, we highlight several surgical pearls that may be useful to perform this technique, along with some pitfalls for which some caution may need to be taken.

With the variations in rotator cuff pathology, tear configuration, and treatment methods available, thorough patient counseling, patient selection, and arthroscopic assessment of an individual's shoulder pathology remains key factor in choosing the most optimum surgical approach to establish value-driven care.

We believe that our single lateral row patch augmentation technique using human dermal allograft described here is an appropriate and effective method in addressing a degenerate tendon that may be associated with small-sized tears.

Conclusions

Patch augmentation using human dermal allograft without traditional rotator cuff repair is a safe, cost-effective, and appropriate surgical treatment option for patients with degenerate rotator cuff tendon associated with small-sized tears in a revision shoulder arthroscopic setting.

Acknowledgments

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