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Patch Augmentation and Patch Extension for Complex Rotator Cuff Tears

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The successful management of large to massive rotator cuff tears is challenging. Multiple factors to include poor tendon quality with fatty degeneration lead to high retear rates despite improved arthroscopic and open repair techniques. Patch augmentation and patch interposition with various grafts have been studied in an effort to both reinforce and bridge massive rotator cuff repairs, and provide an optimal biologic and mechanical environment at the tendon-bone interface. The purpose of this review is to present the current indications, surgical techniques, and outcomes of patch augmentation and patch interposition (extension) for large and massive rotator cuff tears.

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KEYWORDS shoulder, rotator cuff tear, rotator cuff repair, patch augmentation, patch extension

Introduction

Advanced rotator cuff pathology can represent a disabling condition with significant associated shoulder pain, weakness, and dysfunction.[1] Successful surgical treatment of large and massive rotator cuff tears can be challenging. Patient age, medical comorbidities, tear size and tear chronicity, and poor tissue quality may contribute to high rates of failure and poor healing after primary repair.[2-9] Although studies report retear rates of 40%-90% in large to massive rotator cuff repairs, good outcomes and consistent pain relief can be achieved.[6,10] However, retearing has been correlated with worse pain and functional outcomes postoperatively.[6,10-12] Therefore, investigators have sought to develop techniques to optimize biologic incorporation of large and massive rotator cuff repairs to prevent structural failure.

Multiple surgical procedures have been described for the treatment of large or massive rotator cuff tears, including rotator cuff tear debridement and decompression,[13] partial repair (with or without footprint medialization),[14] primary arthroscopic or open repair,[2,6,15] superior capsular reconstruction,[16] latissimus dorsi tendon transfer,[17] and ultimately, reverse total shoulder arthroplasty.[18] The reparability of tears is an important distinguishing feature in the diagnostic algorithm. Recently, rotator cuff patch augmentation has been evaluated as a viable surgical option for repairable tears. The goals of this approach are to reduce retear rates by improving biologic healing, protecting the suture and supporting the repair, and ultimately improving postoperative pain and function. By definition, patch augmentation refers to onlaying a graft over a repaired rotator cuff tear, whereas an "interpositional" or "extension" graft creates a bridge from the residual irreparable rotator cuff tendon to the humeral footprint. Generally, the graft functions as mechanical augmentation and an extracellular matrix (ECM) scaffold to allow organized tissue in-growth and optimize healing potential. Since Neviaser et al's[19] first use of interposition allograft for rotator cuff repair, graft options for this technique have expanded and include synthetic polymers, allograft, autograft, and xenograft materials. Current studies are also investigating the role of additional biologic augmentation with platelet-rich plasma, mesenchymal cells, and growth factors; however, this is outside of the focus of this discussion.[20,21] The purpose of this review is to present the current indications, surgical techniques, and outcomes of patch augmentation and patch extension for large and massive rotator cuff tears.

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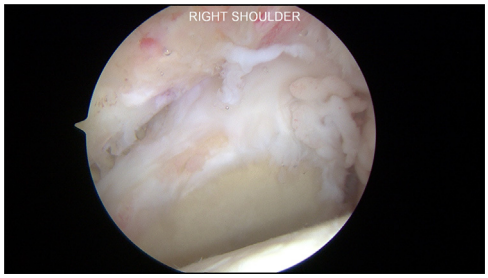

Figure 1 Lateral subacromial view of a right shoulder with a massive, 3-tendon retracted rotator cuff tear with diminished tissue quality. (Color version of figure is available online.)

Surgical Indications

Indications for Patch Augmentation and Patch Interposition (Extension)

(1) Persistent pain and shoulder dysfunction despite at least 6-months of conservative treatment with physical therapy, oral medication, or periarticular injection treatment.
(2) A symptomatic large to massive rotator cuff tear documented by preoperative imaging and intraoperative assessment (Fig. 1).
(3) A repairable tear demonstrated by intraoperative assessment (*patch augmentation*).
    (a) an irreparable tear would indicate the need for *patch interposition.*
(4) Reliable patient able to participate in postoperative rehabilitation regimen.

