Long-term Clinical and Structural Outcomes of Arthroscopic Superior Capsule Reconstruction for Irreparable Rotator Cuff Tears: 10-year Follow-up

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Abstract

Background

Short-term follow-up studies have reported favorable clinical outcomes after arthroscopic superior capsule reconstruction (SCR) for irreparable rotator cuff tears. Our objective here was to assess whether these positive outcomes are maintained long-term and whether cuff tear arthropathy worsens over time after fascia lata autograft SCR.

Methods

This study analyzed data collected prospectively from 34 consecutive patients (36 affected shoulders) with irreparable rotator cuff tears who underwent arthroscopic SCR from 2007 through 2011. Active shoulder range of motion (ROM) and American Shoulder and Elbow Surgeons (ASES), Japanese Orthopaedic Association (JOA), and Visual Analog Scale (VAS) scores were evaluated before SCR and at 1 year, 5 years, and 10 years after surgery; rates of return to participation in sports and physically demanding work were determined as well. In addition, radiography and MRI data were collected before surgery and at 3 and 6 months and at 1, 2, 3, 4, 5, and 10 years afterward. Acromiohumeral distance (AHD) and Hamada grade (stage of cuff tear arthropathy) were evaluated by using radiography. We defined Hamada grades 3 and 4b as acetabularization and grades 4a and 4b as glenohumeral osteoarthritis. Graft survival rate and thickness were assessed by using T2-weighted MRI.

Results

Compared with presurgery values, ASES and JOA scores and active ROM (elevation and external rotation) were increased significantly at 1 year after SCR ($P < 0.001$) and maintained throughout follow-up. At 10 years after SCR, 88% (15 of 17 patients) of workers with physically demanding jobs and 90% (9 of 10 patients) of sports players still participated in these activities. Graft survival rate was 94% (34 of 36 shoulders) at 1 year after SCR, 92% (33 of 36 shoulders) at 2 to 4 years, and 89% (32 of 36 shoulders) at 5 to 10 years. In healed grafts, graft thickness was maintained for at least 10 years after SCR (7.8±2.0 mm at 3 months after SCR, 7.8±1.6 mm at 10 years). The incidence of acetabularization (affected shoulder, 9%; unaffected shoulder, 6%) and glenohumeral osteoarthritis (affected shoulder, 28%; unaffected shoulder, 16%) during the 10 years after SCR did not differ between affected and unaffected shoulders. The complication rate was 2.8% (1 of 36 patients, anchor pull-out).

Conclusion

For irreparable rotator cuff tears, arthroscopic SCR restored shoulder function and relieved shoulder pain, with high rates of return to recreational sports and physically demanding work, and it maintained significant improvements in clinical and structural outcomes for at least 10 years after surgery. In addition, graft healing completely prevented any progression of cuff tear arthropathy. Arthroscopic SCR is an effective surgical option for irreparable rotator cuff tears and retains positive outcomes for at least 10 years.

63 **Level of Evidence**

64 Case series, Level III

65

66 **Key Words**

67 Irreparable, Long-term, Reconstruction, Rotator cuff, Superior capsule, Tear

Introduction

Superior capsule reconstruction (SCR) was developed as an alternative treatment for irreparable rotator cuff tears[16–26]**.** In this technique, an autograft (fascia lata[1,10,17,22–27], biceps long head[2,5], or hamstring[28]) or allograft (dermal graft[3,4,11] or Achilles tendon[12,13]) is attached medially to the glenoid superior tubercle and laterally to the greater tuberosity, on both of which are located the footprints of the superior shoulder capsule. In previous biomechanical studies[16,19–21,23], SCR using fascia lata graft of 8-mm thickness restored static superior shoulder stability without requiring the repair of torn tendons of the supraspinatus and infraspinatus. Short-term follow-up studies showed that active shoulder elevation, shoulder muscle strength, American Shoulder and Elbow Surgeons (ASES) score, and acromiohumeral distance (AHD) all increased significantly after SCR using fascia lata autograft in patients with irreparable rotator cuff tears[3,4,22,23].

In massive rotator cuff tears, the humeral head is migrated superiorly; consequently the residual tendons are shifted inferior to the migrated humeral head, thus becoming redundant and decreasing dynamic shoulder stability. SCR surgery repositions the migrated humeral head and increases the AHD, thereby normalizing the muscle vectors of the anterior and posterior rotator cuff muscles. In addition, the posterior rotator cuff tendons (infraspinatus and teres minor) that become redundant in massive rotator cuff tears are sutured with the graft for re-tensioning during SCR surgery. The improved rotator cuff

muscle vectors and tension restore dynamic shoulder stability after SCR.

Although SCR can even restore both static and dynamic shoulder stability in the glenohumeral joint[16,18–20] in cases of irreparable rotator cuff tears with severely degenerated muscle and tendon, reestablishing dynamic stability completely can be difficult in cases with severe rotator cuff muscle atrophy preoperatively. Despite the favorable short-term clinical outcomes of SCR, suboptimal dynamic shoulder stability may contribute to late-stage worsening of cuff tear arthropathy. In addition, because many patients return to previous injury-inducing activities such as participation in sports or physically demanding jobs after SCR[22], the SCR graft may be torn, with subsequent progression of cuff tear arthropathy during long-term follow-up.

