Rotator cuff repair – The SCOI row method

Rekonstrukcija tetiva rotatorne manžete – SCOI metoda

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Abstract. Arthroscopic rotator cuff repair is the standard of care. The "SCOI Row" method has been developed over three decades of experience. There is a strong debate regarding the best method of arthroscopic repair of the rotator cuff. Our method uses a single row of suture anchors with maximum number of sutures passed through the tendon to repair the rotator cuff arthroscopically under low tension. Debridement of devitalized tendon and only incorporating healthy tendon into the repair is stressed. The biology of the repair is enhanced with bone marrow vents created via microfracture of the greater tuberosity, forming the "Crimson Duvet" or bone marrow super-clot that will envelope the repair site and regenerate the footprint of the rotator cuff. Our outcomes show greater than 90 % healing rates when studied with post-operative MRI scans.

Key words: microfracture; repair; rotator cuff

Sažetak. Artroskopska rekonstrukcija tetiva rotatorne manžete standardni je postupak. Metoda "SCOI row" nastala je nakon tri desetljeća iskustva u liječenju takvih ozljeda, ali rasprave o najučinkovitijoj metodi i dalje traju. Naša metoda sastoji se u postavljanju sidara i što većeg broja tzv. *single row* šavova, uz što manju napetost tetive. Važno je istaknuti da se pritom uklanja devitalizirani dio tetive, a da se sidra postavljaju samo u zdravu kost. Cijeljenje se potiče upotrebom mikrofraktura u područje velikog trohantera potičući stvaranje tzv. "Crimson Duvet" ili superugruška koji se stvara u području hvatišta tetive, te potiče njegovo cijeljenje. Naši rezultati ukazuju na 90 % uspješnog cijeljenja koje je dokazano magnetskom rezonancom.

Ključne riječi: mikrofrakture; rekonstrukcija; rotatorna manžeta

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INTRODUCTION

Since the introduction of rotator cuff repair in the beginning of the 20th century, there have been significant advances in the surgical techniques and tremendous improvement in the quality of life for the patients involved. Although the techniques have changed tremendously from the original open technique described by Codman, the intent of the surgery and desired outcome both remain the same – to heal tendon to bone, improve pain, and restore function of the rotator cuff muscle/tendon complex[1]. Since that time, arthroscopic techniques have emerged as the current standard of care[2]. Currently, debate exists regarding the best method of tendon fixation, including implant choice, ideal suture construct, and the potential benefits of supplemental biologic additives in order to achieve the best repair with the highest chance of healing. In this review, we will discuss our experience and lessons developed during our journey through several generations of rotator cuff repair. The philosophy for management of rotator cuff pathology currently used at the Southern California Orthopedic Institute (SCOI) has been shaped over three decades of assiduous study and careful review of clinical experience. Our methods continue to evolve as we better understand the opportunities available to harness the innate power of the intrinsic healing potential the body has available for this debilitating, yet treatable injury.

HISTORY AND PHYSICAL EXAM OF THE ROTATOR CUFF

It is extremely important to obtain a complete history of a patient's shoulder pain and dysfunction such that a targeted physical exam and appropriate imaging can follow. Rotator cuff disease and injury can present in patients ranging in age from young adults to the elderly. Within this broad spectrum of patients, a variety of concomitant pathologies often exist, contributing to the patient's pain and dysfunction. The confounding pathologies often vary by age and by the patient's work, sport, or activity history. A history and physical exam is the first and most important step for a thorough diagnostic evaluation.

In the younger population, notably teenagers exposed to year round sports, repetitive use injuries are often seen. Overhead activity athletes, such as tennis, swimming, volleyball, and baseball pitching, commonly have problems with overuse injuries and associated tendonitis in relation with instability, glenohumeral internal rotation deficiency (GIRD), and loss of range of motion. A thorough questioning and demonstration of painful motions is necessary to evaluate for these pathologies.

The biology of the repair is enhanced with bone marrow vents created via micro fractures of the great tuberosity, forming the "Crimson Duvet".

Patients within the ages of 25 to 45 years old often are associated with tendonitis from chronic overuse related to overhead activities in workplace. Partial rotator cuff tears are commonly seen in this age group, although full thickness tears are not uncommon, especially with concomitant acute trauma. Within the 45 to 65 year old age group, rotator cuff tears are common and often present with the history and physical exam findings most clinicians associate with classic rotator cuff tears. Acute tears can result from a strenuous lifting activity or a fall, with dramatic and sudden loss of function. Chronic tears related to impingement syndrome often are insidious in onset, with progressive pain, weakness, and inability to tolerate overhead activities experienced over a period of time[3]. Night pain is a commonly reported symptom.

A complete, yet targeted, physical exam enhances the history to provide the surgeon with a preliminary diagnosis to further guide possible imaging and treatment. Every physical exam should begin with a visual inspection of both the patient's unclothed shoulders in order to view any obvious deformity and any side-to-side asymmetry of the musculature. Visible irregularities, including a prominent acromioclavicular (AC) joint, as well as atrophy of the deltoid and/or rotator cuff muscle above and below the spine of the scapula should be noted. Inspection of the upper arm can also reveal a previous rupture of the long head of the biceps tendon and its associated *Popeye* deformity. Atrophy of the trapezius and scapular winging are important to note, as they will require specific neurologic evaluation.

Palpation of various pain generators of the shoulder is a powerful diagnostic tool. A full palpation from medial to lateral, starting at the sternoclavicular joint and ending at the lateral edge of the acromion, can pinpoint specific spots of pain. The AC joint, subscapularis, and biceps tendon within the bicipital groove are all readily palpable and patients will often clearly state their pain has been reproduced with accurate palpation of these structures. In addition, palpation of the subacromial bursa, rotator cuff attachment, posterior parascapular muscles, and levator scapula insertion are important anatomical areas to evaluate.

Provocative maneuvers and muscle strength testing are also useful tools to aid in diagnosis. Many different exam maneuvers have been described to test the specific muscles of the rotator cuff. It is important for a clinician to find a reproducible set of exam maneuvers to master within their own practice. Our preferred series of maneuvers includes testing the strength of the infraspinatus and subscapularis with the elbow at the side. Positioning the arm in 60 degrees of abduction and 45 degrees of forward flexion and the shoulder in internal rotation with the thumb pointing towards the ground tests the supraspinatus. While the patients resists, a downward pressure is applied on the patient's hand. Pain or inability to resist the downward force constitutes a positive exam (Figure 1). The exam should always include maneuvers to demonstrate possible subacromial impingement, and the Neer sign and Hawkins Test are commonly reproducible exam maneuvers for this purpose. The biceps tendon must be tested using *Speed's Test* and the subscapularis muscle is evaluated with the *Belly Press Test*.