Contraindications

(1) Glenohumeral arthritis or inflammatory arthropathy.
(2) Active infection.
(3) Patient not likely or unwilling to be compliant with rehabilitation protocols.

Outcomes of Patch Augmentation Techniques

Allograft

Multiple studies have evaluated the outcomes of both allograft augmentation and interposition for massive rotator cuff tears. This section will focus on those investigations in which patients underwent allograft augmentation of a repairable tear. Multiple acellular human dermal matrices are currently commercially available, although 1 patch option (GraftJacket; Wright Medical Technology, Arlington, TN) has received the most widespread focus in the literature. Other preliminary studies have investigated an alternative acellular human dermal matrix product, including the Arthroflex patch (Arthrex, Naples, FL); however, results are limited and larger studies are warranted.[22] The human dermal tissue forms an acellular collagen ECM scaffold to provide an organized framework for host cell infiltration, vascular ingrowth, and later tissue remodeling.[23] Barber et al performed a randomized, multicenter prospective level II clinical trial comparing arthroscopic GraftJacket augmentation ($n = 22$) of chronic 2-tendon rotator cuff tears with a group receiving arthroscopic repair alone ($n = 20$). Arthrogram-enhanced magnetic resonance imaging (MRI) at 12-months follow up showed intact cuffs in 85% of the augmented group and only 40% of the nonaugmented repairs. Also, American Shoulder and Elbow Society and Constant scores improved significantly from preoperatively to postoperatively, and no adverse reactions were recorded.[23] Burkhead et al followed 17 consecutive patients who underwent open massive rotator cuff repair with GraftJacket augmentation, and found similar results.[24]

Xenograft

The premise behind xenograft technology for augmentation of rotator cuff repairs is that the acellularized ECM will serve as a scaffold to stimulate host inflammatory response and collagen deposition, thus strengthening tendon healing. Multiple products have been studied over the past decade with variable results. The most well-studied device is the porcine small intestine submucosa (Restore Orthobiologic Implant; DePuy, Warsaw, Indiana). Iannotti et al[25] performed a level II, randomized controlled trial to determine the comparative effectiveness of the porcine small intestine submucosal patch augmentation vs a control group without augmentation in 30 shoulders with chronic 2-tendon rotator cuff tears. Patients were followed up for 1-year and underwent an MRI arthrogram to assess the integrity of the repair. The rotator cuff healed in only 4 of the 15 shoulders in the open augmentation group as compared to 9 of the 15 in the control group ($P = 0.11$). Additionally, clinical outcome scores were inferior in the augmentation group. In summary, the authors did not recommend using this patch for chronic massive rotator cuff tears, and attribute the failure rate to the adverse mechanical environment in the immediate postoperative period as the patch undergoes resorption. Walton et al[26] performed a similar prospective study and confirmed these findings (Fig. 2).

Porcine dermal collagen patches are another xenograft which has previously been evaluated. These grafts have the advantage of increased strength compared to porcine submucosa, which may be owing to the presence of collagen cross-linking.[27] Furthermore, acellular dermal collagen patches have not elicited the same inflammatory reaction seen in repairs augmented with porcine small intestine submucosa grafts.[25,26] However, the lack of well-performed level I and II studies with porcine dermal collagen patch augmentation makes it difficult to interpret the results. More recently, bovine collagen grafts have emerged as another option for patch augmentation. Table 1 lists the published case series evaluating the outcomes of rotator cuff repair patch augmentation with xenograft.[25,26,28-32]