The SCR procedure was developed in 2007,[17] but a long-term follow-up study after SCR has not yet been reported. SCR of irreparable rotator cuff tears has achieved good to excellent clinical short- and intermediate-term outcomes,[3,25] but whether these favorable results are maintained and whether late-stage complications arise warrant investigation. Therefore, this study assessed the functional and radiographic results of SCR throughout 10 years of follow-up. To control for the effects of natural aging on shoulder function and osteoarthropathy, functional and radiographic characteristics before surgery were compared with those at 10 years after SCR in both affected and unaffected shoulders.

Materials and Methods

Patient Cohort

The institutional review board of our university (Osaka Medical and Pharmaceutical University) approved this study (approval no. 1854) before initiation of the analysis of prospectively collected data. A total of 48 consecutive patients with 50 affected shoulders underwent SCR using fascia lata autograft for the treatment of irreparable rotator cuff tears by a single surgeon (T.M.) during 2007 through 2011. Of these 48 initially identified patients, 5 had died, 5 had moved and were unable to be contacted, 2 had severe health problems that were unrelated to SCR, 1 refused to participate, and 1 was unable to participate because she was caring for her child with terminal cancer, thus leaving 34 patients (36 affected shoulders) for review. Patients were referred for SCR when they had symptomatic irreparable rotator cuff tears that had failed conservative treatment (i.e., no significant improvement of symptoms). In this study, a rotator cuff tear was defined as irreparable when, after release, the torn tendon still could not be made to cover the original footprint. Exclusion criteria of SCR for the current study were (1) reparable rotator cuff tears, (2) Hamada grade 5, (3) asymptomatic rotator cuff tears, and (4) concomitant nerve problem before surgery.

Surgical Procedure

For arthroscopic SCR (Fig. 1), a graft was made by folding the fascia lata autograft two or three times. Intermuscular septum was sandwiched between two layers of fascia lata (Fig. 2). The optimal graft width in the anteroposterior direction was the same as the width of the defect without partial repair of the torn infraspinatus tendon (graft width in the anteroposterior direction corresponded to the exposed greater tuberosity footprint). In the mediolateral direction the graft was 15 mm longer than the distance from the superior edge of the glenoid to the lateral edge of the greater tuberosity, thus providing sufficient tissue to cover a 15-mm footprint on the superior glenoid.

Fig. 1. Arthroscopic findings before and after SCR. (A) Posterior view of the subacromial space in an irreparable massive rotator cuff tear before surgery. (B) Posterior view of the subacromial space just after surgery.

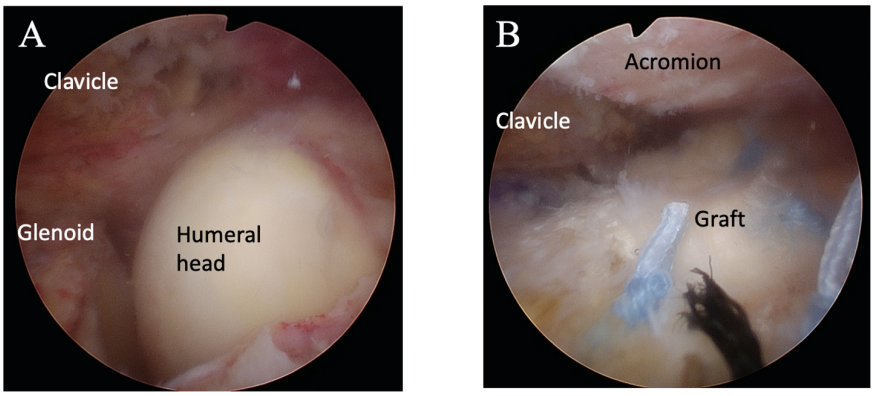
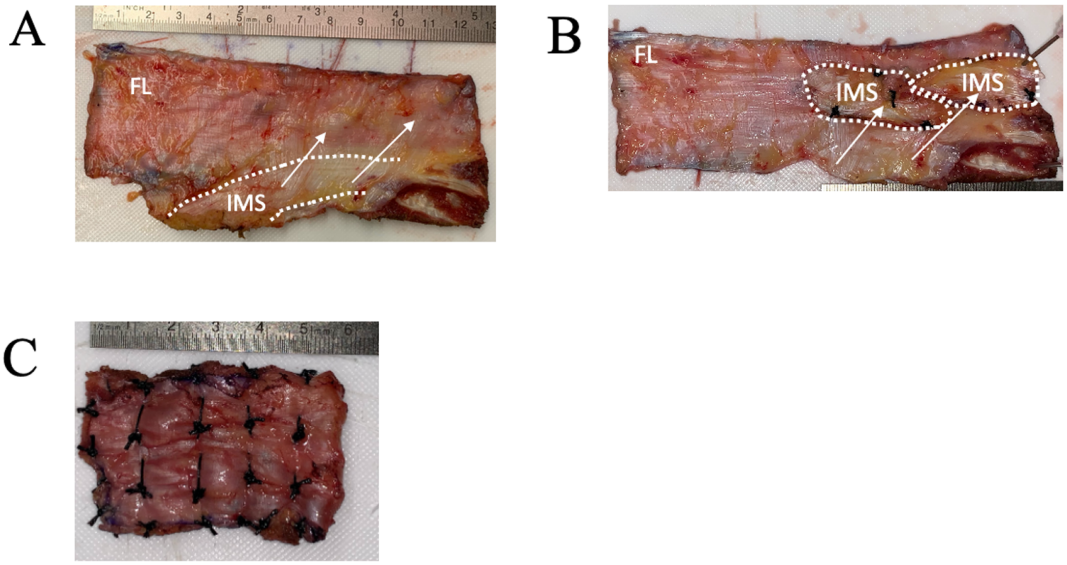


Fig. 2. Making a fascia lata autograft. (A) Harvested fascia lata included the intermuscular septum. (B) The intermuscular septum was disconnected and then moved to the anterior part of the fascia lata. (C) A graft was made by folding the fascia lata, thus sandwiching the intermuscular septum between two layers of fascia lata.



