Original Article Clinics in Orthopedic Surgery 2021;13:395-405 • https://doi.org/10.4055/cios20284

Achilles Tendon Allograft for Superior Capsule Reconstruction in Irreparable Massive Rotator Cuff Tears

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Background: Treatment remains a challenge in massive and irreparable rotator cuff tears (RCTs), and superior capsular reconstruction (SCR) has become an increasingly popular choice. The objective of this study was to evaluate clinical and radiological outcomes after SCR using an Achilles tendon allograft in irreparable massive RCTs.

Methods: From December 2015 to March 2018, 11 patients (mean age, 66.3 ± 5.8 years) with irreparable massive RCTs who underwent SCR using an Achilles tendon allograft were enrolled in this study. The range of motion (ROM), visual analog scale (VAS), clinical scores, muscle strength, and acromiohumeral distance (AHD) were measured preoperatively and at 3, 6, and 12 months, and final follow-up postoperatively. Magnetic resonance imaging (MRI) was performed preoperatively and at 6 months postoperatively to assess the global fatty degeneration index and graft failure. Ultrasonography was also conducted preoperatively and at 3, 6, and 12 months, and final follow-up postoperatively to assess graft continuity.

Results: The mean follow-up period was 27.6 months (range, 24–32 months). The shoulder ROM at final follow-up increased significantly in forward flexion ($p = 0.023$), external rotation ($p = 0.018$), internal rotation ($p = 0.016$), and abduction ($p = 0.011$). All patients showed improvement in VAS score ($p = 0.005$) and clinical scores ($p < 0.001$) compared with the preoperative state. Pseudoparalysis improved in all patients. The AHD was 3.88 mm (± 1.21 mm) preoperatively, 7.75 mm (± 1.52 mm, $p = 0.014$) at 6 months postoperatively, and 6.37 mm (± 1.72 mm, $p = 0.031$) at final follow-up. Graft removal and synovectomy were performed in 1 patient who developed postoperative infections. Radiological failure on follow-up MRI occurred in 2 patients at 6 and 12 months postoperatively, respectively.

Conclusions: SCR using an Achilles tendon allograft in irreparable massive RCTs achieved functional and clinical improvement. The use of Achilles tendon allograft also has the advantages of short operation time without donor site morbidity, sufficient thickness, and robustness; therefore, this allograft can be a useful graft for SCR.

Keywords: *Irreparable, Rotator cuff tear, Superior capsule reconstruction, Achilles tendon allograft*

Received November 19, 2020; Revised December 23, 2020;
Accepted December 23, 2020
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Irreparable massive rotator cuff tears (RCTs) cannot be completely cured after surgical treatment due to tendon retraction with inelasticity,[1] muscle atrophy,[2] and fatty infiltration.[1,2] Therefore, even after repair, rotator cuff healing remains a difficult problem, which can lead to the progression of arthritis of the shoulder joint after surgery.[1,2] For such irreparable RCTs, treatments including debridement,[3] partial repair,[4] latissimus dorsi transfer,[5] pectoralis major

transfer,[6] graft interposition,[7] and biodegradable spacer interposition[8] can be considered. However, the result of such treatments can be unsatisfactory and unsuccessful. In addition, when arthroscopic options are not viable, some surgeons will choose reverse total shoulder arthroplasty. However, in active and physiologically young patients, reverse total shoulder arthroplasty is not the preferred option because of concerns of early loosening, complications, and permanent destruction of the glenohumeral joint.[9] Mihata et al.,[10] in their biomechanical cadaveric study, reported the superior capsule as an important structure contributing to the superior stability of the glenohumeral joint. The superior capsule is located under the supraspinatus and infraspinatus; it ranged from the superior portion of the glenoid medially to the greater tuberosity of the humerus laterally.[10] According to Mihata et al.,[10] operative techniques to reconstruct the superior capsule can restore the superior stability of the humeral head.

Mihata et al.[11] also reported that arthroscopic superior capsule reconstruction (SCR) in 23 patients (average age, 65.1 years) can achieve functional improvement by restoring the stability of the glenohumeral joint. However, harvesting autologous tensor fascia lata requires longer operation time and causes donor site morbidity.[12] To solve these problems, dermal allografts, xenografts, and synthetic patches for SCR were introduced for augmentation during rotator cuff repair.[13-15] Although dermal allografts eliminate donor site complications, they have a thickness of 1 to 5 mm, which is thinner than the normal anatomical thickness of the superior capsule.[16] Mihata et al.[17] compared 4- and 8-mm-thick grafts and reported that the 8-mm-thick graft was more effective at reducing superior translation. Therefore, they speculated that an Achilles tendon allograft could be a good graft for SCR because of its sufficient thickness and absence of donor site morbidity. However, patient outcomes after SCR using an Achilles tendon allograft remain unclear.

