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Superior capsular reconstruction: current evidence and limits

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- The treatment of rotator cuff tears (RCTs) has evolved. Nonsurgical treatment is adequate for many patients; however, for those for whom surgical treatment is indicated, rotator cuff repair provides reliable pain relief and good functional results. However, massive and irreparable RCTs are a significant challenge for both patients and surgeons.
- Superior capsular reconstruction (SCR) has become increasingly popular in recent years. It works by passively restoring the superior restriction of the humeral head, thus restoring the pair of forces and improving the kinematics of the glenohumeral joint. Early clinical results using fascia lata (FL) autograft were promising in terms of pain relief and function.
- The procedure has evolved, and some authors have suggested that FL autografts could be replaced by other methods. However, surgical techniques for SCR are highly variable, and patient indications remain undefined. There are concerns that the available scientific evidence does not support the popularity of the procedure.
- This review aimed to critically evaluate the biomechanics, indications, procedural considerations, and clinical outcomes associated with the SCR procedure.

Keywords

- rotator cuff tears
- massive and irreparable
- superior capsular reconstruction
- fascia lata
- dermal allograft
- restoring the pair of forces and improving the kinematics

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Introduction

The treatment of rotator cuff tears (RCTs) has evolved in recent decades. Nonsurgical treatment is adequate for many patients; however, for those for whom surgical treatment is indicated, rotator cuff repair provides reliable pain relief and good functional results (1). However, massive and irreparable RCTs (MIRCTs) are a significant challenge for patients and surgeons. Commonly defined as a full-thickness injury involving at least two tendons or measuring >5 cm in the coronal plane, massive rotator cuff injuries are estimated to comprise approximately 20% of all RCTs and 80% of recurrent tears (2, 3, 4). Even though shoulders with MIRCTs may maintain sufficient stability, they are often extremely painful and effectively render the shoulder non-functional. Shoulder pseudoparesis has been defined as >90° active shoulder elevations with a full passive range of motion (ROM) and no neurological impairment (5, 6). In severe cases, the loss of function can be profound, with complete loss of active shoulder elevation (0°) that persists even after infiltration, called pseudoparalysis. Pseudoparesis indicates weakness with some movement (paresis), and pseudoparalysis indicates the absence of movement (paralysis) (5, 6, 7).

Although shoulder function can be restored if complete repair and healing of the torn tendon are achieved, some massive RCTs are irreparable and remain difficult to treat due to tendon retraction and inelasticity often related to the chronicity of the tear (6, 8, 9). Treatment options for MIRCTs depend on several factors, including patient age, activity level, the severity of joint arthropathy, and the degree of disability (6). Although partial repair, tendon transfer, and reverse total shoulder arthroplasty can deal with these tears, an optimal treatment in which glenohumeral function and joint preservation are achieved has yet to be determined (10). Superior capsular reconstruction (SCR) has increasingly been performed in recent years (6). Initially proposed by Mihata *et al.* (11) it acts by passively restoring the superior restriction of the humeral head, thus restoring the pair of forces and improving the kinematics of the glenohumeral joint. Fascia lata (FL) autografts showed promising results for pain relief

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and function in previous studies (12), and further studies have suggested the use of a dermal allograft instead of FL autografts (13, 14, 15, 16). However, surgical techniques for SCR are highly variable, and patient indications remain undetermined. There are concerns that the available scientific evidence does not support the popularity of the procedure (17). This review is aimed to critically evaluate the biomechanics, indications, procedural considerations, and clinical outcomes associated with the SCR procedure.

Biomechanics

Normal shoulder function is a result of interactions between the rotator cuff and deltoid muscles that balance the multiplanar coupling forces of the glenohumeral joint (18). When the deltoid contracts, the superior rotator cuff stabilises the humeral head. The downward vector of the deltoid and rotator cuffs provided a force couple in the coronal plane. The posterior and anterior cuff tendons function similarly in the transverse plane (19). The disruption of this force couple in a large or massive RCT causes proximal humeral head migration and narrowing of the subacromial space. Torn tendons that cannot participate in load sharing increase the load on the remaining fibres, which may cause tear propagation, particularly if the remaining tendon is of poor quality, which, if progresses, may result in rotator cuff arthropathy (6, 19).