To prevent damage to the biceps tendon, superior labrum, and suprascapular nerve, a radiofrequency device was used to release the connection between the biceps tendon anchor and residual supraspinatus and infraspinatus muscles. Whenever possible, the biceps anchor was left intact and the graft was placed over the biceps. The rate of biceps tenodesis was 8.3% (3 of 36 shoulders), for tendons severely dislocated from the bicipital groove.

The medial side of the fascia lata autograft was attached to the superior glenoid by using two suture anchors (4.5-mm Corkscrew FT, Arthrex, Naples, FL). With the shoulder in

30 to 45 degrees of abduction[20] and neutral rotation, the lateral side of the fascia lata was attached to the rotator cuff footprint on the greater tuberosity by using either a compression double-row technique[7,14,15] with 4.5-mm Corkscrew FT Suture Anchors (Arthrex) or a transosseous equivalent technique using SwiveLock anchors and FiberTape (Arthrex). Finally, side-to-side sutures were added between the graft and the infraspinatus or teres minor tendon to improve force coupling in the shoulder joint. In all patients, acromioplasty was performed to create a flat acromial undersurface and remove any acromial spurs[18].

Postoperative Protocol

For 4 weeks after surgery, the shoulder was immobilized in 30 to 45 degrees of abduction by using an abduction sling (Block Shoulder Abduction Sling; Nagano Prosthetics and Orthotics, Osaka, Japan; https://naganogishi.jp/). After the immobilization period, passive and active-assisted exercises were initiated to promote scaption. At 8 weeks after SCR, patients began to perform exercises to strengthen the rotator cuff and scapular stabilizers. Physical therapists assisted all patients.

Clinical and Structural Outcomes

Shoulder ROM, function, and pain were evaluated before surgery and then at 1, 5, and 10 years after SCR surgery. Active shoulder elevation, external rotation at the side, and

internal rotation were measured. Shoulder function was assessed by using the ASES and Japanese Orthopaedic Association (JOA) scoring systems. Severity of shoulder pain was assessed according to the Visual Analog Scale (VAS).

The rate of postoperative complications at 10 years after SCR was determined. In addition, rates of return to participation in physical work or recreational sports were investigated in those patients who had had physically strenuous jobs (17 patients: 9 farmers, 4 carpenters, 2 construction workers, 1 dry-cleaner, and 1 athletic trainer) or played recreational sports (10 patients: 2 table tennis, 2 martial arts, 2 yoga, 1 badminton, 1 swimming, 1 bowling, and 1 cycling) before injury. All racket-sport players had SCR on the dominant side.

Radiography and MRI were performed before surgery and then at 3 and 6 months and 1, 2, 3, 4, 5, and 10 years after SCR surgery. AHD and Hamada grade[9] (stage of cuff tear arthropathy) were evaluated by using standard radiography. We defined Hamada grades 3 and 4b as acetabularization and grades 4a and 4b as glenohumeral osteoarthritis. Fatty degeneration of the rotator cuff muscles was evaluated according to the Goutallier grading system.[8] Graft healing and thickness were assessed by using T2-weighted MRI (1.5-T closed-type scanner). By using SYNAPSE software (accuracy, 0.05 mm; FUJIFILM Medical System, Loveland, CO), graft thickness at 1 cm posterior to the bicipital groove in the coronal

plane of T2-weighted MRI was measured at the greater tuberosity side (medial aspect of the footprint on the greater tuberosity).

Statistical Analysis

Shoulder ROM, ASES and JOA scores, VAS score, AHD, and Goutallier grade were evaluated in 35 shoulders (excluding one patient who underwent reverse shoulder arthroplasty after SCR); these parameters before surgery were compared with those at 1, 5, and 10 years after SCR by using one-way analysis of variance followed by Tukey's post-hoc test or the chi-square test. Graft thickness and AHD before surgery were compared with values at 3 and 6 months and 1, 2, 3, 4, 5, and 10 years after SCR by using one-way analysis of variance followed by Tukey's post-hoc test. By using the chi-square test, rates of acetabularization and of glenohumeral osteoarthritis were compared between affected and unaffected shoulders before surgery and at 10 years after SCR; in affected shoulders between before surgery and 10 years after SCR; and in unaffected shoulders between before surgery and 10 years after SCR (2 patients, who underwent SCR for both shoulders, were excluded from these analyses). Graft tear rate was compared between sports participants and non-participants and between patients involved in physical work and the non-physical work group by using the chi-square test. All statistical analyses were performed by using Statistica

software (version 6, StatSoft, Tulsa, OK). Where appropriate, data are shown as means ± 1 standard deviation of the mean. A significant difference was defined as $P < 0.05$.