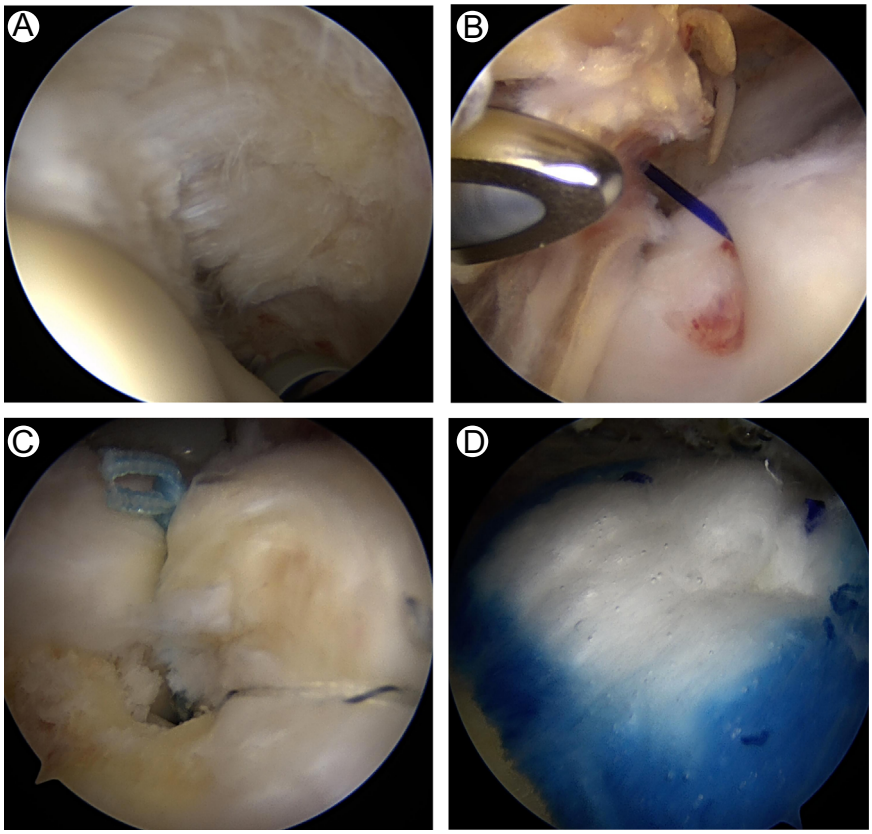

Figure 2 (A) Intra-articular view of a left shoulder through a posterior viewing portal demonstrating advanced tendinopathy and significant rotator cuff fraying. (B) Subacromial view from the posterior portal demonstrating full thickness tear propagation after needle localization. (C) Lateral subacromial view of a single anchor rotator cuff repair with attenuated tissue quality. (D) All-arthroscopic xenograft augmentation (Rotational Medical, Plymouth, MN) overlying the previous rotator cuff repair and fixed with bioabsorbable staples. (Color version of figure is available online.)

Synthetic

The theoretical benefit of synthetic patch augmentation of rotator cuff repairs is that the graft is immune tolerant, and still able to serve as an ECM scaffold to allow for host tissue response and connective tissue in-growth.[33] Multiple studies have evaluated various synthetic patch augmentation options, including both absorbable and nonabsorbable devices. Synthetic devices include the poly-L-lactide patch (X-Repair; Synthasome), polypropylene patch (Repol Angimesh, ANGIOLOGICA BM Srl, Pavia, Italy), and a nonabsorbable reticulated polycarbonate polyurethane patch (Biomerix, Fremont, CA). The outcomes after synthetic patch augmentation, summarized in Table 1, are variable with retear rates ranging from 10%-62%.[30, 34-36] Future investigations are needed to elucidate the ideal synthetic augmentation patch.

Outcomes of Patch Interposition (Extension) Techniques

In contradistinction to patch augmentation where primary repairs are reinforced, interpositional (extension) grafts serve to connect the torn irreparable rotator cuff stump to the greater tuberosity. This must also be distinguished from contemporary descriptions of superior capsular reconstruction, which is rigidly fixed at the both glenoid and humeral attachments to statically resist superior humeral head migration during motion.