The purpose of this study was to evaluate clinical and radiological outcomes after SCR using an Achilles tendon allograft in irreparable massive RCTs. We then attempted to confirm the usefulness of an Achilles tendon allograft as a graft for SCR. We hypothesized that SCR using an Achilles tendon allograft can improve patients' clinical and radiological outcomes.

METHODS

Patients

The Institutional Review Board approved this study (IRB No. 2019-11-003). Informed consent was waived due to the retrospective nature of this study. A single center retrospective review was conducted for patients treated with SCR with a minimum follow-up of 24 months. All patients who had undergone SCR with an Achilles tendon allograft between December 2015 and March 2018 were included. The inclusion criteria were as follows: (1) large-to-massive full-thickness RCT that was detected using preoperative magnetic resonance imaging (MRI) and confirmed arthroscopically; (2) failure of non-operative treatment; (3) RCT that was considered irreparable despite the use of interval slides; and (4) patients with a need for active performance. The exclusion criteria were as follows: (1) history of fractures or operations on the affected shoulder (except for arthroscopic rotator cuff repair); (2) severe bone deformity (Hamada classification type V); (3) cervical nerve palsy; (4) axillary nerve palsy; (5) deltoid muscle dysfunction; (6) shoulder joint infective arthritis, and (7) patients without the need for active performance.

Clinical Evaluation

All clinical outcome measurements were performed by one author (HGC). The range of motion (ROM), visual analog scale (VAS) score, American Shoulder and Elbow Surgeons (ASES) score, Korean Shoulder Scoring system (KSS) score, University of California at Los Angeles (UCLA) score, Constant score, and muscle strength (manual muscle testing [MMT]) were measured preoperatively and at 3, 6, and 12 months, and final follow-up postoperatively. Active forward flexion, external rotation, abduction, and internal rotation were measured using a goniometer. Internal rotation was defined as the highest vertebral body that the patient was able to reach with the thumb of the affected arm. Depending on the vertebral body level, the scores were as follows: below the buttocks, 0 point; between the buttocks and L5, 1 point; between L4 and L1, 3 points; and above T12, 5 points. Pseudoparalysis was defined with symptoms as follows: (1) no shoulder stiffness, (2) < 90° of active shoulder elevation, and (3) positive drop-arm sign. Muscle strength was determined by MMT using the full can test and empty can test[18] on a scale of 0 to 5, where 5 indicates normal amount of resistance to applied force, 4 resistance between 5 and 3, 3 ability to move the segment (the arm) through its ROM against gravity, 2 ability to move the segment through its ROM but not against gravity, one presence of contraction in the muscle without joint motion, and 0 no muscle contraction.

Radiological Evaluation

To reduce measurement errors, all assessments were reviewed at 6-week intervals by two blinded independent

observers (HGC and WSK). Simple shoulder X-ray was performed for all patients preoperatively and at 3, 6, and 12 months and final follow-up postoperatively. Acromiohumeral distance (AHD) was measured as the distance between the inferior aspect of the acromion and the subchondral lamina of the humeral head using the shoulder anteroposterior X-ray (Fig. 1).[15,19] Cuff arthropathy of the shoulder joint was classified according to the Hamada classification.[20] All patients underwent preoperative MRI to evaluate fatty infiltration according to the Goutallier grade,[2] which was measured in the supraspinatus, infraspinatus, and subscapularis tendon. To confirm graft failure, MRI and ultrasonography were performed postoperatively. MRI was reacquired in all patients 6 months after surgery. Ultrasonography was performed during outpatient follow-up at 3, 6, and 12 months and final follow-up postoperatively (Fig. 2). Graft failure was defined as the occurrence of discontinuity of graft on ultrasonography or MRI. There were no missing data.

Surgical Technique

All operations were performed by a senior author (KWL). Under general anesthesia, patients were placed in the beach chair position, with the operative arm draped free. Evaluation of the glenohumeral joint and investigation on the occurrence of lesions on structures, such as the biceps long head and subscapularis tendon, were conducted by inserting an arthroscope in the posterior portal. Tenotomy or tenodesis was performed when the biceps long head had a degenerative tear. When a subscapularis tear was noted, repair was performed. Routine acromioplasty was then conducted after inserting the arthroscope into the subacromial space. Anteroposterior and mediolateral sizes of the RCTs were measured using a probe. Labrum on the superior surface of the glenoid and remnant rotator cuff tissue on the greater tuberosity were debrided. A measuring probe was used to examine the size of the superior capsule defect with shoulder abduction by 30°. Depending on the location of the defect, two suture anchors were inserted into the superior glenoid between 10 to 11 and 1 to 2 o' clock (Y-knot RC All-Suture Anchor; ConMed Linvatec, Largo, FL, USA). Similarly, 2 suture anchors were inserted into the rotator cuff footprint of the greater tuberosity (TWINFIX Ultra HA Suture Anchor; Smith & Nephew, Andover, MA, USA) (Fig. 3). The suture anchor was inserted through the Neviaser portal if the anchor