Results

Patient Characteristics

The study population comprised 34 patients (13 women, 21 men) with 36 affected shoulders (33 primary cases and 3 revision cases after failed rotator cuff repair); the mean age at surgery was 66.1 years (range, 45 to 78 years). The rotator cuff tears involved the supraspinatus and infraspinatus in 21 shoulders; the supraspinatus, infraspinatus, and subscapularis in 13 shoulders; and the supraspinatus, infraspinatus, and teres minor in 2 shoulders (Table I). The mean tear size in the anterior–posterior direction was 4.2 cm (range, 2 to 7 cm).

TABLE I Patient age and severity of rotator cuff tear

	Healed shoulders (n = 32)	Unhealed shoulders with graft tears (n = 4)	Total (n = 36)
Age at surgery (years)[a]	66.0 (45–78)	66.5 (58–71)	66.1 (45–78)
Tear size in anterior–posterior direction (cm)	4.1 (2–7)	5.3 (3.5–7)	4.2 (2–7)
Torn tendons (shoulders)			
2 tendons: supraspinatus and infraspinatus	20	1	21
3 tendons: supraspinatus and infraspinatus, subscapularis	11	2	13
3 tendons: supraspinatus and infraspinatus, teres minor	1	1	2

Where applicable, data are given as means (range).

[a] Two patients underwent superior capsule reconstruction in both shoulders, yielding a study population of 34 patients but 36 shoulders.

Active Shoulder ROM

Active shoulder elevation was 93 ± 52 degrees before SCR. At 1 year after SCR, active elevation was significantly increased to 148 ± 25 degrees ($P < 0.001$); this increase was

223 maintained even at 5 years (159 ± 17 degrees) and 10 years (156 ± 23 degrees) after SCR
224 (Table II).

TABLE II Preoperative and postoperative shoulder range of motion (ROM)

	Before surgery	1 year after SCR	5 years after SCR	10 years after SCR
Active elevation (degrees)				
Total (n = 35)	93 ± 52	148 ± 25	159 ± 17	156 ± 23
Healed (n = 32)	89 ± 52	149 ± 26	162 ± 14	159 ± 18
Graft tear (n = 3)	140 ± 20	137 ± 23	130 ± 28	123 ± 42
P (n = 35)				
vs preoperative		<0.001	<0.001	<0.001
vs 1 year after SCR			0.35	0.72
vs 5 years after SCR				0.93
Active external rotation (degrees)				
Total (n = 35)	28 ± 17	39 ± 16	42 ± 18	46 ± 19
Healed (n = 32)	28 ± 18	40 ± 16	45 ± 17	48 ± 18
Graft tear (n = 3)	33 ± 6	30 ± 17	27 ± 12	20 ± 20
P (n = 35)				
vs preoperative		<0.001	<0.001	<0.001
vs 1 year after SCR			0.07	0.98
vs 5 years after SCR				0.17
Active internal rotation (degrees)				
Total (n = 35)	L3 (Femur–T7)	L2 (S–T7)	L2 (S–T10)	L1 (S–T3)
Healed (n = 32)	L3 (Femur–T7)	L1 (S–T7)	L1 (L4–T10)	L1 (L5–T3)
Graft tear (n = 3)	L4 (S–L3)	L4 (S–L3)	L4 (S–L3)	L4 (S–T12)
P (n=35)				
vs preoperative		0.29	0.11	0.08
vs 1 year after SCR			0.42	0.92
vs 5 years after SCR				0.81

Where applicable, data are provided as means ± 1 SD or medians (range).

225

226 Likewise, active shoulder external rotation was significantly increased at 1 year after SCR
227 compared with before surgery ($P < 0.001$); this increase was maintained at 5 years (42 ± 18
228 degrees) and 10 years (46 ± 19 degrees) after SCR (Table II). Active shoulder internal
229 rotation did not change significantly after SCR in this series (Table II).

230 Before surgery, active shoulder elevation, external rotation, and internal rotation in the
231 affected shoulders were significantly less than those in the unaffected shoulders (Table III).

232 At 10 years after SCR, active shoulder elevation, external rotation, and internal rotation did
233 not differ between unaffected and affected shoulders because SCR increased ROM
234 significantly in all affected shoulders. Likely because of aging, active elevation in unaffected
235 shoulders at 10 years after SCR (158 ± 18 degrees) was less than before surgery (166 ± 13
236 degrees) (Table III).

TABLE III Comparison of shoulder ROM between affected side and unaffected side

	Before surgery		10 years after SCR		*P* (preoperative vs 10 years after SCR)
	Affected side	Unaffected side	Affected side	Unaffected side	(Unaffected side)
Active elevation (degrees)	93 ± 52	166 ± 13	156 ± 23	158 ± 18	0.01
P (affected vs unaffected)	<0.001		0.72		
Active external rotation (degrees)	28 ± 17	55 ± 19	46 ± 19	52 ± 21	0.24
P (affected vs unaffected)	<0.001		0.36		
Active internal rotation (degrees)	L3	T12	L1	T12	0.22
P (affected vs unaffected)	<0.001		0.32		

Where applicable, data are given as means ± 1 SD.