The superior capsule lies beneath the supraspinatus and is attached medially to the superior glenoid and laterally to the greater tuberosity of the humerus (11). An insertional footprint of the superior capsule between 5 and 9 mm from medial to lateral at the greater tuberosity was observed in cadaver studies (20, 21). It is thought to act as a static stabiliser, working with the superior rotator cuff to provide strength (22). The effects of increased joint translation in the presence of an RCT and a concomitant superior capsular defect have been reported (23). We also may encounter a superior capsule torn due to their intimate relationship in the presence of an RCT (24). Biomechanical analysis in cadavers reported that using FL patch grafts to reconstruct the superior capsule, subacromial contact pressures, and superior translation were restored to the normal pre-cut levels (11). Isolated repair of the tendon only did this partially (11). This study suggested that reconstructing the superior capsule by anchoring the graft to the glenoid medially and the greater tuberosity laterally could restore the joint depression effect of the torn superior cuff, which serves as the foundation for SCR. Several theories have been suggested as to why this works, although no studies have definitively proven one theory over the other. These can be defined as (i) the spacer effect (the graft cushions the humeral head's contact on the acromion's undersurface), (ii) the trampoline theory (tension within the graft acts to depress the humeral head), and (iii) the force coupling effect theory (the graft incorporates healing to native cuff tissue and restores the force couple by transferring force from the residual cuff) (6, 19, 25).

Indications

Determining the best indications and suitable candidates for SCR is difficult due to the lack of mid- to long-term outcome data. The right candidate is according to Frank *et al.* 'a patient with intolerable pain or unacceptable dysfunction who have failed nonoperative treatment with MIRCTs and have minimal to no rotator cuff arthropathy, an intact or reparable subscapularis tendon, and a functional deltoid muscle'. (26).

Indications for SCR include a massive, irreparable posterosuperior tear of the rotator cuff, an intact or repairable subscapularis tendon, intolerable pain despite conservative treatment (at least 6 weeks), and minimal or absent evidence of arthritis (preserved glenohumeral joint space on true anteroposterior and axillary radiographs) (2, 13). A good passive ROM of the shoulder, especially in flexion and abduction, is also an important preoperative factor for SCR (13).

Patients with moderate-to-severe RCT arthropathy (Hamada score $\geq$3) or established arthritis of the glenohumeral joint are not good candidates for SCR. Reverse total shoulder arthroplasty provides consistent pain relief and improved function in the elderly, in those who are more sedentary, and in those who have had multiple failed cuff repairs (27, 28, 29). SCR may also be considered unjustified due to preserved motion, functional demands, and perhaps associated comorbidities and should not be considered in patients with significant bone defects, shoulder muscle dysfunction (deltoid, latissimus dorsi, or pectoralis muscle), or severe shoulder stiffness (13).

Other alternative procedures for irreparable posterosuperior RCTs include debridement, biceps tenotomy or tenodesis, subacromial decompression, tendon transfer, and bridging graft (30).

Technical considerations

Graft selection

FL autograft

In 2012, Mihata *et al.* proposed an arthroscopic technique for SCR using an FL autograft for irreparable symptomatic RCTs (11, 12). This technique is advantageous with a greater fixation force, graft size, and thickness and enhanced tissue healing due to its unique histological characteristics (12, 22, 31).

A harvested FL autograft is two to three times the size of the superior capsular defect and can be folded several times to reach a final thickness of 6–8 mm (21, 32). Mihata *et al.* showed that using an FL graft (8 mm thick) for SCR significantly decreases the peak subacromial contact pressure (a decrease of 246% at 0° and 158% at 30° abduction) and superior translation (a decrease of 135% at 0° and 130% at 30° abduction) after RCT. Stability increased when using a thicker graft (8 mm vs 4 mm), when fixed at 10°–30° glenohumeral abduction (31).

Arthroscopic SCR using an FL autograft is a reliable and practical treatment for irreparable RCTs that can restore shoulder stability and improve shoulder function with excellent clinical outcomes and high rates of return to physical activity (12, 33, 34, 35). It has also been reported to restore shoulder function in patients with severe preoperative pseudoparalysis. Out of 88 patients (mean follow-up: 60 months) who underwent arthroscopic SCR using an FL autograft, no significant difference was observed in subjective or functional outcomes between patients with varying degrees of preoperative active shoulder elevation (no pseudoparalysis, moderate: <90° active arm abduction, and severe pseudoparalysis: <90° active arm abduction and positive arm drop sign) (35). In 96.4% (27/28) of patients with moderate pseudoparalysis and 93.3% (14/16) of patients with severe pseudoparalysis, pseudoparalysis was reversed, whereas two patients who remained pseudoparalytic had graft ruptures (35).