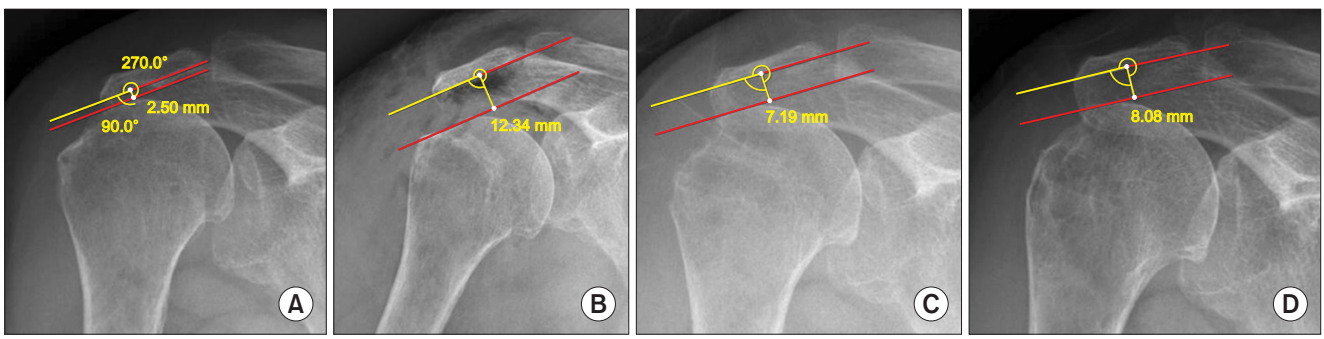

Fig. 1. Simple right shoulder anteroposterior X-ray of a 73-year-old female. Acromiohumeral distance (AHD) was measured as the distance between the inferior aspect of the acromion and the subchondral lamina of the humeral head. (A) Preoperative AHD (2.50 mm). (B) Postoperative AHD (12.34 mm). (C) Six months postoperative AHD (7.19 mm). (D) Seventeen months postoperative AHD (8.08 mm).

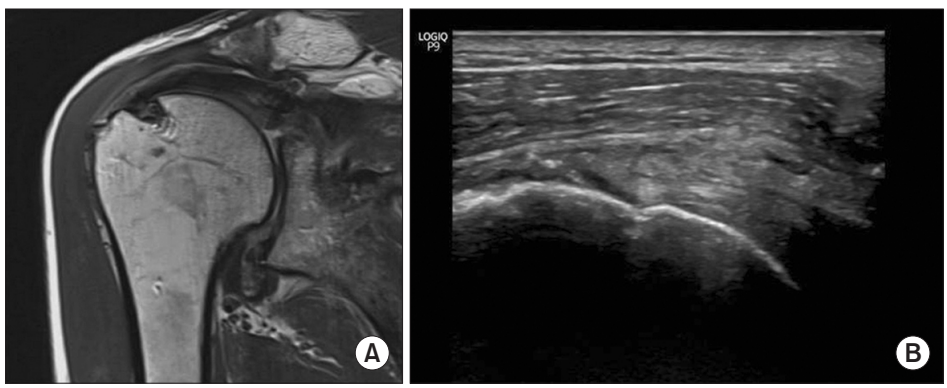

Fig. 2. Follow-up magnetic resonance imaging (A, coronal view) and ultrasonography (B, longitudinal view) of the right shoulder of a 63-year-old men at 6 months after superior capsular reconstruction with an Achilles tendon allograft.

insertion was difficult through the lateral or anterolateral portal. The Achilles tendon allograft was folded into two layers to match the size of the defect of the superior capsule with an average thickness of 7.4 mm (range, 6.5–8.6 mm) (Fig. 4). The Achilles tendon was individualized for each patient according to the distance between each of the four suture anchors. The distance between the four suture anchors was measured using stripe suture limb bulging from the suture anchor, and graft preparation was based on this (Fig. 5). To retain a sufficient contact surface between the graft and bone, the graft was prepared to be at least 5 mm larger than the distance between these suture anchors toward medial (glenoid side), anterior, and posterior sides. In addition, more than extra 10 mm of the graft was left to the lateral side to cover the greater tuberosity (Fig. 6). The lateral portal was then extended to the distal side to allow the graft to pass through. An additional 3-cm longitudinal incision was made when the lateral portal position was located too anterior or posterior. The glenoid side was fixed in advance using the double pulley technique. A strand of the suture limb from each of the suture

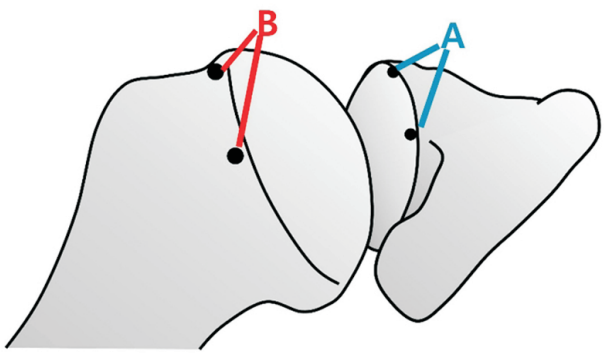

Fig. 3. Schematic illustration of the right shoulder to show the insertion site of suture anchors. We inserted two suture anchors into the superior glenoid surface (A) and two suture anchors into the greater tuberosity area (B).