Allograft

Several studies have evaluated the role of allograft interposition for massive irreparable rotator cuff tears with good short-term outcomes and minimal complications. However, all 4 studies are level IV case series without a control group.[37-40] Despite these series demonstrating favorable short-term subjective and objective outcome measurements and low retear rates with GraftJacket interposition,[37-40] anecdotal results and clinical outcomes have varied widely.

Xenograft

There is a paucity of evidence studying the outcomes of patch interpositional xenograft use in rotator cuff repair surgery. Neumann et al performed a level IV case series of 61 patients who underwent porcine dermal matrix xenograft interposition for a massive rotator cuff tear. At a mean of 50.3 months follow up, patients had significant improvement in pain, range of motion, and manual muscle strength. Postoperative ultrasound demonstrated that 91.8% of repairs were intact at

Table 1 Studies Evaluating Outcomes of Rotator Cuff Repair Augmentation

Study	Level of Evidence	Inclusion Criteria	No. of Patients	Surgical Technique	Graft Used	Retear Rate and Outcomes	Imaging Assessment
Allograft							
Barber et al[23]	II	Large, massive RCTs	Aug-22, control-20	Arthroscopic	Acellular human dermal matrix; GraftJacket (Wright Medical Technology, Arlington, TN)	Retear rate: aug group-15%, control group-60%; significant improvement in outcome scores (ASES, Constant)	MRI at mean 14.5 mo
Burkhead et al[24]	IV	Massive RCTs	Aug-17	Open	Acellular human dermal matrix; GraftJacket	25% Retear rate (3/12). Significant improvement in pain scores, UCLA scores, and active forward flexion	MRI (11), CTA (1) at 1-y
Xenograft							
Bokor et al[31]	IV	Partial thickness RCTs	Aug-13	Arthroscopic	Bovine collagen bioinductive patch (Rotation Medical, Plymouth, MN)	No tear progression in any patients at 24 mo; significant improvement in scores (ASES/Constant)	MRI at 12 and 24 mo
Giannotti et al[28]	IV	Massive RCTs	Aug-3	Mini-Open	Porcine dermal collagen (Zimmer, Warsaw, IN)	No failures. Improvement in pain, ROM, and strength	MRI
Cho et al[29]	IV	Massive RCTs	Aug-5	Mini-Open	Porcine dermal collagen (Permacol, Covidien, Mansfield, MA, USA)	20% Retear rate. Significant improvement in clinical outcome scores (VAS/UCLA/ASES)	MRI at 6 mo
Ciampi et al[30]	III	Massive RCTs	Aug (syn)-52, aug (xeno)-49, control-51	Mini-Open	Collagen bovine pericardium (TUTOPATCH, Tutogen Medical GmbH, Neunkirchen am Brand, Germany)	Retear rate: aug group-51%, control group-41%; no significant difference	Ultrasound at 1-y
Walton et al[26]	III	Large, massive RCTs	Aug-10, control-12	Open	Porcine small intestine submucosa; Restore Orthobiologic Implant (DePuy, Warsaw, Indiana)	Retear rate: aug group-60%, control group-58%; xenograft group had worse objective outcomes	MRI at 2-y
Iannotti et al[25]	II	Large, massive RCTs	Aug-15, control-15	Open	Porcine small intestine submucosa; Restore Orthobiologic Implant	Retear rate: aug group-73%, control group-40%; inferior outcomes in augmentation group	MRI at 1-y
Synthetic graft							
Lenart et al[33]	IV	Large, massive RCTs	Aug-13	Open	poly-L-lactic acid (X-Repair; Synthasome Inc, San Diego, CA, USA)	62% Retear rate. Significant improvement in clinical outcome scores (PENN/ASES)	MRI at 1-y
Proctor [35]	IV	Large, massive RCTs	Aug-18	Arthroscopic	poly-L-lactic acid; X-Repair	17% Retear rate at 12 mo, 22% at 42 mo, significant functional improvement	Ultrasound at 1-y
Ciampi et al[30]	III	Massive RCTs	Aug (syn)-52, aug (xeno)-49, control-51	Mini-Open	Polypropylene (Repol Angimesh, ANGIOLOGICA BM Srl, Pavia, Italy)	Retear rate: aug synthetic group-17%, control group-41%; significant improvement in function, strength at 3-y follow up	Ultrasound at 1-y
Encalada-Diaz et al[36]	IV	Small, medium RCTs	Aug-10	Mini-Open	Polycarbonate polyurethane (Biomerix, Fremont, CA)	10% Retear rate; significant improvement in VAS, SST, ASES, & ROM	MRI at 1-y