Concern about the donor-site morbidity remains a major drawback that discourages surgeons from obtaining FL autografts for SCR. To mitigate these disadvantages, a minimally invasive technique for FL autograft harvesting was proposed, in which two horizontal (transverse) 2 cm skin incisions were made in the ipsilateral thigh (33, 36, 37). At the 2-year follow-up, no significant subjective dysfunction of the donor area was observed; the study suggested that this was likely because damage to the FL tensor muscle superiorly (hip) and inferiorly (knee) distal iliotibial band was avoided (38). However, this minimally invasive technique required an FL autograft size of 15–20 × 3 cm to obtain a graft of at least 5 mm thickness after folding, resulting in a relatively large donor FL defect. Therefore, the optimal FL autograft harvesting technique remains undetermined and should be guided by the patient's subjective compensating factors, including painless shoulder function and avoidance of donor-site morbidity.

Dermal allograft

On SCR evolution, acellular dermal allografts have been used, which are advantageous with lack of donor-site morbidity, easier graft preparation, adequate graft thickness and subsequent construct strength, and reduced surgical time (13, 14, 15, 16). However, the downside is the increased cost of allografts.

Successful biological incorporation has been reported in the recent literature. Snyder *et al.* reported that the use of an acellular human dermal matrix after rotator cuff augmentation resulted in excellent incorporation with surrounding cuff tissues through the reorganisation of associated collagen fibres, revascularisation with numerous blood vessels, and little to no inflammatory response (15). Using a dermal allograft as a scaffold for remodelling the superior capsule promotes incorporation with the host tissue and has a low immunologic risk.

Arthroscopic SCR using a dermal allograft has also shown favourable short-to-mid-term improvements in subjective and functional outcomes (2, 8, 13, 14, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62). Hirahara *et al.* reported that SCR with dermal allograft resulted in better functional outcomes, American Shoulder and Elbow Surgeons (ASES) scores (49–85), and decreased visual analogue scale (VAS) scores (5.3–0.9; $P < 0.001$) in 18 patients. During the first 12 months, ultrasound examinations revealed signs of pulsatile vessels in 10 patients (56%), and all the constructions were intact at the final follow-up (40). Similar trends were observed in a multicentre cohort study by Denard *et al.* who reported successful outcomes in approximately 70% of the cases after arthroscopic SCR using dermal allografts. Among the 59 patients (mean age: 62 years; follow-up: 17.7 months), forward flexion, external rotation, mean ASES scores, and subjective shoulder values improved from 130° to 158°, 36° to 45° ($P < 0.001$), 43.6 to 77.5, and 35.0 to 76.3, respectively, whereas the VAS decreased from 5.8 to 1.7 ($P < 0.001$), postoperatively. The acromiohumeral interval, viewed on postoperative radiographs, was also improved by 1 mm (from 6.6 to 7.8 mm) at 2 weeks postoperatively. However, these changes decreased to 0.1 mm (from 6.6 to 6.7 mm) at the final follow-up. Postoperative magnetic resonance imaging revealed complete healing in 45% of cases (9 of 20 shoulders). The dermal allografts with a thickness of <3 mm failed to heal at the final follow-up and had poor outcomes (39).

The biomechanical implications of Denard *et al.* suggest that graft thickness, particularly allografts with a thickness of <3 mm, may be critical in resulting failure after SCR with a dermal allograft (39). Mihata *et al.* reported that dermal allograft thickness positively correlates with glenohumeral strength after SCR. The 4 mm and 8 mm FL autografts reduced peak subacromial contact pressures after SCR, but only the thicker graft reduced superior translation (31). A study using dermal allografts with a thickness of 1–3 mm reported 40% success on 1 mm thick graft but 67.8% overall success across the range. Furthermore, when 1 mm grafts were excluded, the success rate increased to

75.5%. They also reported better healing rates with 3 mm thick allografts (39). Hirahara *et al.* also demonstrated that grafts with a thickness of >3 mm achieved better pain relief and ASES scores (14).