Figure 1. The supraspinatus stress test is an accurate physical exam maneuver to evaluate the strength of the rotator cuff.

It is very important to evaluate the range of motion of the shoulder as well. Adhesive capsulitis can mimic rotator cuff pathology and is best evaluated with the patient supine on the exam table by comparing internal and external rotation with the arm abducted to 90°.

IMAGING

Our radiograph series for patients with suspected rotator cuff injuries includes four images: a true anterior-posterior (AP) view of the glenohumeral joint, an AC joint view (Zanca view), axillary lateral view, and supraspinatus outlet (arch view). The AP view gives the examiner an overall indication of the health of the bony shoulder anatomy, including any arthritic changes and the bone quality of the greater tuberosity. Although rare, acromial "keel" spurs are best evaluated on the AP radiograph (Figure 2). The outlet radiograph is important to evaluate the acromial morphology and bone spurs, which may be related to impingement of the rotator cuff. The Bigliani classification is commonly used to classify this morphology as Type I (flat), Type II (curved) and Type III (hooked) varieties[4]. The SCOI modification to the classification scheme adds an important descriptor for the thickness of the acromion measured at the intersection of the anterior and middle third of the acromion[5]. We add a descriptor

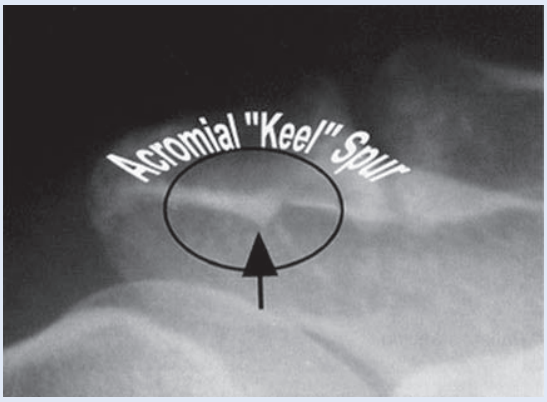

Figure 2. Acromial "keel" spur seen on a true AP radiograph of the shoulder

for a thin acromion of less than 8mm (Type A), average acromion of 8 to 12 mm (Type B) and thick acromion greater than 12 mm (Type C). This more detailed combined classification scheme allows for thorough study of pre-operative images for appropriate planning of any subacromial decompression. We have noted a thick acromion can cause "encroachment" of the bony space that the cuff must pass beneath without actual spur formation.

MRI has become the gold standard imaging modality for the diagnosis of rotator cuff disease. We will summarize some highlights of our use of MRI images in diagnosis and preoperative planning. The collection of fluid within the subacromial bursa is an important finding to evaluate for often missed partial thickness bursal-sided cuff tears. Significant collection of fluid seen pooling down the lateral bursa can form a "puddle", seen on coronal T2 weighted or fat-saturation sequences (Figure 3). The quality of the tendon itself is best viewed on the coronal T2 images, and should appear as a thick, robust tapering cable with distinct fibers that flow parallel from the muscle into the footprint. Disruption of the harmonious flow of the tendon fibers on T2 coronal images will be evident with increase signal intensity within the rotator cuff and disruption of the smooth tapering pattern (Figure 4). The size and shape of the tear are important to understand prior to surgery and careful study of the MRI is needed to form a surgical plan. Concomitant pathology can also be evaluated. The quality and thickness of the tendon should be evaluated, as well as the health and possible atrophy of the rotator cuff muscles.

Crimson Duvet or bone marrow super-clot envelope the repair site and regenerate the footprint of the rotator cuff.

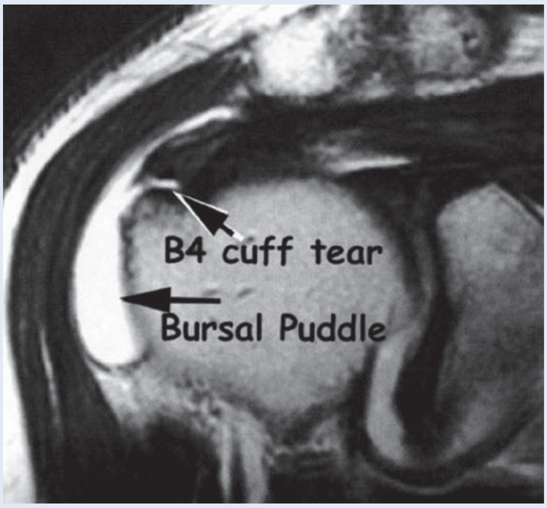

Figure 3. Collection of subacromial fluid with associated bursal-sided tear on a coronal MRI image

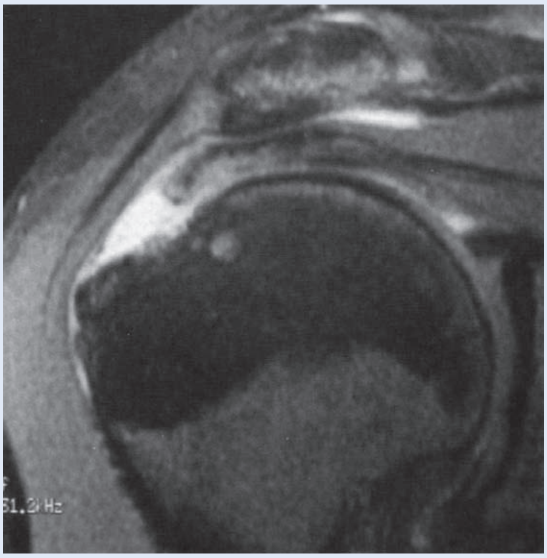

Figure 4. Disruption of the harmonious flow of the tendon fibers on T2 coronal images will be evident with incrase signal intensity within the rotator cuff and disruption of the smooth tepering pattern.