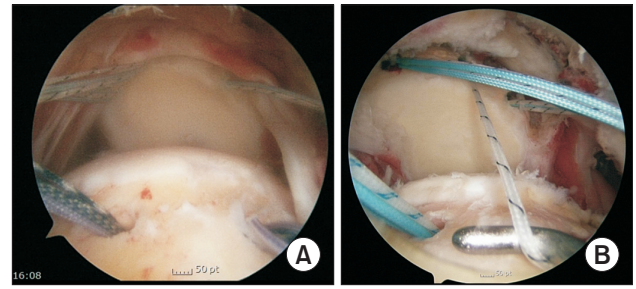

Fig. 5. Arthroscopic image of the right shoulder, with the patient in the beach chair position (lateral viewing portal). (A) Four suture anchors were inserted into the superior glenoid and the greater tuberosity areas. (B) The distance between all four anchors were carefully measured with one stripe suture limb from each glenoid anchor.

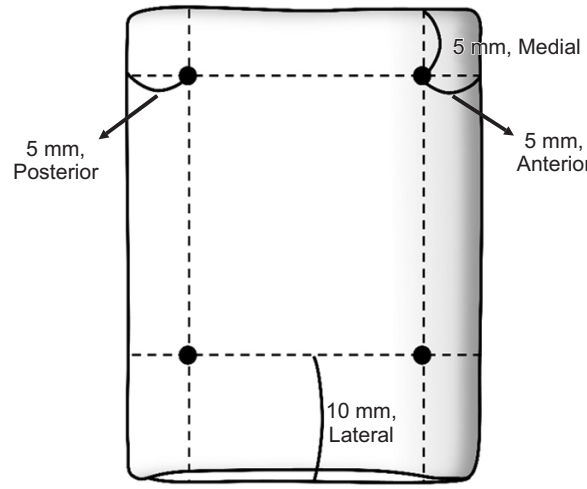

Fig. 6. Schematic illustration of marking the location of each anchor on the prepared graft. The positions of the four anchors were carefully marked on the graft. We routinely added an additional 5 mm of tissue to the medial, anterior, and posterior margins to decrease the risk of suture cut-out. An additional 10 mm of tissue was added laterally to cover the greater tuberosity.

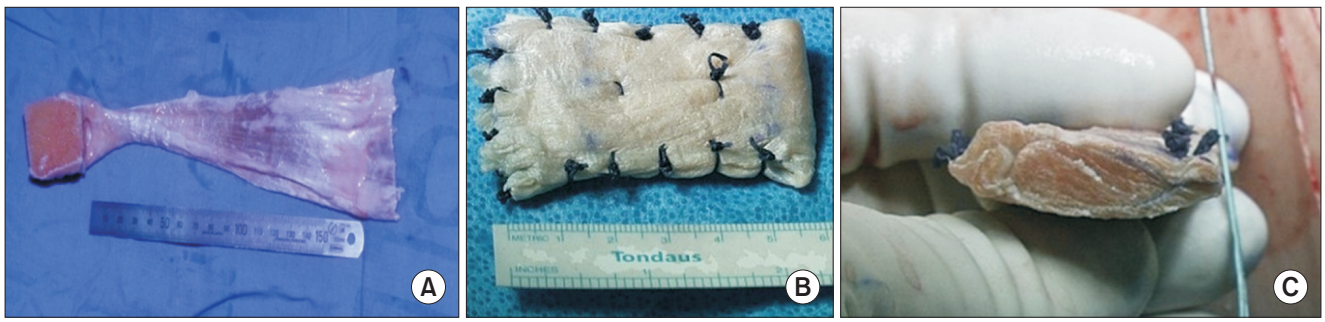

Fig. 4. Preparation of the Achilles tendon allograft. (A) Before preparation. (B) Length measurement after preparation. (C) Thickness measurement after preparation.