Alternative graft options

Alternative grafting options for SCR have recently expanded to include the long head of the biceps (LHB) tendon autograft (63, 64, 65, 66, 67), FL autograft layered over polyethylene terephthalate scaffold (68), FL allograft (69), Achilles tendon allograft (70, 71), dermal xenograft (72, 73), and synthetic grafts (74). Based on the available literature, we have found that using alternative grafts can lead to adequate results that are comparable to those of more conventional grafting options.

A retrospective case series of 24 patients (mean age: 60 years; median follow-up: 25 months) treated for MIRCTs with SCR used LHB autograft to determine its viability. The patients showed significant ($P < 0.001$) improvement in mean subjective outcomes, including the Constant (50–70), ASES (45–80), and VAS (5.2–1.4) scores. Ultrasound observations also revealed that 91.7% (22/24) of the patients' repair constructs remained healed at the 1-year follow-up, while all the infraspinatus tendons healed at the final follow-up (66). Similarly, Kocaoglu *et al.* found that the functional outcomes of patients with partial RCTs treated with SCR using LHB autografts (14 patients) or FL autografts (12 patients) improved significantly with a minimum follow-up of 2 years. No significant difference was observed in functional outcomes, pain scores, or relapse rates between the two techniques (67). These findings highlight that SCR with an LHB autograft is a safe and reliable technique for the treatment of severe pathological conditions of the rotator cuff and can protect the integrity of the rotator cuff years after surgery.

The use of alternative xenografts and synthetic graft options for SCR has become popular because of the lack of donor site morbidity (74). The risk of immune rejection and long-term viability warrant further investigation. Despite improvements in functional outcomes in SCR with an acellular dermal xenograft, procedural complication rates have been reported to be up to 30%, with 15% attributed to immunologic graft rejection and 15% due to graft failure due to insufficient graft healing at the final follow-up (73). Similar observations have been made using synthetic grafts for SCR. Okamura *et al.* (74) used synthetic grafts such as synthetic polytetrafluoroethylene or Teflon felt grafts and achieved improved clinical outcomes with a low graft rupture rate.

Future comparative research on long-term outcomes remains essential to determine the optimal SCR graft selection. Surgeons who are considering using acellular dermal xenografts or synthetic grafts as grafts for SCR should inform patients about the immune rejection and long-term failure risks.

Surgical technique

SCR has gained popularity among surgeons; however, there is extreme variability among surgical techniques, including graft type, graft thickness, fixation methods, the position of the arm for graft fixation, concomitant procedures, and an arthroscopic or open approach. Patients can also be placed in a beach chair or lateral decubitus position. No definitive technique can be considered superior (32).

After completion of the rotator cuff preparation and capsular release, the size of the defect is measured in the coronal and sagittal planes with an arthroscopic ruler, with the arm in approximately 30° of abduction and 10°–15° of external rotation. The superior surface of the glenoid is prepared with a mechanical reamer before anchor insertion to increase surface bleeding (Fig. 1).

Glenoid fixation

The most commonly used method for SCR graft fixation in the glenoid is the placement of two suture anchors (one anterior at the 2 o'clock position and one posterior at the 10 o'clock position), usually through the Neviaser portal (Fig. 2). The role and importance of the number of suture anchors for glenoid fixation have yet to be defined because no clinical outcome studies comparing glenoid fixation methods have been reported. In a cadaveric biomechanical