ASES, American Shoulder and Elbow Surgeons score; Aug, augmentation group; RCTs, rotator cuff tears; ROM, range of motion; SST, simple shoulder test; UCLA, University of California, Los Angeles; VAS, visual analog scale.

Table 2 Studies Evaluating Outcomes of Rotator Cuff Repair with Interpositional Graft Use

Study	Level of Evidence	Inclusion Criteria	No. of Patients	Surgical Technique	Graft Used	Retear Rate/Outcomes	Imaging Assessment
Allograft							
Venouziou et al[39]	IV	Massive RCTs	Interpos-14	Open	Acellular human dermal matrix; GraftJacket (Wright Medical Technology, Arlington, TN)	Significant improvement in ASES, pain, and ROM.	None
Modi et al[38]	IV	Massive RCTs	Interpos-61	Open	Acellular human dermal matrix; GraftJacket	No retears. Significant improvement in clinical outcome scores	MRI - mean follow up 3.6 y
Gupta et al[40]	IV	Massive RCTs	Interpos-24	Mini-Open	Acellular human dermal matrix; GraftJacket	24% retear rate (all partial tears); significant improvement in pain, ROM, outcome scores and strength	Ultrasound at 3-y
Wong et al[37]	IV	Large, massive RCTs	Interpos-45	Arthroscopic	Acellular human dermal matrix; GraftJacket	Significant improvement in mean clinical outcome scores (UCLA, ASES, WORC)	None
Xenograft							
Neumann et al[41]	IV	Massive RCTs	Interpos-61	Mini-Open	Porcine acellular dermal matrix; Conexa (Tornier, Inc., Edina, MN, USA)	8.2% retear rate; significant improvement in pain, ROM, and strength	Ultrasound at mean 50.3 mo
Badhe et al[42]	IV	Massive RCTs	Interpos-10	Open	Porcine dermal collagen (Zimmer Patch, formerly known as Permacol; Tissue Science Laboratories plc, Aldershot, Hampshire, UK)	20% retear rate; significant improvement in pain, Constant scores, ROM, and abduction strength	MRI (8), Ultrasound (2) at mean 4.5 y
Synthetic graft							
Petrie et al[43]	IV	Massive RCTs	Interpos-29	Open	Polyester ligament augmentation reconstruction system (LARS) patch (Arc-sur-Tille, France)	2 Patients required revision with good results; significant improvement in pain and subjective outcome scores	None
Nada et al[44]	IV	Massive RCTs	Interpos-21	Mini-Open	Polyethylene terephthalate (Dacron Xiros, Leeds, United Kingdom)	12% Retear rate; significant improvement in Constant scores	MRI at 3 y
Audenaert et al[45]	IV	Massive RCTs	Interpos-41	Open	Polyethylene terephthalate Mersilene mesh (Ethicon, Inc., Somerville, NJ)	7.3% retear rate; significant improvement in pain, Constant scores, and performance of daily activities	Ultrasound at mean 43 mo
Hirooka et al[46]	IV	Small, medium, large, massive RCTs	Interpos-27	Open	Gore-Tex patch (W.L. Gore & Associates, Flagstaff, AZ)	Significant improvement in mean subjective outcome scores and pain relief	None
Visuri et al[48]	IV	medium, large, massive RCTs	Interpos-14	Open	Carbon fiber tow device (Integraft; Hexcel Medical, Dublin, CA).	11 Patients had excellent results, and 3 (fair/poor) results	None
Ozaki et al.[47] (1986)	IV	Massive RCTs	Interpos-25	Open	Polytetrafluoroethylene (Teflon; Dupont Company, Wilmington, DE)	23 of 25 Patients had satisfactory results	None