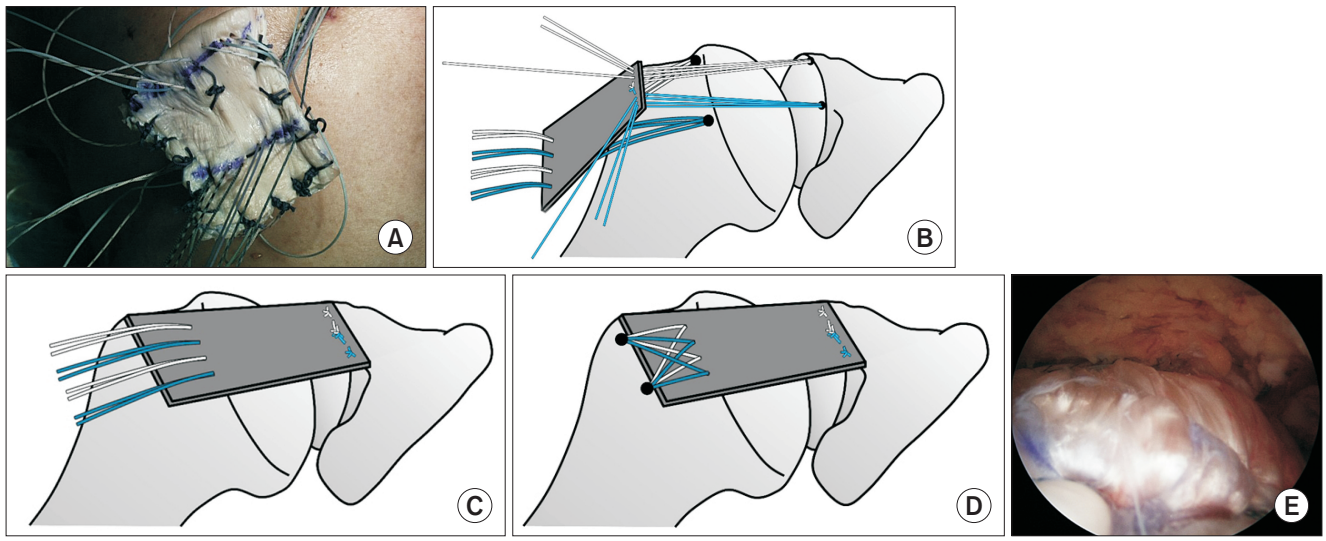

Fig. 7. (A) External image of the prepared Achilles tendon allograft on the right shoulder of the patient before insertion into the joint. (B) Schematic illustration of the right shoulder to show the graft insertion and fixation technique. One suture limb from each of the glenoid anchors was tied to the other over a switching stick. The remaining suture limbs were then pulled. (C) After graft insertion into the joint and confirmation of graft position into the superior glenoid, the remaining suture limbs were tied to each other as a static knot. (D) Double-row suture bridge knotless fixation of the graft upon the greater tuberosity. (E) Arthroscopic image of the right shoulder, with the patient in the beach chair position (lateral viewing portal) after the final graft insertion.

anchors inserted into the glenoid was separated, making a knot on the medial side of the graft and moving the graft to the glenoid by pulling an unknotted suture limb (Fig. 7A and B). When the suture limbs were passed through the medial side of the graft, the retracted rotator cuff tissue was passed together to overlap the medial side of the graft. After confirming that the graft had been sufficiently moved to the superior surface of the glenoid, medial knots were made using the remaining suture limbs for fixation (Fig. 7C). Subsequently, the lateral part of the graft was fixed more distal to the suture anchors inserted into the greater tuberosity using the suture bridge technique (Fig. 7D and E). Using side-to-side sutures with Ethibond, the graft was then secured at the posterior aspect to the remnants of the infraspinatus.

Postoperative Rehabilitation

Immobilization with an abduction brace was maintained for the first 6 weeks after surgery. Passive forward flexion and active external rotation exercises were then performed. Active forward flexion and strengthening exercises were started at 3 months after surgery. Daily and leisure activities were recommended to start at 6 to 9 months after surgery depending on the recovery state of the patients.

Statistical Analysis

Data were analyzed using IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA). The Wilcoxon signed-rank test was used for comparison given the small sample size. A $p < 0.05$ was considered statistically significant. Intra- and interobserver agreements were assessed using intra-class correlation coefficients (ICCs) calculated with the one-way random-effect model. An ICC < 0.40 indicates poor agreement; 0.40 to 0.75, fair to good (moderate) agreement; and 0.76 to 1.00, excellent agreement.

RESULTS

Patient Characteristics

Fifteen patients met the study inclusion criteria. No patients declined to participate in the study. However, 1 patient was lost to follow-up and 3 patients had not completed the 24-month follow-up period, leaving 11 patients (73.3%; 7 men and 4 women) available for the analysis at a mean of 27.6 months postoperatively (range, 24–32 months). The average age of these patients was 66.3 ± 5.8 years. Four of the 11 patients presented with a symptom of pseudoparalysis, which was defined as the inability to abduct or have forward flexion of less than 90° with normal passive range of shoulder motion and the absence of neurologic impairment. All patients were accompanied by an infraspinatus tear in preoperative MRI and arthroscopic findings. Subscapularis tears were detected in 6 patients, and repair was performed. In the Hamada classification, 7 patients were classified into type 2, and the other 4 patients were classified into type 3 (Table 1). The average antero-