THE SCOI PHILOSOPHY OF ROTATOR CUFF REPAIR

As arthroscopic rotator cuff repairs have become the standard of care, controversy exists regarding the optimal surgical approach and repair method to achieve the best outcomes. Review of the mini-open rotator cuff repairs from the past gives us perspective on the current debate regarding arthroscopic repair. During the mini-open approach, a flat undersurface acromial edge was created and the rotator cuff tendon was mobilized on the bursal and articular sides. A trough was typically made just lateral to the articular margin through which bone tunnels would be made to pass suture and secure the tendon to bone. Early arthroscopic repairs replicated this method of fixation, but Galatz and Yamaguchi published their ultrasound study suggesting a single row of anchors resulted in high failure rates and suggested a second, or double row, of anchors might yield a superior repair[6].

Advocates of double row techniques have cited a more anatomic restoration of the rotator cuff footprint as a justification for their techniques[7]. Improved mechanical properties, larger tendon-to-bone contact area, and increased initial fixation strength have all be offered to support the need for double row techniques. Continuing this trend, transosseous equivalent fixation techniques have developed as a means to provide even stronger fixation of the tendon to the tuberosity with greater surface contact[8]. Although both double row and transosseous equivalent techniques seem logical and appeal to an orthopaedic surgeon's desire to restore native anatomy, the purported benefits have yet to be validated in the literature. Of the most notable Level I and II studies to date, the outcomes between single and double row repairs have been equivalent[9,10].

Our understanding of the rotator cuff footprint itself has changed dramatically in recent years. The classic and well adopted anatomy of greater tuberosity and tendon attachments described by Alan Curtis have been challenged by recent arthroscopic and cadaveric dissections[11]. Mochizuki et al. have provided us with a different understanding of the relationship of the infraspinatus and supraspinatus tendon attachments on the footprint[12]. Rather than the broad and well aligned side-by-side rectangular insertion sites, a more complex and asymmetric relationship exists. The infraspinatus attaches to the vast majority of the tuberosity, wrapping around the much smaller and triangular shaped insertion of the supraspinatus (Figure 5a,b). The double row fixation of the supraspinatus tendon over this entire area would not constitute an anatomic reconstruction of the native tendon according the Mochizuki's description of the tendon insertions.

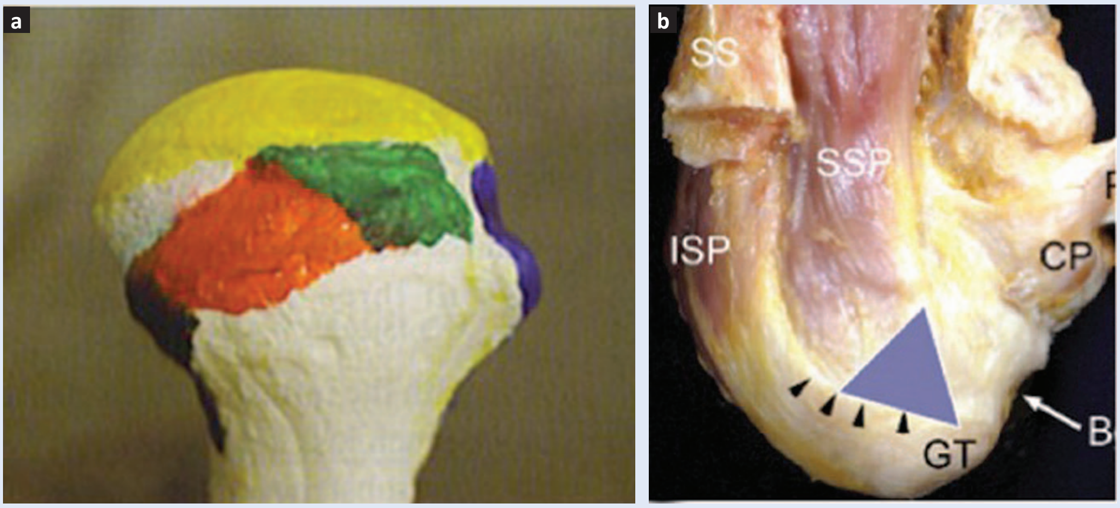

Figure 5. a) Traditional schematic of the rotator cuff tendons arrange on the footprint; b) New dissection showing the infraspinatus wrapping around the supraspinatus.

It is important to understand the pathology within the rotator cuff tendon with regards to where and why the tendon tears. The largely avascular area of the tendon, approximately 1 cm from the insertion site, has been well described[13,14]. This area of poor blood supply is predisposed to degenerative changes and ultimately tearing[15]. Tears resulting from this hypovascular area leave two areas of tendon that must be resected prior to reconstruction – first the frayed and degenerative medial tendon edge, and second the disconnected stump of tendon laterally still attached to the tuberosity. Debridement of these edges is an important step to ensure only healthy tendon is incorporated in the repair. Recent literature has shown these distal edges of the torn supraspinatus harbor high concentrations of pro-apoptotic and pro-inflammatory molecules and cytokines (including Bax, caspases 3,8,9, TNF-alpha, and IL-10). A debridement of 4-7 mm of the edge of the torn surpraspinatus tendon is recommended to enhance the healing potential of any repair[16].

The length of the remaining tendon must be taken into consideration when planning for a repair. With an appropriate debridement, the remaining length of repairable tendon is obviously shorter than the native tendon. If the shorter tendon were to then be pulled over the tuberosity to cover the entire footprint, the increased tension of the repair and on the muscle must be taken into consideration. Christian Gerber has studied the changes occurring within the muscles themselves and has shown there is loss of the muscle fiber length with associated fatty infiltration and retraction[17]. Increased tension has been shown to be deleterious to healing and optimal muscle function. The functional outcome of a rotator cuff repair is inversely proportional to the rotator cuff repair tension[18]. It is important to note the potential trap of over tensioning a repair is not exclusive to double row repairs, as a single row repair with anchors placed on the on the lateral edge of the footprint also creates a high tension repair.