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238 Shoulder Functional Scores and VAS Scores

239 Compared with preoperative functional scores (ASES, 26.6 ± 17.4; JOA, 49.8 ± 12.9),
240 ASES and JOA scores were increased significantly at 1 year (ASES, 89.1 ± 12.5; JOA, 90.4
241 ± 9.2; $P < 0.001$), 5 years (ASES, 95.1 ± 5.3; JOA, 94.0 ± 5.7; $P < 0.001$), and 10 years
242 (ASES, 92.2 ± 11.0; JOA, 91.1 ± 9.4; $P < 0.001$) after SCR (Table IV). In addition, the ASES
243 score was greater at 5 years after SCR than at 1 year afterward ($P = 0.01$). Compared with
244 that before SCR (7.0 ± 1.9), the VAS score was decreased at 1 year (0.7 ± 1.2, $P < 0.001$), 5
245 years (0.5 ± 1.1, $P < 0.001$), and 10 years (0.3 ± 1.1, $P < 0.001$) after SCR (Table IV).
246

TABLE IV Preoperative and postoperative shoulder scores and Visual Analog Scale (VAS) scores

	Before surgery	1 year after SCR	5 years after SCR	10 years after SCR
ASES score				
Total (n = 35)	26.6 ± 17.4	89.1 ± 12.5	95.1 ± 5.3	92.2 ± 11.0
Healed (n = 32)	26.3 ± 18.2	89.7 ± 12.1	96.1 ± 3.8	93.0 ± 10.5
Graft tear (n = 3)	30.0 ± 2.9	83.3 ± 17.6	85.0 ± 9.5	83.3 ± 15.3
P (n = 35)				
vs preoperative		<0.001	<0.001	<0.001
vs 1 year after SCR			0.01	0.65
vs 5 years after SCR				0.22
JOA score				
Total (n = 35)	49.8 ± 12.9	90.4 ± 9.2	94.0 ± 5.7	91.1 ± 9.4
Healed (n = 32)	49.1 ± 13.2	91.4 ± 7.8	95.3 ± 3.8	92.3 ± 8.1
Graft tear (n = 3)	30.0 ± 2.9	79.5 ± 17.2	81.3 ± 6.7	78.5 ± 15.0
P (n = 35)				
vs preoperative		<0.001	<0.001	<0.001
vs 1 year after SCR			0.07	0.98
vs 5 years after SCR				0.17
VAS score				
Total (n = 35)	7.0 ± 1.9	0.7 ± 1.2	0.5 ± 1.1	0.3 ± 1.1
Healed (n = 32)	6.9 ± 1.9	0.6 ± 1.1	0.3 ± 0.8	0.3 ± 1.1
Graft tear (n = 3)	7.7 ± 0.6	1.7 ± 1.5	3.0 ± 1.4	0.0 ± 0.0
P (n = 35)				
vs preoperative		<0.001	<0.001	<0.001
vs 1 year after SCR			0.56	0.43
vs 5 years after SCR				0.99

ASES, American Shoulder and Elbow Surgeons; JOA, Japanese Orthopaedic Association

Where applicable, data are given as means ± 1 SD.

Return to Participation in Sports and Physically Demanding Work

All 10 patients who had played sports before their injuries had returned fully to their previous activities by 1 year after SCR, and 9 of these 10 patients were still participating in their sports at 10 years after SCR. Graft tear rate did not differ significantly between sports participants (1/10, 10%) and the non-sports group (3/26, 12%) ($P = 0.91$).

All 17 patients who had ceased to do physically demanding work owing to shoulder pain or dysfunction (or both) before surgery had returned to their previous occupations by 1 year

after SCR. At 10 years after SCR, 15 of these 17 patients (88%) were still working in their physically demanding jobs; the remaining 2 patients were no longer working because they had reached retirement age; they had no adverse symptoms. Graft tear rate did not differ between the participants who had physically demanding jobs (2/17, 12%) and those who did not (2/19, 11%) ($P = 0.92$).

Graft Survival Rate and Thickness

Graft survival rate was 94% (34 of 36 shoulders) at 1 year after SCR, 92% (33 of 36 shoulders) at 2 to 4 years, and 89% (32 of 36 shoulders) at 5 to 10 years (Fig. 3). In the 30 patients (32 shoulders) whose grafts remained intact, graft thickness did not vary significantly during the 10 years after SCR (3 months after SCR, 7.8 ± 2.0 mm; 6 months, 8.0 ± 2.2 mm; 1 year, 8.1 ± 1.9 mm; 2 years, 8.4 ± 2.1 mm; 3 years, 8.5 ± 2.3 mm; 4 years, 8.0 ± 2.2 mm; 5 years, 8.2 ± 1.9 mm; 10 years, 7.8 ± 1.6 mm) ($P = 0.91$) (Fig. 4).