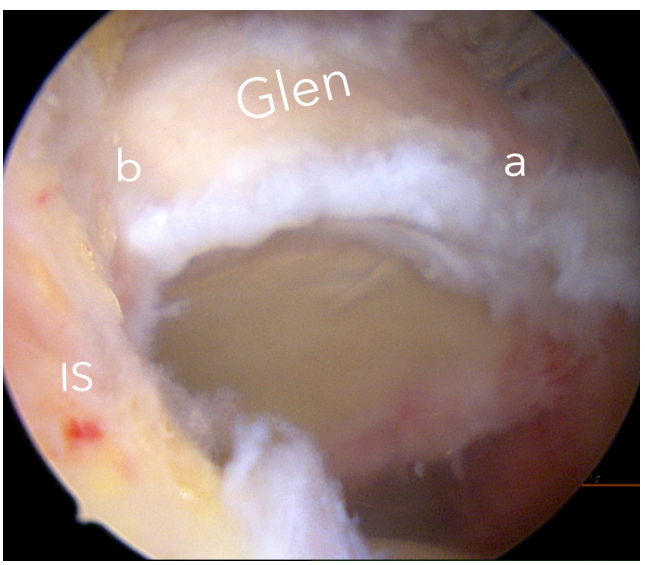

Figure 1
Intraoperative arthroscopic view. (a) The anterior rim of the glenoid; Glen, the superior border of the glenoid and (b) the posterior rim of the glenoid; IS, infraspinatus.

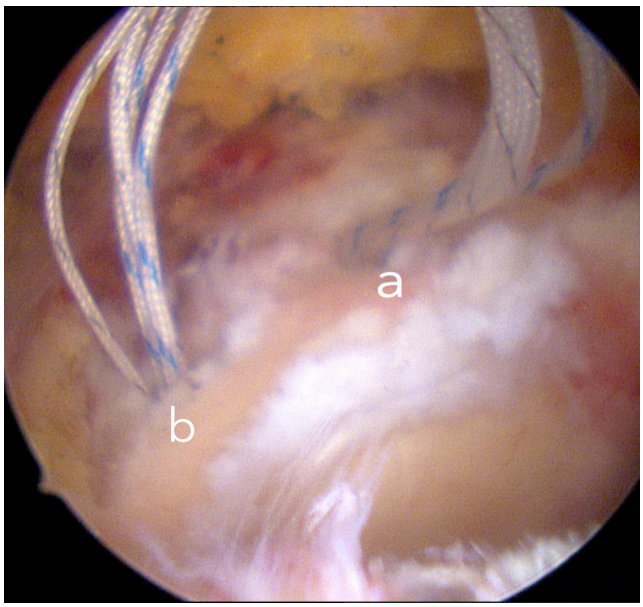

Figure 2
Intraoperative arthroscopic view of the superior part of the glenoid. (a) anterior anchor and (b) posterior anchor.

study using FL allograft for SCR, three fixation points on the glenoid were observed to provide significantly lower levels of subacromial contact pressure compared to two fixation points. There was also a less superior translation of the humerus with three-point fixation than with two-point fixation. This suggests that to better restore glenohumeral stability, SCR graft fixation to the glenoid with three suture anchors instead of two suture anchors is necessary (75).

There is no consensus on the ideal place where the anchors should be placed for anchoring the suture choirs. Pennington *et al.* (55) recommended placing the glenoid anchors on the superior glenoid rim along the superior joint margin because the subchondral bone at the joint margin, compared to the bone at the glenoid neck, may better provide glenoid fixation, while most other studies advocated placing the glenoid anchors medial to the glenoid rim along the glenoid neck (39, 46, 47, 49, 54, 69). However, there are no studies evaluating the effect of the glenoid anchor location. Furthermore, several studies support debridement or resection of the upper labrum (34, 44, 55, 56, 68), whereas other studies maintain the upper labrum (13, 14, 33, 39, 46, 47, 49, 51, 52, 54, 58, 62, 63, 64, 65, 71). The role of the superior labrum in the SCR has not yet been defined.

Greater tuberosity fixation

The most common method for SCR graft fixation to the greater tuberosity is double-row equivalent transosseous fixation using two medial- and two lateral-row suture anchors. However, to our knowledge, no clinical outcome studies have compared double-row vs single-row SCR graft fixation for greater tuberosity. The only study that used single-row SCR graft fixation (FL autograft or dermal allograft) had a high magnetic resonance imaging graft failure rate (36.1%) and a high reoperation rate (36.1% of cases required SCR revision) (76), suggesting that greater tuberosity fixation should be performed with an equivalent double-row transosseous fixation.

Shoulder position during graft fixation ranged from 0° to 45° of abduction, 10° to 70° of forward flexion, and 0° to 10° of external rotation (12, 13, 16, 33, 39, 49) (Fig. 3).