Table 2 (continued)

Study	Level of Evidence	Inclusion Criteria	No. of Patients	Surgical Technique	Graft Used	Retear Rate/Outcomes	Imaging Assessment
Autograft							
Mori et al[49]	III	Large, massive RCTs	Interpos-24, partial repair-24	Arthroscopic	Fascia lata autograft	Retear rate: interpos group-8.3%, partial repair group-41.7%; significant improvement in outcome scores (ASES, Constant)	MRI at final follow up (mean-3 y)
Scheibel et al[50]	III	Small, medium RCTs	Interpos-20	Open	Autologous humeral periosteal flap	20% Retear rate. Significant improvement in clinical outcomes (SST/Constant)	MRI at 1-y

ASES, American Shoulder and Elbow Surgeons Score; interpos, interposition group; RCT, rotator cuff tear; ROM, range of motion; SST, simple shoulder test; UCLA, University of California, Los Angeles; WORC, Western Ontario Rotator Cuff.

final follow up.[41] Additionally, Badhe et al[42] studied the effect of porcine dermal collagen (Zimmer Patch, formerly known as Permacol; Tissue Science Laboratories plc, Aldershot, Hampshire, UK) interposition for irreparable massive rotator cuff tears, and similarly found a low retear rate.

Synthetic

Several studies have evaluated the clinical outcomes of synthetic patch extension devices. All of these patches are made from nonabsorbable material. Petrie et al performed a single surgeon prospective evaluation of 29 patients with 31 symptomatic irreparable massive rotator cuff tears with grade 3 or 4 Goutallier fatty degeneration who underwent open repair with an interpositional polyester ligament augmentation reconstruction system patch (Arc-sur-Tille, France). Postoperative Oxford shoulder score and visual analog score results demonstrated a statistically significant improvement at follow-up, compared with preoperative values ($P < 0.0001$). Two patients required revision with good postoperative results.[43] Several other series have evaluated the outcomes of various synthetic devices. Despite satisfactory reported outcomes, these case series are limited by their small sample sizes and lack of postoperative imaging assessment. Table 2 lists the published series evaluating synthetic interpositional devices.[44-48]

Autograft

The use of autograft patch augmentation or interposition is rare owing to donor site morbidity and the many other commercially available synthetic, xenograft, and allograft options. Therefore, there has been limited study on autograft patch interposition. Mori et al[49] conducted a level III retrospective study comparing an arthroscopic autograft fascia lata patch graft procedure ($n = 24$) and partial repair ($n = 24$) for irreparable large or massive rotator cuff tears in shoulders with low-grade (1 or 2) fatty degeneration of the infraspinatus. The fascia lata patch graft procedure showed an 8.3% retear rate with both improved clinical scores and recovery of muscle strength, whereas the partial repair group had a retear rate of 41.7%. Further clinical study is needed to determine the benefit of this procedure in the setting of donor site morbidity. Scheibel et al[50] also reported good results of open rotator cuff repair with a proximal humeral rotational periosteal flap augmentation, including 26% with large to massive tears. A total of 4 patients (20%) demonstrated a retear of the tendon on postoperative MRI, and ectopic ossifications in the supraspinatus tendon were found in 4 patients (20%), although this had no impact on the final clinical results.