Fig. 3. Average graft survival rate (%) during 10 years after SCR

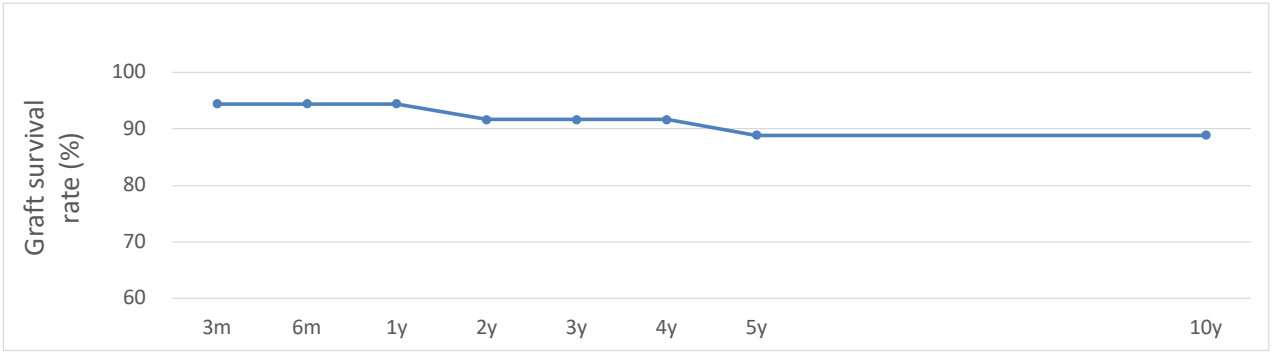
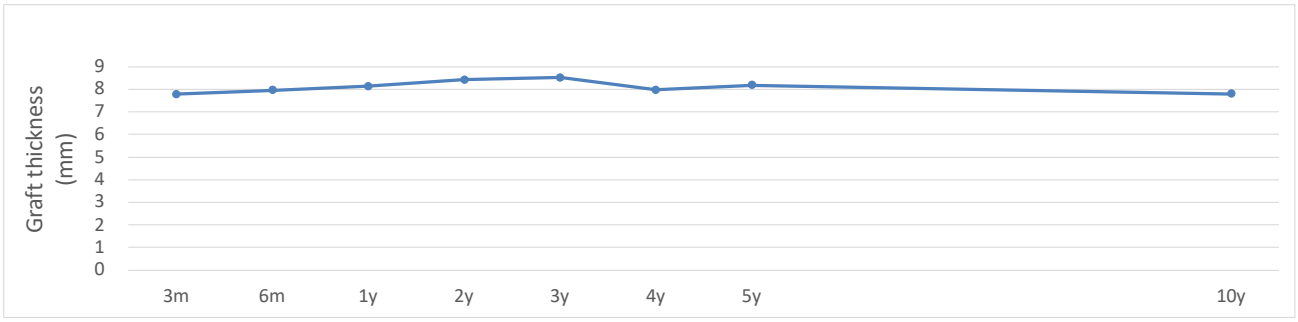


Fig. 4. Average graft thickness (mm) during 10 years after SCR



Rates of Acetabularization and Glenohumeral Osteoarthritis

Before surgery, the rate of acetabularization was 34% (11/32 shoulders) in affected shoulders and 3% (1/32 shoulders) in unaffected shoulders. The immediate increase in AHD due to SCR abolished previous acetabularization in all shoulders that underwent surgery. Compared with presurgery values, the rate of acetabularization at 10 years after SCR was significantly decreased in the healed graft cases ($P = 0.0002$) but increased in patients whose grafts had torn ($P = 0.03$). The rate of acetabularization at 10 years after SCR was similar between affected (9%) and unaffected shoulders (6%).

Long-term outcomes of SCR

The rate of glenohumeral osteoarthritis before surgery was 6% (2/32 shoulders) in affected shoulders and 0% (0/32 shoulders) in unaffected shoulders. Compared with presurgery values, the number of shoulders with glenohumeral osteoarthritis at 10 years after SCR was increased in both affected (28%, P = 0.02) and unaffected (16%, P = 0.02) shoulders. The rate of glenohumeral osteoarthritis at 10 years after SCR did not differ between affected and unaffected shoulders (P = 0.23). Postoperative glenohumeral osteoarthritis was present in all four shoulders with graft tear after SCR.

Acromiohumeral Distance

Before SCR, the AHD was narrower in affected shoulders (3.5 ± 2.2 mm) than in unaffected shoulders (7.3 ± 2.2 mm) ($P = 0.02$). AHD in affected shoulders increased promptly after SCR (3 months after SCR: 10.3 ± 2.4 mm) ($P < 0.001$), and this increase was maintained throughout the 10-year follow-up (6 months, 9.6 ± 2.8 mm; 1 year, 9.5 ± 2.5 mm; 2 years, 8.9 ± 2.9 mm; 3 years, 8.6 ± 2.6 mm; 4 years, 9.0 ± 2.7 mm; 5 years, 8.7 ± 3.0 mm; 10 years, 8.2 ± 2.8 mm) (Fig. 5). AHD in unaffected shoulders was 7.8 ± 2.4 mm at 10 years after SCR and did not differ from that in affected shoulders in patients with healed grafts (Fig. 6). However, AHD at 10 years after SCR was significantly less than before SCR in all 3 of the remaining patients with postoperative graft tear; 1 patient, who underwent reverse shoulder arthroplasty after graft tear, was excluded from this analysis.