Table 1. Patient Demographics

Patients no.	Age (yr)	Sex	Tear size (mm)		Previous surgery	Duration of symptom (mo)	SSC involvement	Pseudoparalysis	AHD (mm) (preoperative/ postoperative)	Hamada classification	Follow-up (mo)	Failure
			AP	ML								
1	73	Female	40	43	-	120	Intact	-	3.09/6.28	3	32	-
2	63	Male	35	45	-	36	Full → repair	-	3.46/4.49	2	31	-
3	73	Female	58	54	-	6	Intact	○	2.5/8.08	2	31	-
4	60	Male	30	44	-	18	Partial → repair	-	3.61/5.79	2	30	-
5	58	Male	33	36	-	12	Intact	○	3.13/2.36	2	28	○
6	73	Male	32	45	RCT repair	9	Full → repair	-	6.62/5.98	3	27	-
7	69	Male	55	54	-	3	Partial → repair	○	4.8/9.02	2	26	-
8	60	Male	66	51	RCT repair	5	Intact	○	3.95/3.75	2	26	○
9	62	Female	34	43	-	8	Intact	-	3.65/8.13	2	24	-
10	71	Female	42	46	-	3	Partial → repair	-	5.13/9.9	3	24	-
11	67	Male	47	37	-	72	Full → repair	-	2.78/4.84	3	25	○ (Infection)

AP: anteroposterior, ML: mediolateral, SSC: subscapularis, AHD: acromiohumeral distance, RCT: rotator cuff tear.

posterior tear size was 42.9 ± 12.1 mm (range, 29.6–66.1 mm), and the medial retraction was 45.3 ± 5.9 mm (range, 35.8–54.1 mm).

Clinical Outcomes

The active shoulder ROM was significantly improved in forward flexion, external rotation, internal rotation, and abduction compared with the preoperative ROM at follow-up (Table 2). The mean preoperative VAS score was 4.1 ± 1.5. It improved at 3 months (1.7 ± 1.5, p = 0.022), 6 months (1.4 ± 1.1, p = 0.017), 12 months (1.1 ± 0.8, p = 0.005), and final follow-up (1.1 ± 0.9, p = 0.005). The ASES, Constant, KSS, and UCLA clinical scores were also significantly improved. Muscle strength seemed to improve at 3 and 6 months postoperatively, but it was not statistically significant. Muscle strength significantly improved at final follow-up (p = 0.038). Among the 4 patients with pseudoparalysis preoperatively, 3 showed improvement at 6 months after surgery, and all improved at 12 months (Table 3).

Radiological Outcomes

The intra- and interobserver agreements were excellent, as determined using the ICC (0.93). The average preoperative AHD was 3.88 ± 1.21 mm, and it increased significantly to 8.43 ± 1.93 mm (p = 0.007) at 3 months postoperatively. At 6 months, 12 months, and final follow-up, the average AHDs was 7.75 ± 1.52 mm, 6.44 ± 2.47 mm,

Table 2. Shoulder ROM

ROM	Preoperative	3-Month follow-up	6-Month follow-up	12-Month follow-up	Last follow-up
Foward flexion (°)	93.0 ± 34.88	139.5 ± 14.0 (p = 0.005*)	144.0 ± 15.4 (p = 0.005*)	140.5 ± 23.4 (p = 0.011*)	137.3 ± 27.8 (p = 0.023*)
External rotation (°)	24.0 ± 9.9	31.5 ± 6.7 (p = 0.027*)	42.5 ± 14.9 (p = 0.008*)	42.5 ± 15.1 (p = 0.007*)	41.0 ± 17.9 (p = 0.018*)
Internal rotation (score)	1.7 ± 1.4	4.0 ± 1.1 (p = 0.006*)	3.8 ± 1.4 (p = 0.007*)	3.0 ± 1.3 (p = 0.016*)	3.0 ± 1.3 (p = 0.016*)
Abduction (°)	94.5 ± 32.5	138.0 ± 20.9 (p = 0.005*)	140.5 ± 22.9 (p = 0.005*)	142.0 ± 30.7 (p = 0.007*)	143.5 ± 37.0 (p = 0.011*)

Values are presented as mean ± standard deviation.
ROM: range of motion.
*Statistically significant.