Graft and suture management

One of the most important aspects of arthroscopic SCR is graft passage and suture management. To avoid tangles of sutures inside the shoulder, studies recommend passing all sutures outside the body before placing the graft in the shoulder (13, 14, 33, 39, 46, 48, 49, 54, 57, 60, 61, 69). However, this requires accurate measurements between suture anchors placed on the glenoid and greater tuberosity to ensure adequate tension of the graft, because once the sutures are passed through the graft outside the shoulder, the graft tension can no longer be adjusted after moving to the shoulder. Therefore, some studies have advocated for suture passage after graft delivery in the shoulder to allow tensioning of the graft after it is passed to the shoulder (34, 44, 47, 50, 51, 52, 53, 55, 56, 58, 59, 62, 68, 76). Due to the large size of SCR grafts, placement in the shoulder is often difficult. Techniques such as the double-pulley technique (33, 34, 39, 46, 49, 59, 69), the

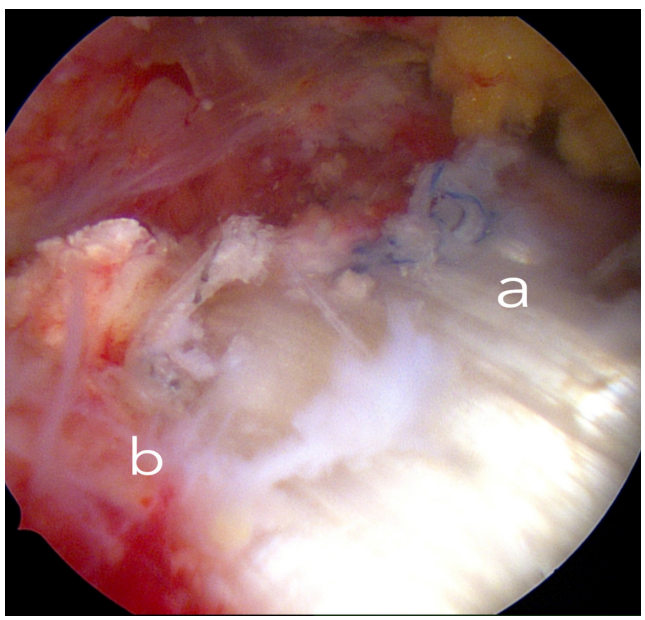

Figure 3
Medial fixation of the graft over the glenoid. (a) anterior and (b) posterior.

pulling-suture technique (48, 68), the dual single-pulley technique (51, 52) and the pull-over technique (53) have been developed to facilitate graft passage. Most studies have used a combination of these techniques (13, 14, 50, 54, 58, 61, 69).

One advantage of the LHB autograft is that the graft is already a part of the shoulder and does not require passage; it is also already attached to the superior glenoid.

Concomitant procedures

Margin convergence or side-by-side repair is another commonly performed procedure, concomitant with SCR (32). This procedure involves repairing the posterior margin convergence only (remnant of infraspinatus or teres minor) or repairing the posterior and anterior margin convergence (remaining supraspinatus tissue, rotator interval, or subscapularis tissue) and tying the posterior cuff to the graft fixed from the SCR. Most studies defended the convergence of the posterior and anterior margins (13, 14, 39, 44, 46, 47, 49, 51, 52, 53, 54, 55, 57, 63, 64, 68), but some advocated only posterior margin convergence (33, 53, 58, 61, 62, 69, 71, 76) because it is believed that the addition of anterior margin convergence with the side-by-side repair of the subscapularis graft could overload the graft and restrict shoulder ROM.