At SCOI, we advocate a tension-free repair and have developed the "SCOI Row" method. A single row of medial anchors is placed just adjacent to the articular cartilage. The anchors are triple loaded to maximize the number of sutures passes through tendon to provide the most secure fixation with minimized tension on the repair. Studies have shown increased strength, less gap formation, and higher resistance to cyclical loading with a greater number of sutures per anchor[19,20]. These principles are the basis for our medial-based, tension-free, single row repair. The second component of the SCOI Row repair involves improving the local biology of the footprint to promote healing and restore the native footprint. The proximal humerus holds a rich bank of bone marrow, which we access via multiple microfracture holes. These punctures, made laterally on the tuberosity, each create a direct vascular channel from the rich medullary supply within the humeral head and over the footprint on the tuberosity. The marrow released from these vents envelopes and clots over the tuberosity, bringing with it stem cells and growth factors – we have coined this the "Crimson Duvet". This term describes both the vivid reddish pigment and the blanket-like coverage the "super clot" provides over the bony footprint (Figure 6). An elegant animal study has shown cell descendent from the bone marrow vents are part of the healed tendon[21]. Clinical studies have also shown increased healing rates with bone marrow vents when compared to similar repair constructs without bone marrow vents[22].

With the successful creation of the bone marrow vents, we have observed new tissue that forms lateral to the repair site – a form of tendon regenerate consistent with the native rotator cuff tendon over the footprint. Histological viewing of samples from the new tissue is consistent with normal appearing tendon (Figure 7). Our own review of 100 consecutive patients receiving SCOI row repairs for large sized tears (2-4 cm) showed 90 % healing rate when studied with MRI and 95 % healing when no side-to-side sutures were needed[23]. The WORC scores of the patients with intact repairs was 91.9, compared with a score of 61.9 for the patients with a recurrent tear. In the event of recurrence, the failure pattern after a SCOI Row repair is almost always Type I failure, amenable to repeat repair. Type II failures (at the musculotendenous junc-

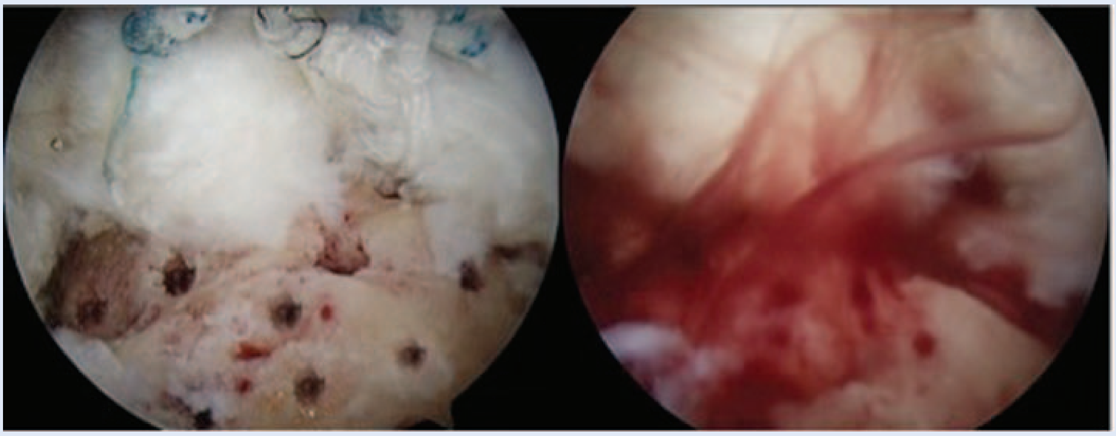

Figure 6. Microfracture of the tuberosity creating vascular channels and the emerging Crimson Duvet bone marrow enveloping the footprint

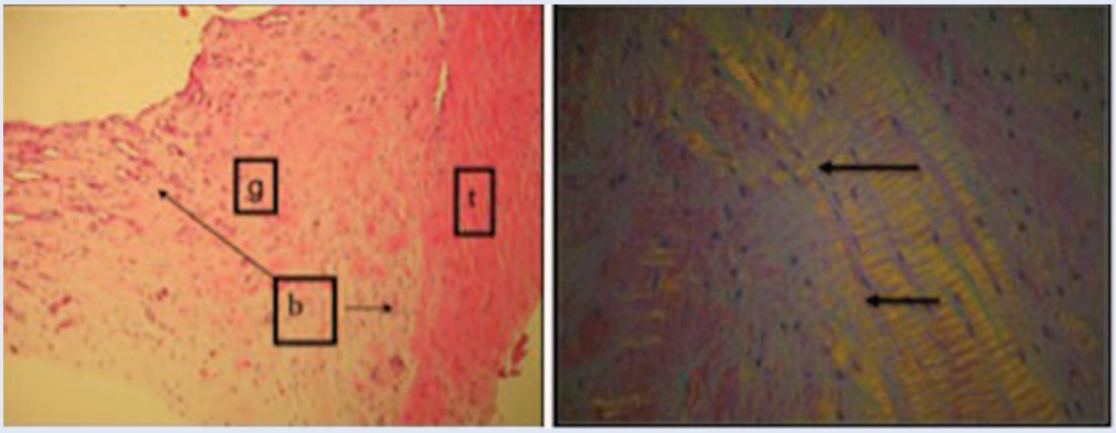

Figure 7. Biopsy specimen revealing mature tissue lateral to the SCOI Row repair

tion) are disastrous to re-repair, and this is the mode of failure often seen in double row repairs. The decreased costs of single row repairs due to the limited number of implants needed must also be considered. Double row constructs generally require double the number of implants compared with single row repairs, usually doubling the cost of implants.

REPAIR TECHNIQUE

The three components of the SCOI Row rotator cuff repair include:

A single row of strong anchors each loaded with three high-strength sutures. These sutures are passed through in simple stitches through the prepared cuff edge in a fan shaped array to evenly distribute the tension and avoid compromising the tenuous circulation.

Insertion of the anchors near the medial edge of the natural rotator cuff footprint, entering at a 45 degree "tent peg" angle under the subchondral bone, just a few millimeters lateral to the cartilage.

Microfracture or "bone marrow vents" created laterally on the tuberosity, from which the Crimson Duvet super clot will emerge to supply the fibrin clot, the stem cells and platelets and growth factors, and ultimately a new permanent blood supply to the healed/regenerated tendon.