Table 3. Clinical Outcomes

Variable	Preoperative	3-Month follow-up	6-Month follow-up	12-Month follow-up	Last follow-up
VAS score	4.11 ± 1.5	1.7 ± 1.5 (p = 0.022*)	1.41 ± 1.1 (p = 0.017*)	1.1 ± 0.8 (p = 0.005*)	1.09 ± 0.9 (p = 0.005*)
ASES score	51.6 ± 11.4	67.7 ± 11.4 (p = 0.021*)	79.0 ± 13.1 (p = 0.001*)	77.3 ± 15.4 (p < 0.001*)	76.4 ± 13.6 (p < 0.001*)
Constant score	45.2 ± 16.5	67.2 ± 9.8 (p = 0.019*)	75.4 ± 14.1 (p = 0.003*)	73.8 ± 13.4 (p < 0.001*)	75.7 ± 13.7 (p < 0.001*)
KSS score	54.6 ± 9.7	64.2 ± 11.0 (p = 0.032*)	76.4 ± 10.7 (p < 0.001*)	77.1 ± 12.3 (p < 0.001*)	76.7 ± 9.8 (p < 0.001*)
UCLA score	17.4 ± 5.1	24.1 ± 4.8 (p = 0.009*)	28.1 ± 4.9 (p < 0.001*)	27.6 ± 4.7 (p < 0.001*)	27.4 ± 4.3 (p < 0.001*)
Muscle power	2.73 ± 1.00	3.27 ± 0.9 (p = 0.261)	3.55 ± 0.82 (p = 0.133)	3.73 ± 0.91 (p = 0.047*)	3.71 ± 0.86 (p = 0.038*)
Pseudoparalysis (case)	4	2	1	0	0

Values are presented as mean ± standard deviation.
VAS: visual analog scale, ASES: American Shoulder and Elbow Surgeons, KSS: Korean Shoulder Scoring system, UCLA: University of California at Los Angeles.
*Statistically significant.

Table 4. Radiologic Outcomes

Variable	Preoperative	3-Month follow-up	6-Month follow-up	12-Month follow-up	Last follow-up
Acromiohumeral distance (mm)	3.88 ± 1.21	8.43 ± 1.93 (p = 0.007*)	7.75 ± 1.52 (p = 0.014*)	6.44 ± 2.47 (p = 0.026*)	6.37 ± 1.72 (p = 0.031*)
Goutallier grade (supraspinatus)	3.5 ± 0.8		3.3 ± 1.0 (p = 0.272)		
Goutallier grade (infraspinatus)	3.3 ± 0.8		3.2 ± 1.0 (p = 0.192)		
Goutallier grade (subscapularis)	2.5 ± 1.2		2.4 ± 1.2 (p = 0.201)		

Values are presented as mean ± standard deviation.
*Statistically significant.

and 6.37 ± 1.72 mm, respectively, showing statistically significant improvement after surgery, but the average distance score decreased over the course of time (p = 0.014, p = 0.026, and p = 0.031, respectively). Progressive decrease of the AHD during the follow-up period was not statistically significant (p = 0.246, p = 0.197, and p = 0.187). Global fatty degeneration index (Goutallier grade) on MRI performed at 6 months postoperatively did not show a significant difference in the supraspinatus, infraspinatus, and subscapularis compared with the preoperative values (p = 0.272, p = 0.192, and p = 0.201, respectively) (Table 4).

Failures

One patient suffered surgical site infection 2 months after surgery. This patient had a history of intra-articular injection at another hospital; thus, graft removal and synovectomy were performed (patient number 11). After that, the patient was managed with conservative treatment with rehabilitation and showed reduced pain, improved clinical score, and improved muscle strength at 25-month follow-up. In addition, 2 patients developed graft discontinuity in the greater tuberosity area on ultrasonography and showed decreased AHD at 6 and 12 months after surgery (patient no. 5 and 8; failure) (failure rate = 27.3%). One of them had a history of previous rotator cuff repair surgery. Both patients showed reduced pain, improved clinical score, and improved muscle strength at final follow-up (28 months and 26 months postoperatively, respectively). Additional surgery, such as reverse shoulder arthroplasty, was not required for any patient.

DISCUSSION

The most important finding of this study is that we confirmed the usefulness of the Achilles tendon as a graft for SCR. In addition, good clinical and radiological results were obtained after SCR using the Achilles tendon allograft. During the follow-up of at least 24 months, the grafts were well maintained in approximately 73% of the patients (8/11). Patients who developed postoperative infection, graft discontinuity on ultrasonography, and decreased AHD also showed pain reduction and functional improvement at final follow-up.

Symptoms complained by patients with irreparable massive RCTs include pain, decreased shoulder ROM, and reduced muscle power. In studies investigating patients who underwent a latissimus dorsi transfer[21] or partial repair,[22] improvement was observed in pain reduction but not in muscle power. However, Mihata et al.[11] reported that patients who underwent SCR showed significant improvement in muscle power. In addition, Pennington et al.[15] found that muscle power in forward flexion, abduction, and external rotation improved 1 year after SCR. In another study, functional outcome and pain significantly improved after SCR, but muscle power and shoulder ROM were not significantly different compared with the preoperative values. In this study, muscle power improved from 2.73 ± 1.0 preoperatively to 3.71 ± 0.86 (p = 0.038) at final follow-up. This improvement is maybe related to severely deteriorated muscle power before surgery. As the pain was reduced after SCR, the patients could actively participate in the rehabilitation protocol, and the muscle power similar to that of the contralateral side could be regained. In addition, the biomechanical recovery after SCR could affect the recovery of muscle power.