The addition of posterior lateral repair of the SCR FL allograft to the infraspinatus (posterior margin convergence) decreased superior glenohumeral translation and subacromial peak contact pressure in a cadaveric biomechanical study (22). When compared to the FL allograft with only posterior margin convergence, the addition of anterior lateral FL allograft repair to the subscapularis (anterior margin convergence) had no significant difference in biomechanical effect. Therefore, they recommended only convergence of the posterior margin to the SCR using an FL graft (22) (Fig. 4). In another cadaveric biomechanical study, Mihata *et al.* (77) showed that SCR using an FL allograft with the convergence of the anterior and posterior margins resulted in decreased total glenohumeral ROM. Contrastingly, they showed that SCR using a dermal allograft with anterior and posterior margin convergence did not decrease total glenohumeral ROM, suggesting that when performing SCR with an FL autograft, the use of anterior and posterior margin convergence is not recommended; however, when performing SCR with a dermal allograft, the use of anterior and posterior margin convergence is recommended. The FL autograft was more rigid than the dermal allograft, which may explain these findings (77). A recent biomechanical assessment of superior capsule continuity after SCR determined that SCR performed without side-by-side sutures decreased subacromial peak contact pressure (91% of intact shoulders at 30° abduction) but did not alter superior humeral translation (22). Alternatively, the addition of posterior sutures side by side prevented superior glenohumeral translation (110% of intact shoulders at 30° abduction) and significantly reduced peak subacromial pressure (83% of intact shoulders at 30° abduction). No difference in superior contact or translational pressure was observed between the side-by-side anterior and posterior SCR repair techniques or the side-by-side posterior SCR repair technique alone (22). Side-to-side repair may be beneficial after SCR to restore capsular continuity in the transverse plane and improve glenohumeral stability.

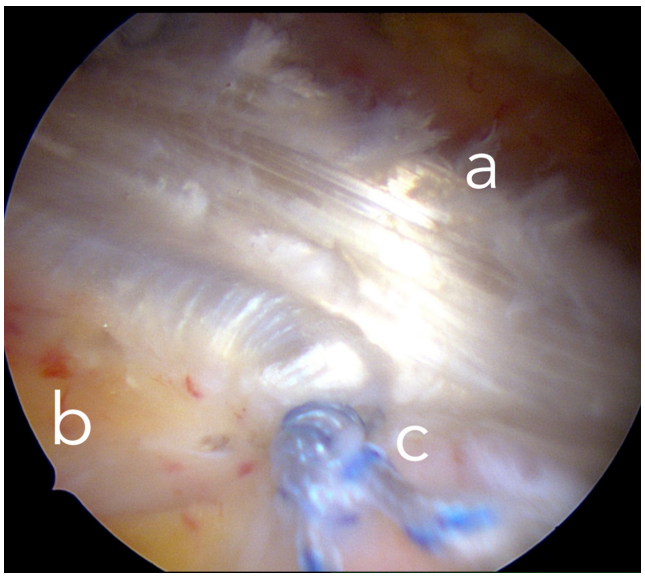

Figure 4
Concomitant side-by-side suture of the graft with the infraspinatus. (a) anterior border of the graft; (b) infraspinatus; and (c) side-by-side suture of the graft with the anterior part of the infraspinatus.

Regarding the role of concomitant subscapularis and infraspinatus repairs with SCR, most studies recommend that the subscapularis and infraspinatus repairs be performed concurrently to restore the force coupling of the glenohumeral joint (13, 14, 39, 46, 48, 49, 51, 61, 63). Mihata *et al.* (34) reported on postoperative retears of the infraspinatus, although the SCR graft remained intact. Several studies have also advocated over-the-top rotator cuff repair, incorporating over-the-top repair of any remaining native rotator cuff tissue over the SCR graft during graft fixation at greater tuberosity. However, no studies have evaluated the role of the concomitant subscapularis, infraspinatus, or over-the-top rotator cuff repairs.

Common procedures that are performed in conjunction with SCR include subacromial decompression and acromioplasty (32). Although acromioplasty has been

shown in some cases to increase the risk of coracoacromial arch rupture, these events are uncommon and are frequently overcome by reliable improvements in final shoulder mechanics. Mihata *et al.* showed that SCR with concomitant acromioplasty decreased the subacromial contact area compared to SCR without acromioplasty and did not change the humeral head position, superior translation, or contact pressure (78). A previous literature suggests that acromioplasty may help reduce SCR graft retear by flattening the inferior surface of the degenerative acromion (12).

A polypropylene mesh was recently used to augment the SCR construction. Kholinne *et al.* compared the clinical outcomes between conventional SCR using FL autografts with and without mesh augmentation. Although improvements were observed in clinical and radiological outcomes for both groups postoperatively, the mesh group demonstrated significantly greater improvements ($P < 0.001$) in ASES, ROM (anterior elevation and external rotation), and graft healing rate (83.3% vs 58.8%, $P = 5.04$) than patients treated with conventional SCR at the final follow-up. The conventional SCR group had a shorter time from surgery to graft failure (<6 months) (79). These findings suggest that mesh augmentation can reduce graft failure and improve clinical outcomes and should be considered a viable adjunct to SCR.