306 Fig. 5. Average AHD (mm) in repaired shoulder during 10 years after SCR

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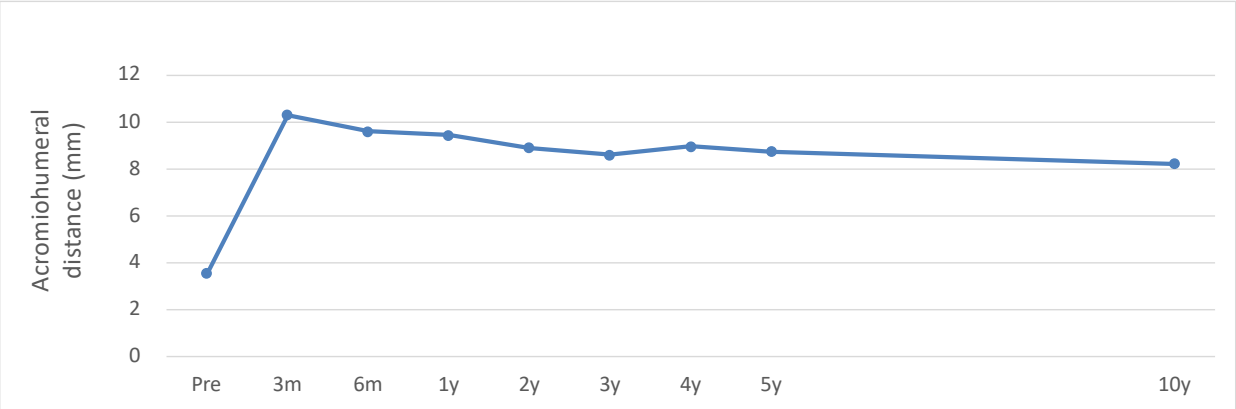

313 Fig. 6. X-ray and T2-weighted MRI findings before and after arthroscopic SCR. All images

314 are from the same patient. (A) X-ray of the affected shoulder before surgery. AHD 4 mm,

315 Hamada grade 2. (B) X-ray of the unaffected shoulder before surgery. AHD 10 mm, Hamada

316 grade 1. (C) Coronal MRI before surgery. The torn supraspinatus tendon is severely retracted,

317 and the supraspinatus muscle is severely atrophied and infiltrated with fat. (D) Sagittal MRI

318 before surgery. Goutallier grade 4 in the supraspinatus muscle. (E) X-ray at 1 year after SCR.

319 AHD 11 mm, Hamada grade 1. (F) Coronal MRI at 1 year after SCR. Healed graft shows iso-

320 intensity. (F) Sagittal MRI at 1 year after SCR. Goutallier grade 4 in the supraspinatus

321 muscle. (G) X-ray of the affected shoulder at 10 years after SCR. AHD 11 mm, Hamada

322 grade 1. (H) X-ray of the unaffected shoulder at 10 years after SCR. AHD 10 mm, Hamada

323 grade 1. (I) Coronal MRI at 10 years after SCR. Healed graft shows low-intensity signal. (J)

324 Sagittal MRI at 10 years after SCR. Goutallier grade 4 in the supraspinatus muscle.

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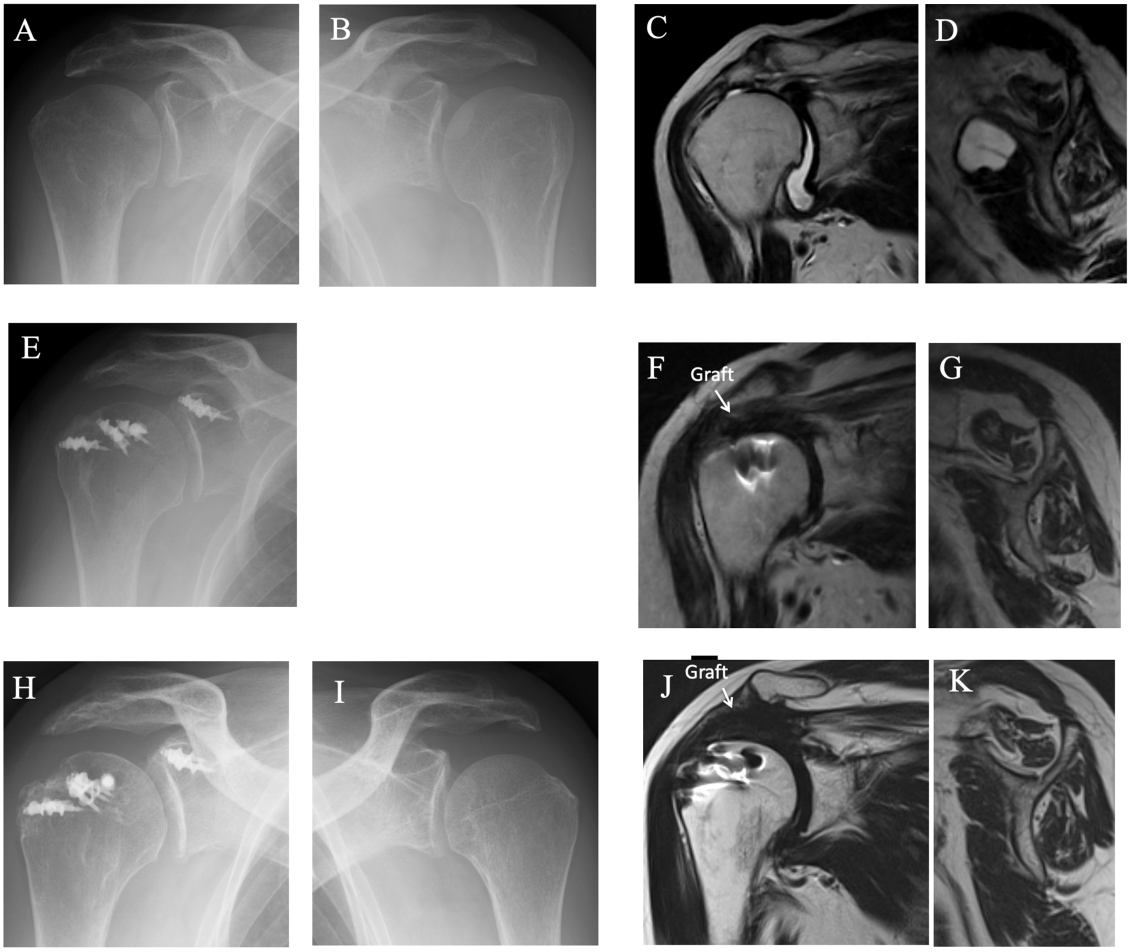