Summary of Studies

Steinhaus et al[51] performed a systematic review of clinical outcomes and retear rates after patch use in rotator cuff repair surgery, between 1986 and January 2015. Twenty-four studies (levels II -IV) met inclusion criteria—level II,[2] level III,[3] and

level IV[19] (Tables 1 and 2). The frequency-weighted mean age was 61.9 years with 35.4 months of follow up. Patch augmentation and interposition techniques demonstrated similar improvements in patient-reported outcome measures, range of motion, and strength. However, xenografts showed less favorable improvement in outcome scores and activities of daily living as compared to the other graft types. The overall retear rate was 25% (patch augmentation—34%, patch interposition—12%), whereas rates of retearing by graft were 44%, 23%, and 15% for xenografts, allografts, and synthetic grafts, respectively. The authors concluded that retear rates may be lower with patch interposition techniques, or in patients with allograft or synthetics. Another more recent systematic review by Ferguson et al[52] evaluated 10 studies and found that allograft augmentation was functionally and structurally superior to primary repair controls, whereas the pooled xenograft augmentation procedures did not demonstrate superiority vs primary repairs. The review also found that synthetic polypropylene patches were associated with improved structural integrity and functional outcomes compared to both xenograft and primary repair. Future randomized studies are needed, which include some of the newer bioinductive xenograft patches.

Complications

The systematic review by Steinhaus et al[51] reported a relatively low pooled complication rate of 3.5% (12 of 340). The most common complication was a severe noninfectious inflammatory reaction seen in 7 patients treated with porcine small intestine submucosa (Restore) patch augmentation,[25,26] with 5 of these patients required formal debridement and irrigation. Several authors have hypothesized that the inflammatory reactions to residual porcine DNA material may be the causative factor.[53-55] Other complications included 1 deep infection in an immunocomprised patient who underwent allograft augmentation[37] and 1 case of recurrent bursitis.[23] Additional complications were related to asymptomatic cystic changes of the greater tuberosity after carbon fiber patch interposition,[48] although these radiographic changes had no repercussions on overall patient function.

Preferred Surgical Technique

The authors prefer to use rotator cuff repair augmentation with an allograft acellular human dermal matrix for patients with repairable rotator cuff tears, suboptimal tissue quality or