The patient is positioned in the lateral decubitus position, with the arm in 70 degrees of abduction and 15 degrees of forward flexion, and a 15-point diagnostic arthroscopy is performed from the posterior mid-glenoid portal (PMGP) and the anterior mid-glenoid portal (AMGP). Working from both portals, a motorized shaver is used to debri-

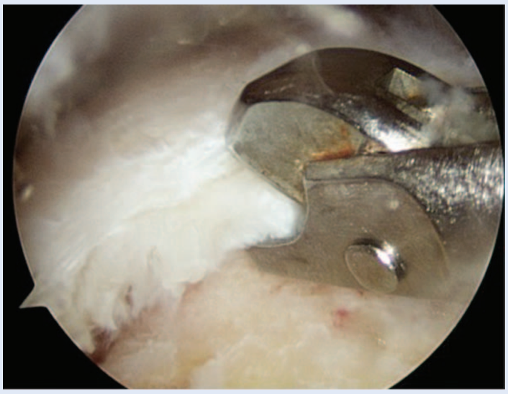

Figure 8. Trimming the thin, frayed degenerative edge of torn cuff with a suction punch.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

de the frayed edges of the torn tendon on the articular side. It is best to debride the torn tendon remaining on the footprint of the humeral neck and articular crescent while viewing inside the glenohumeral joint since they are not easily seen while viewing from the subacromial space.

The arm is then moved into the bursoscopy position of 15 degrees of abduction and a diagnostic bursoscopy is performed. Care is taken to debride the posterior bursal curtain and lateral bursal shelf to improve visualization for the upcoming repair.

Our mid-lateral subacromial portal (MLSP) is made at least 3 cm from the lateral acromial edge and at the position directly inline with the center of the cuff tear. Any subacromial decompression or distal clavicle excision can be performed at this time. After these adjunct procedures, the surgeon can assess the remaining rotator cuff and plan the final repair. A final debridement of the thin avascular tendon edge may be performed; we prefer to use a suction punch to ensure a full thickness bite, leaving a sharp and healthy edge to be the contact point to bone as the most lateral portion of tendon in the repair (Figure 8).

Our outcomes show more than 90 % healing rates when studied with post-operative MRI scan.

While viewing from the MLSP, we test the insertion site of our suture anchors with a spinal needle. We use one triple loaded suture anchor for each 1.2 cm of torn tendon and may need more than one percutaneous puncture to ensure the proper positioning of the anchors. The angle of insertion is critically important and we place our anchors at a 45-degree angle to the subchondral bone. This angle will guarantee the strongest fixation of cuff edge and best resistance to anchor pull-out[24] (Figure 9). if the angle is too vertical, the

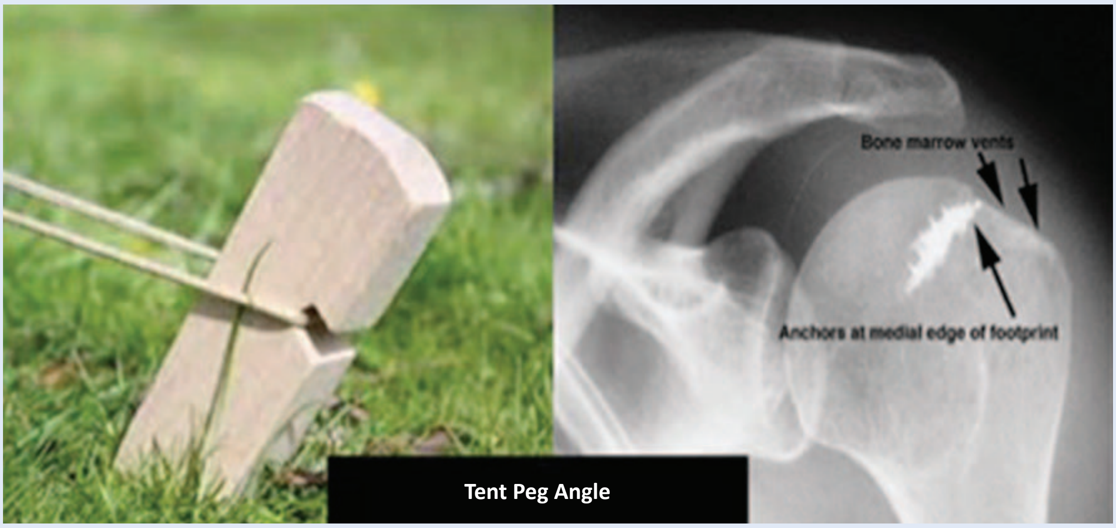

Figure 9. The anchors are inserted 5 mm lateral to the articular cartilage at a 45 degree, or “tent peg”, angle
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

anchor may rotate in the softer bone of the tuberosity and risk pullout or allow gap formation. The anchor should be seated such that the eyelet is facing the cuff tendon to help minimize suture crossing. Pilot holes are placed for the selected anchors, and using either the starting awl for the anchor or a different microfracture device, vent holes are made in the tuberosity, beginning a few millimeters away from the anchor pilot holes. The vents should be at approximately 1.5 cm deep and aimed down the humeral shaft. The appearance of fat globules bubbling from the bone marrow vents ensures appropriate depth of penetration. We recommend four to seven vents depending on the size of the tear (Figure 10). We do not use "fully threaded" but rather standard eyelet anchors and prefer to seat them 3 mm below the cortical surface in order to permit bone marrow flow from the anchor socket. This deeper seating also minimizes artifact form the "frequency shift" that forms around titanium implants, which might interfere with a future MRI scans.

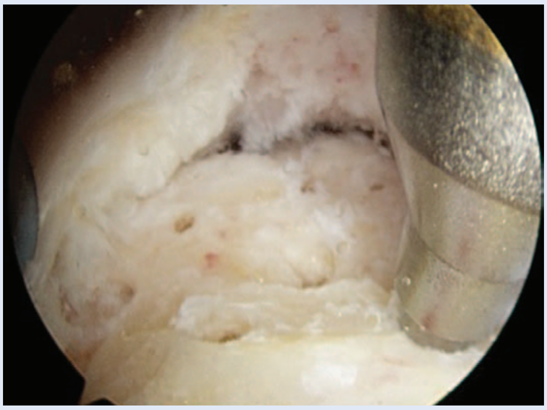

Figure 10. Microfracture awl used to create bone marrow vents with fat globules emerging.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