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327 Goutallier Grade

328 Before surgery, the Goutallier grade of the supraspinatus muscle was grade 2 in 3
329 shoulders, grade 3 in 12 shoulders, and grade 4 in 20 shoulders. The Goutallier grade at 10
330 years after SCR did not differ significantly from that before surgery in either the
331 supraspinatus ($P = 0.61$), subscapularis, infraspinatus, or teres minor muscles ($P = 0.98$ to
332 0.99).

333

334 Complications

335 The rate of SCR-related complications other than graft tear was 2.8% (1 of 36 patients);
336 this patient had pull-out of suture anchors at the lateral footprint of the greater tuberosity due
337 to severe osteoporosis resulting from 25 years of steroid treatment for autoimmune disease.
338 At 1 month after SCR the suture anchors were removed, after which her graft healed owing to
339 fixation from the mattress sutures at the medial humeral anchors. There were no infections or
340 donor-site complications in this series.

341

342 **Discussion**

343 In this first report of long-term follow-up after arthroscopic SCR for the treatment of
344 irreparable rotator cuff tears, ASES and JOA scores and active ROM at 1, 5, and 10 years
345 after SCR were improved significantly compared with preoperative values. In addition, the
346 VAS score was lower at 10 years after SCR than before SCR. Furthermore, neither ASES or
347 JOA score, active ROM, or VAS score differed between 1 year and 10 years after SCR.
348 Therefore, arthroscopic SCR restored shoulder function and relieved shoulder pain in patients
349 with irreparable rotator cuff tears by 1 year after surgery, and this improvement in clinical
350 outcomes was maintained for at least 10 years.

By 1 year after SCR using fascia lata autografts, all patients who had enjoyed sports or had physically strenuous jobs before surgery had returned to their previous levels of participation. Continued participation in these activities might cause deterioration of the SCR graft over time, leading to the cessation of these pursuits because of shoulder dysfunction. However, 9 of the 10 patients (90%) in the current study who had played sports before surgery continued to do so at the same level even at 10 years after SCR, and 15 of 17 the patients (88%) still performed similar levels of physically intense work. In addition, graft tear rate at 10 years after SCR did not differ between sports participants and non-participants or between patients who had physically demanding jobs and those that did not. These results suggest that SCR is appropriate for when patients with irreparable rotator cuff tears want to return to sports participation and physically demanding work.

When the torn tendons in massive rotator cuff tears are not repaired, rotator cuff tear arthropathy and cartilage degeneration typically increase with time.[6] In the current study, the incidence of acetabularization and glenohumeral osteoarthritis at 10 years after SCR did not differ significantly between affected and unaffected shoulders. In addition, AHD had increased by the first postoperative time point (3 months after SCR), and this increase was maintained throughout the 10-year follow-up. Therefore, the improved glenohumeral stability after SCR protects against worsening of cuff tear arthropathy, even for irreparable rotator cuff tears.

In our patients, SCR graft thickness did not change significantly during the 10 years of follow-up and was a mean of 7.8 mm at 10 years after surgery. Furthermore, AHD increased promptly after SCD, with maintenance of this increase for at least 10 years. The mean AHD at 10 years after SCR was 8.2 mm in affected shoulders and 7.8 mm in unaffected shoulders. A previous biomechanical study showed that SCR using a fascia lata graft 6 to 8 mm thick completely normalized superior stability to the intact level. Therefore, in the current study, the AHD, which indicates superior glenohumeral stability, remained intact (Hamada grade 1) at 10 years after SCR in healed patients, likely because of the sufficient thickness of the graft (reconstructed superior capsule).

The current study has several limitations. First, any follow-up period of 10 years or longer includes aging-associated effects. In this study, to prevent the misinterpretation of age-associated effects as those due to SCR, active shoulder ROM and radiographs were evaluated in affected as well as unaffected shoulders. Second, the SCR procedure in this series used only fascia lata autograft; in some countries, dermal allograft is used for SCR. Clinical outcomes and complications after SCR using dermal allograft may differ from our results because of differences in the biomechanical properties and thickness between the 2 types of graft. Finally, 28% of the subject population initially identified could not be evaluated at 10 years after SCR because of situations that could not be overcome, such as death, severe health problems unassociated with SCR, or our inability to trace the patients or their families.

However, 72% of consecutive patients from the first case of SCR were evaluated through physical, MRI, and radiographic examinations at 10 years or longer after SCR, thus supporting the utility of the current long-term follow-up study.

Conclusions

For irreparable rotator cuff tears, arthroscopic SCR restored shoulder function and relieved shoulder pain, with high rates of return to recreational sports and physically demanding employment and maintenance of significant improvements in clinical and structural outcomes at 10 years after surgery. The graft survival rate at 10 years of follow-up was 89%. Graft healing completely prevented worsening of cuff tear arthropathy after arthroscopic SCR. For these reasons, arthroscopic SCR is an effective surgical option for irreparable rotator cuff tears and provides sustained positive outcomes at 10 years.

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