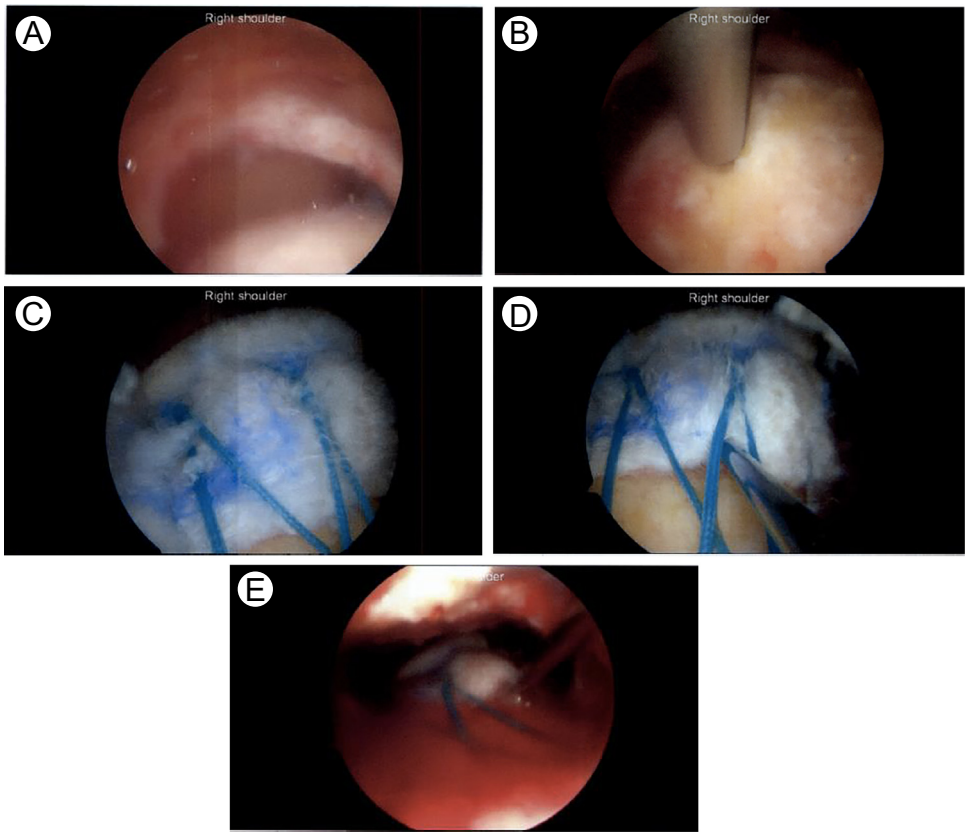

Figure 3 (A) Subacromial view of a right shoulder with a large 2-tendon rotator cuff tear after debridement and decompression. (B) Humeral footprint preparation with minimal 5 mm medialization of the articular margin and posteromedial anchor placement. (C) Finalized double row rotator cuff repair with acellular dermal allograft patch augmentation (Arthroflex, Arthrex, Naples, FL). (D) Platelet-rich plasma (PRP) injected at the patch-footprint interface to facilitate biologic incorporation. (E) Final image demonstrating the "crimson duvet" generated by marrow stimulation of the humeral footprint and PRP injection. (Color version of figure is available online.)

tendon attenuation, and younger patient age or higher functional demands. Regional anesthesia is the senior author's preference, although general anesthesia may be preferred by some surgeons. The patient is placed in the beach-chair position. Standard examination under anesthesia is performed to assess degree of atrophy and range of motion, particularly with stabilization of the scapula. Following establishment of the posterior viewing portal, diagnostic arthroscopy of the glenohumeral joint and subacromial space is performed, and rotator cuff tear size is measured. A careful subacromial bursectomy or decompression are performed to allow an optimal view from the lateral portal and global access of the rotator cuff (Fig. 3A). Rotator cuff mobilization is performed and as needed, interval releases to confirm that footprint restoration can be achieved without undue tension. If required, the articular margin can be medialized up to 5 mm to facilitate direct rotator cuff repair, and 2-3 double-loaded 4.75-mm biocomposite suture anchors are placed for the medial row repair of the supraspinatus and infraspinatus (Fig. 3B). Sutures are retrieved and passed in mattress fashion through the tendon in a mattress configuration using a retrograde suture passer. A slightly oversized (ie, 2-3 cm × 2 cm), acellular dermal allograft patch is prepared, and the 4 medial holes are created in the patch approximately 5 mm from the medial margin using an awl or the insertion handle for the suture anchor. The patch is subsequently shuttled down the lateral cannula over the medial row sutures, and mattress sutures are tied with simple alternating half hitches to secure the patch. Next, the patch is laid over the top of the greater tuberosity, and the medial sutures are then crossed to create a suture bridge configuration. Accordingly, paired sutures brought over the top of the patch to compress it in situ, and these are secured laterally with two 4.75-mm knotless anchors to create a transosseous-equivalent, double repair (Fig. 3C). Additional free sutures or tapes can be passed at the anterior and posterior corners of the patch in an inverted mattress luggage tag fashion and fixed into the lateral row to prevent "dog ear" formation. Optional orthobiologic adjuncts, such as platelet-rich plasma (Fig. 3D and E), may be added to enhance biologic incorporation at the site of repair and augmentation.

Conclusion

The treatment of large to massive rotator cuff tears is challenging. Patch augmentation and interposition is indicated in patients with shoulder pain and dysfunction who have failed an appropriate trial of conservative treatment. Patch augmentation of large to massive repairable rotator cuff tears results in improvement of clinical and functional outcomes with an acceptable retear rate and low complication rates. Synthetic grafts and allografts have shown more improvement compared to xenografts based on the current literature; however, in the setting of newer xenograft devices, future clinical trials are needed. Furthermore, synthetic, allograft, and xenograft patch interposition for irreparable tears is a viable surgical option for this difficult problem. Studies have demonstrated similar improvements in clinical and functional outcomes with a trend toward lower retear rates when compared to augmentation, although surgical indications may vary. Although numerous available options exist, the ideal graft for augmentation or interposition with advanced rotator cuff tears remains yet undetermined.

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