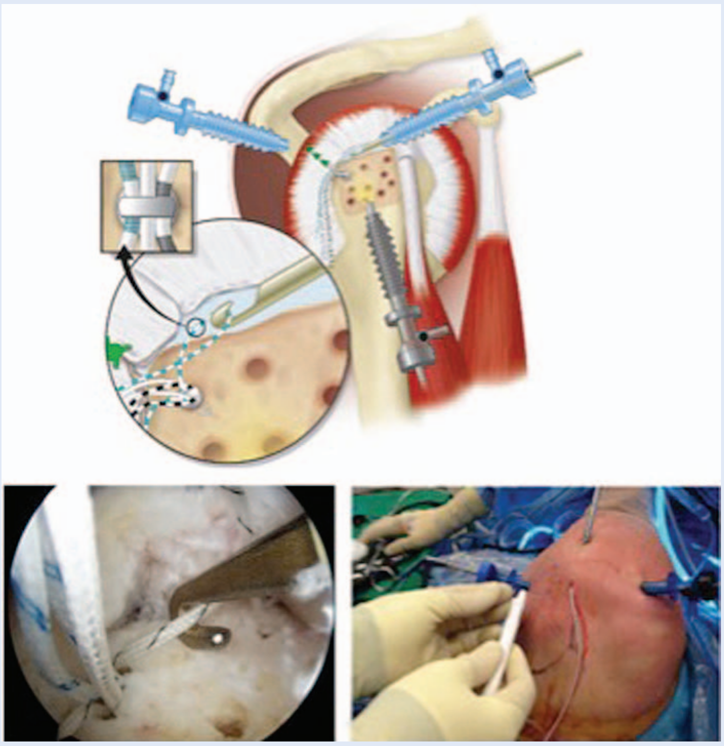

Figure 11. The medial limb of the posterior suture is retrieved into the anterior cannula using the crochet hook, and the end of the retrieved suture is color purple with a skin marker.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

We prefer to pass our sutures from posterior to anterior using "suture shuttle" technique. First we retrieve the posterior-most suture that exits the anchor on the cuff side (medial side) out the AMGP in preparation for suture shuttling. After the appropriate suture hook is selected and from the PMGP the cuff tissue is penetrated from top to bottom, 6 mm posterior to the anchor and 1 to 1.5 cm medial to the free edge. Care must be taken to visualize the needle as it exits the undersurface of the tendon to ensure any delamination has been penetrated by the suture hook (Figure 11). The suture shuttle is deployed and retrieved out the AMGP. The suture previously retrieved in the AMGP is loaded into the shuttle and carried back through the cuff tissue and out the PMGP. The partner suture from the anchor is retrieved into the PMGP and both limbs of these partners suture are placed external to the cannula and within Suture Savers (Conmed/Linvatec, Largo FL) in order to avoid tangling of sutures and preserve organization and facilitate suture tying (Figure 12). This process is repeated, working from posterior to anterior for each anchor. The appropriate numbers of anchors are placed and sutures are passed, using various angles of suture hooks as needed depending on the necessary angle of penetration needed. The gentle pressure of the

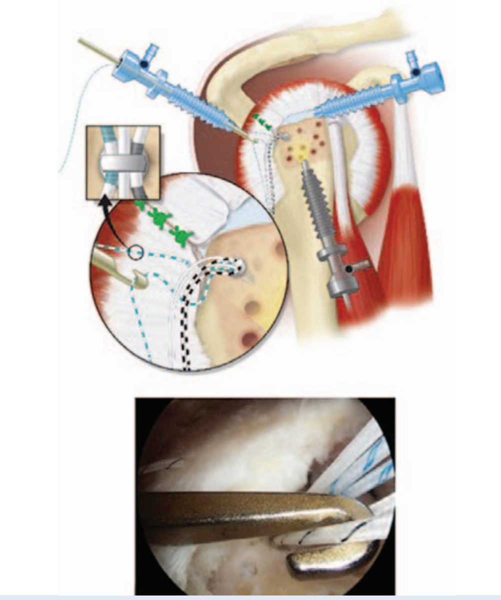

Figure 12. Retrieve the partner of the first posterior suture out the posterior cannula with a crochet hook. Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

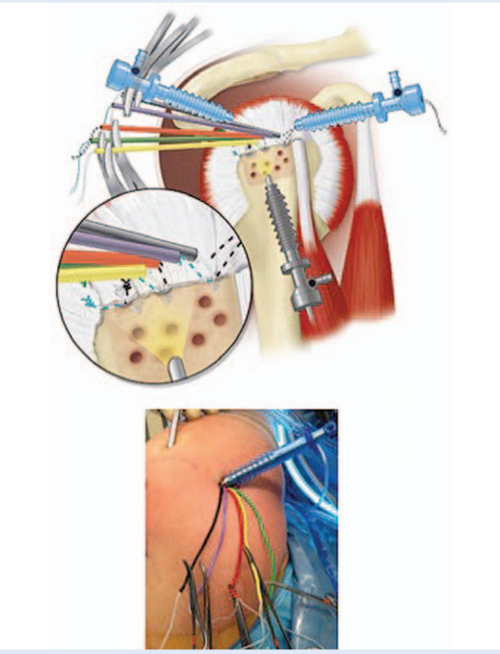

Figure 13. Preliminary reduction of the rotator cuff tendon is appreciable with the use of Suture Savers for suture management.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

Suture Savers will allow a preliminary "soft" reduction of the rotator cuff tendon to the bone and can be appreciated before any sutures are tied (Figure 13). Also, since the suture savers are situated on the bursal side of the cuff where the suture has been passed, it will serve as a visual marker key of that position facilitating the choice of the best location for the next suture passage.
Once all the sutures are passed, the suture pairs are tied, from anterior to posterior. For the anterior most sutures, we view from the MLSP and tie from the AMGP. For the remaining sutures, we view from the AMGP and tie from the LSAP. We use the SMC knot (sliding locking knot) and cut the sutures to leave a 3 mm tail from the knots. Once all the knots are tied, the scope is returned to the MLSP for viewing the final repair. The fluid inflow is suspended and the bone marrow can be observed to flow from the bone marrow vents and envelope the repair site (Figure 14). After skin portal closure, we use of the ProWick (Arthrex, Inc., Naples, FL) postoperative dressing and apply an UltraSling4 ER (DJ Orthopaedics Global, Carlsbad, CA) which supports the arm in 15 degrees of external rotation and 30 degrees of abduction.