Several studies have reported favorable results of SCR using an autologous tensor fascia lata or dermal allograft.[11,14,16,23] However, the disadvantages of using autologous tensor fascia lata include donor site morbidity and longer operation time.[10,11] According to de Campos Azevedo et al.,[24] 16 of 22 (72.7%) patients felt discomfort at the donor site, which was related to daily activity limita-

tion and subjective loss of strength. Hirahara and Adams[23] performed SCR using a dermal allograft to reduce donor site complications caused by the use of autologous tensor fascia lata and reported successful results in approximately 70% of their cases. In a cadaveric biomechanical study comparing dermal allograft and autologous tensor fascia lata, the dermal allografts were elongated by 15% after surgery, whereas the autologous tensor fascia lata length was unchanged.[25] Such elongation could lead to superior translation of the humeral head, which could damage the graft in the subacromial space.[25] Mihata et al.[17] also compared the results of the thickness of the autologous tensor fascia lata graft and reported that an 8-mm-thick graft was more effective than a 4-mm-thick graft in reducing superior translation. However, dermal allograft has a disadvantage; it is difficult to completely improve superior stability of the glenohumeral joint due to its thinness.[14] The authors of this study drew a conclusion that the Achilles tendon allograft has appropriate length and thickness compared with the dermal allograft, and it would be possible to achieve the graft with proper length and thickness.[26] Thus, when the graft was prepared, an average graft thickness of 7.4 mm (range, 6.5–8.6 mm) was achieved by folding the Achilles tendon allograft twice, thereby increasing superior stability of the glenohumeral joint and preventing superior translation of the humeral head. In addition, the Achilles tendon allograft can be an attractive and alternative option for replacing the dermal allograft because of its robustness and successful results in the treatment of other ligamentous and tendinous reconstructions throughout the various joints.[26,27]

In some patients with irreparable massive RCTs, active shoulder elevation is reduced to 90° mainly due to a loss of the "force couple" that stabilizes the humeral head during elevation. This condition is similar to that in nerve injuries, such as cervical palsy and axillary nerve palsy, and is therefore referred to as pseudoparalysis.[28] In the case of irreparable RCTs in patients with pseudoparalysis, it represents bad condition functionally. Mihata et al.[29] reported an improvement in pseudoparalysis except for patients with graft tears. In this study, we observed improvement in all 4 patients with pseudoparalysis at final follow-up. This finding may be due to the recovery of shoulder joint stability and force couple after SCR.

Various grafts are currently used for SCR, and numerous studies have reported different results; however, which graft is the best option remains unclear. Graft tear rate after SCR using an autologous tensor fascia lata graft ranges from 5% to 30%.[11,30] Among the studies using dermal allograft, Hirahara and Adams[23] reported a 37.5% failure rate in at least 2-year follow-up period, and Denard et al.[14] reported a 55% failure rate. In the present study, 2 patients were diagnosed with graft failure because graft discontinuity was observed on ultrasonography at 6 and 12 months, respectively, after surgery. One of these patients had a history of previous rotator cuff repair surgery. The total failure rate was 27.3%, including the patient who developed postoperative infection, which led to synovectomy and graft removal. The infection rate was 9.1% (1/11), which was higher than that of other studies reported in the systemic review,[16] but this 1 patient had a history of intra-articular injection at another hospital 6 weeks after surgery. Therefore, the overall failure rate of this study was not higher than that of the other studies using autologous tensor fascia lata or dermal allograft, except for the studies conducted by Mihata et al.[11,29] In addition, the failure rate of this study is sufficiently reliable because all patients underwent MRI at 6 months postoperatively, and ultrasonography and X-ray were frequently performed during follow-up to observe graft failure. In the 2 failure cases, the graft was torn at the side of the greater tuberosity. However, even in the failure cases, rehabilitation was possible as pain decreased immediately after surgery. As a result, the functional improvement was obtained at the final follow-up. This may also be due to the sufficient spacer effect due to the characteristics of the Achilles tendon such as robustness and ultimate tensile strength.[27] Therefore, highly acceptable results are expected to be obtained if a large-scale and long-term study will be conducted in the future.

This study has several limitations. First, it was a retrospective short-term study. All patients were followed up for a minimum of 24 months and achieved satisfactory clinical outcomes. However, further studies are needed to determine what changes will occur in functional and radiological outcomes in the long-term follow-up. Second, the total sample size was small. Third, no control group was included for comparative analysis. If possible, a comparison of SCR with other surgical techniques or Achilles tendon allograft with other grafts could provide more meaningful results. Finally, the lost to follow-up rate was quite high in this study and it can have a negative effect on the validity of the study. However, it was inevitable because of the pandemic situation.

In conclusion, good functional and clinical outcomes were obtained after SCR using an Achilles tendon allograft. Because of the sufficient thickness and robustness, as well as short operation time without donor site complications, the Achilles tendon allograft can be a useful graft for SCR.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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