Clinical outcomes

SCR leads to significant improvements in clinical outcomes in patients with MIRCTs at ≥12 months (80, 81).

The initial short-term results of Mihata *et al.* using FL autograft were positive, with mean ASES scores improving from 24 to 93, a mean increase of 4.1 mm in acromiohumeral distance, and increased shoulder muscle strength (11). They also reported mean anterior active elevation (84°–148°) and external rotation (26°–40°). In subsequent follow-up studies, the authors showed similar good results regarding patient-reported outcome measures and ROM (12). Mihata *et al.* also reported the reversal of pseudoparalysis in 96 and 93% of patients with moderate and severe pseudoparalysis, respectively (35). The study by de Campos Azevedo *et al.* also using FL autograft presented a 9.1% improvement in shoulder ROM with low complication rates (4.5%) and low reoperation rates (4.5%) (33).

The outcomes of dermal allograft studies have been equally encouraging. In a series of 59 patients with short-term follow-up (mean: 17.7 months), mean ASES scores improved from 44 to 78, and subjective shoulder values improved from 35 to 76. Forward flexion improved from a mean of 130° to 158° and external rotation improved from 36° to 45° (1). Burkhart *et al.* reported that at a minimum of 2 years (with a mean of 34 months), a follow-up study of 41 patients also showed excellent outcome scores with a mean improvement in ASES from 52 to 90 at 1 year and 89 at the final follow-up. Active anterior elevation improved from an average of 140° to 172° at 1 year and to 167° at the final follow-up and external rotation improved from 37° to 48° and then to 59° (2).

Studies have also examined pain after SCR, and all reported significant improvements in VAS pain scores after the procedure (2, 14, 39, 44). Chillemi *et al.* showed improvement in the VAS score, a 0% complication rate, and a 0% reoperation rate after arthroscopic SCR using a LHB autograft; however, there were only nine patients in the study, and the mean follow-up time was only 6 months (64). Mihata *et al.* also reported high rates of return to sports and physical activity. It was observed that after SCR, 100% of an athletic cohort returned to sports and 94% returned to heavy manual work (34).

Complications

Although SCR has been developed as a widespread and viable treatment option for MIRCTs, recent literature has reported postoperative complication rates of between 13.9 and 19% (range: 0–47.6%), including new tears, loss of attachment, or a partially healed graft (45, 47).

Regarding the site of graft failure, Smith and colleagues reported that 69.8% of failures occurred on the humeral side, 16.9% on the interstitial side, and 13.2% on the glenoid attachment (45). Studies reported that the mean revision surgery rate after SCR failure ranged from 6.9 to 8.9% (range: 0–36.1%) and consisted of revision SCR, reverse total shoulder arthroplasty, debridement procedure for infection, arthroscopic release for shoulder stiffness, balloon spacers, and subpectoral biceps tenodesis opening for biceps pain (45, 47).

Clinical and radiographic results are critical determinants of success after SCR. Mihata *et al.* observed that patients in the unhealed SCR group (graft tears or new tears of the repaired rotator cuff tendon) had significantly lower mean ASES (77 vs 96) and Japanese Orthopaedic Association scores (81.1 vs 94.9) than those in the healed group at the final follow-up (12). Recent literature suggests that the possible indicators of SCR failure may also include preoperative subscapularis tendon integrity and postoperative fatty infiltration (79, 82). Takayama *et al.* found that SCR for MIRCTs in patients with unrepairable subscapularis had worse clinical outcomes and shoulder function compared to patients with repairable subscapularis. Furthermore, no patient treated for SCR with irreparable subscapularis recovered from pseudoparalysis (82). These pre- and postoperative indicators should be considered when deciding on SCR for the treatment of MIRCTs.

Conclusion

SCR is a surgical option for patients with symptomatic MIRCTs that have failed to respond to conservative treatment and present with an intact or repairable subscapular tendon and minimal glenohumeral osteoarthritis. SCR provides satisfactory clinical and radiological outcomes. The small number of comparative studies with a high level of evidence does not allow us to state the precise indications, comorbidities, and technical factors that will optimise patient outcomes. However, this can be a valuable treatment solution for carefully selected patients.

ICMJE conflict of interest statement

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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