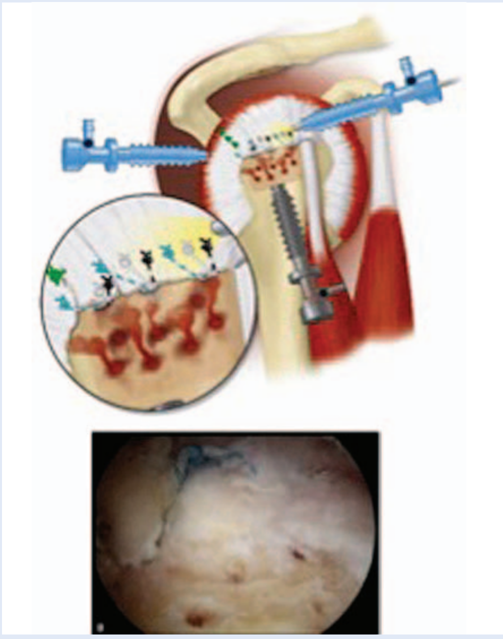

Figure 14. Finale view of the repair.
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Our postoperative protocol includes use of the UltraSling ER brace for 5 weeks and permits elbow, wrist and hand exercises and pendulum exercises during this time. Supervised physical therapy begins at 6 weeks with initiation of active-assisted elevation and progressive resisted exercises of the scapula and rotator cuff as symptoms allow. Most activities of daily living are allowed at 2 months but heavy lifting and return to sports are delayed until 6 months in the usual case.

RESULTS

In 2013 we evaluated a series of 45 patients with 48 medium-to-large rotator cuff tears (average age 57.6 years, mean follow up 39 months). Shoulder pain improved from 3.3 preoperatively to 9.3 post-operatively on the UCLA shoulder index. Function scores improved from 5.4 to 9.5 and patient satisfaction scores improved from 0 to 4.9 out of a possible 5.24[22]. In a more recent review submitted for publication, 52 shoulders with 2 to 4 cm full thickness tears were evaluated with MRI at a minimum of 1 year postoperatively. A 95.2 % healing rates was shown in repairs not requiring margin convergence sutures, and a 90.4 % healing rates was shown when including all repairs.

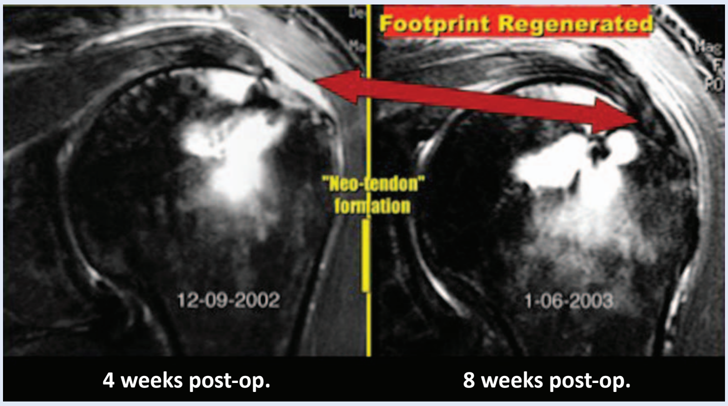

Figure 15. Regeneration of the footprint seen on MRI at 4 weeks and 8 weeks.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

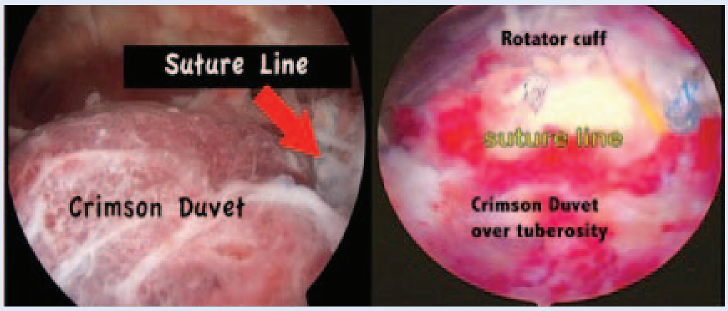

Figure 16. 1 week postoperatively, the Crimson Duvet appears like a red blanket covering the tuberosity, the suture line, and the cuff.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

Our shoulder team at SCOI has performed more than 4,000 arthroscopic rotator cuff repairs using the SCOI Row technique. In doing so, we have also had the opportunity to perform many postoperative MRI scans for a variety of reasons, allowing us to evaluate the healing of the repairs. The rotator cuff typically appears to reattach to bone and the new footprint regenerates at about 6 to 8 weeks. This process continues to mature and at 8 to 10 weeks we can expect to see the regenerating footprint up to 2 cm further lateral from the anchors insertion site (Figure 15). The Crimson Duvet that covers the footprint is comprised of mesenchymal stem cells and a rich fibrin matrix that supports the regeneration of the tendon footprint. We had the opportunity to perform repeat arthroscopy and evaluate the healing of the rotator cuff repair at 1 week post-operatively. We observed a maturing Crimson Duvet with rich, dense tissue lateral to the suture line (Figure 16). In a separate case, viewing the footprint during repeat arthroscopy at 2 years post-rotator cuff repair to address a biceps tendon injury revealed total regeneration of the lateral footprint (Figure 17).

ROTATOR CUFF REPAIR WITH AUGMENTATION

Non-healing and re-tearing after the repair of rotator cuffs remains a significant problem with a rate as high as 60-90 % in some studies. The cause of this problem is likely multifactorial, but age, tear size, and tear chronicity have been implicated. Although it is impossible to precisely identify the patients that will not heal a standard rotator cuff repair, evaluating all the risk factors may lead a surgeon to consider some form of

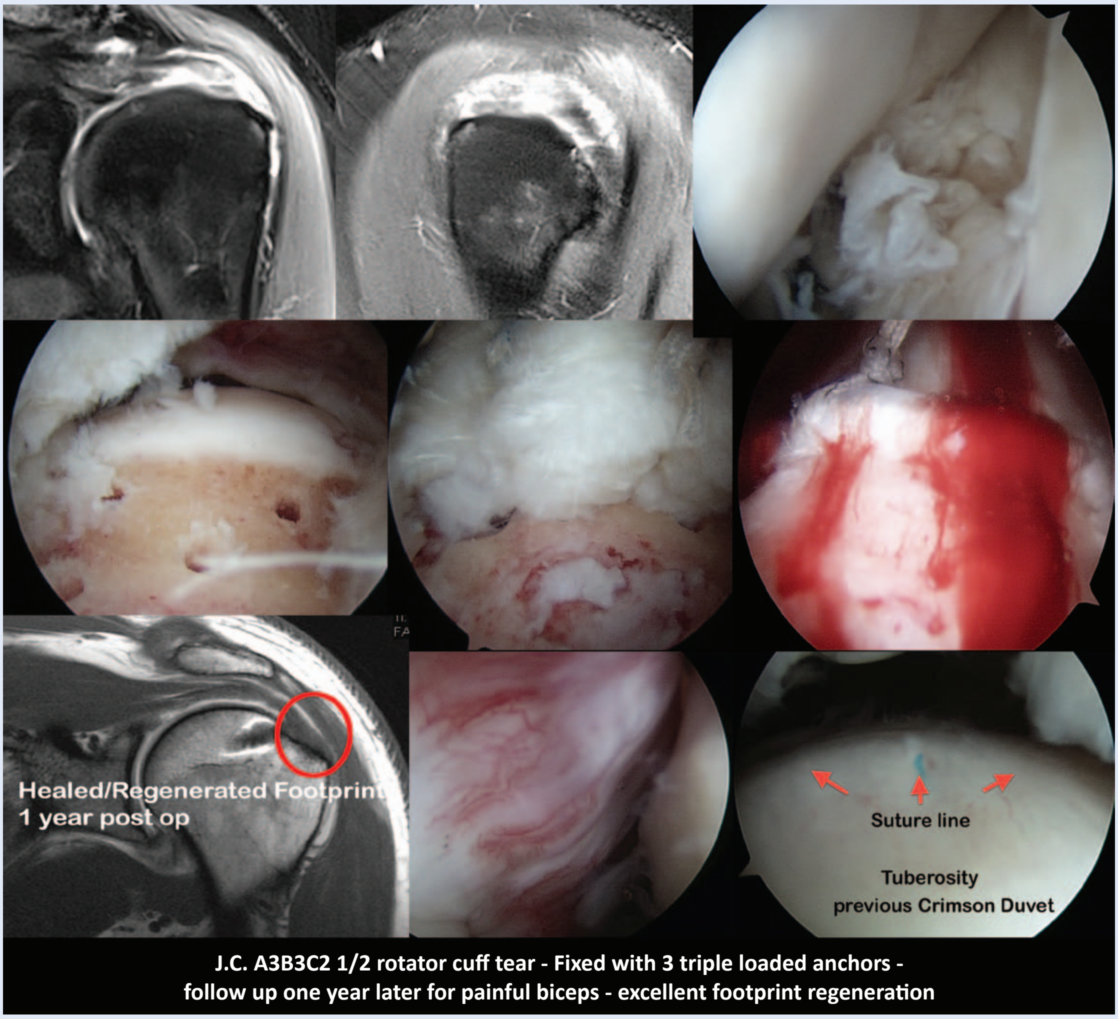

Figure 17. Collage of preoperative imaging, initial rotator cuff repair, postoperative MRI, and postoperative repeat arthroscopy at 12 months showing regeneration of the footprint.
Figure was previously published in: Shoulder arthroscopy, 3e (Snyder SJ et al.), Chapter 20: Arthroscopic Evaluation and Treatment of Bursal-Sided, Intratendon, and Full-Thickness Rotator Cuff Tears Using the SCOI Row Technique

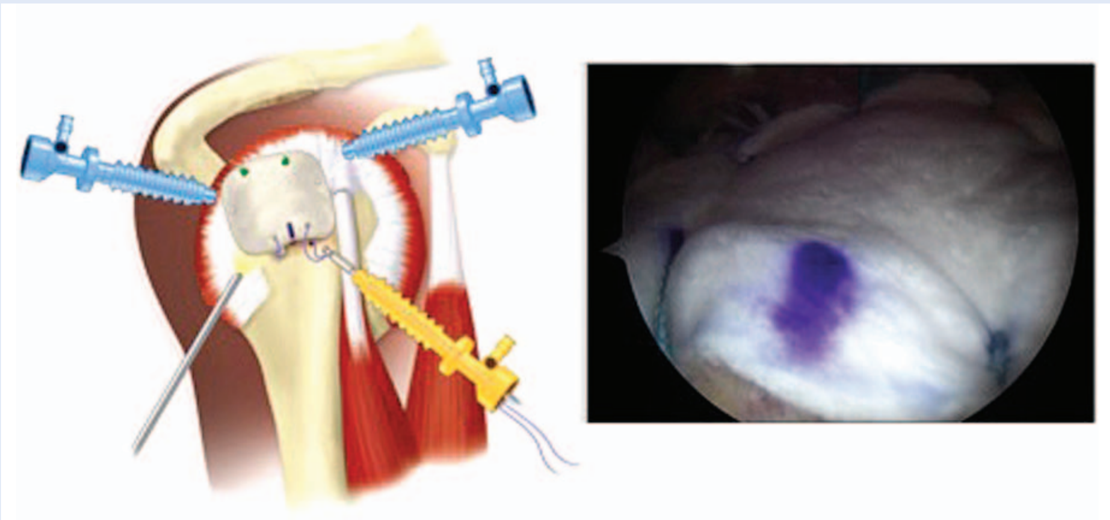

Figure 18. Graft insertion to deploy as an augmentation to the SCOI Row rotator cuff repair.

augmentation to the repair. Allograft scaffolds have a strong track record in reconstructive surgery and we use human dermal allograft for augmentation of rotator cuff repairs[24]. It is acellular, non-crosslinked, and usually 2 mm thick. Lacking any immunogenicity and having long shelf life with easy storage make it an ideal graft for rotator cuff augmentation. The collage fibers and vascular channels of the allograft afford an ideal binding site for the Crimson Duvet and the stems cells it contains. Through the technique of carefully "patching" the graft over the SCOI Row rotator cuff repair, the graft also acts a biomechanical load sharing implant, helping reduce the tension at the repair-bone interface (Figure 18). Although a technically demanding procedure to perform arthroscopically, excellent outcomes have been reported in rotator cuffs that otherwise would have been likely to fail[24].

Conflicts of interest statement: The authors report no conflicts of interest.

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