Superior Capsular Reconstruction Versus Middle Trapezius Tendon Transfer for Isolated Irreparable Supraspinatus Tendon Tears

Static Versus Dynamic Reconstruction

Jung Gon Kim,* MD, Chaemoon Lim,* MD, Bo Taek Kim,* MD, and Chang Hee Baek,*† MD
Investigation performed at Yeosu Baek Hospital, Jeollanam-do, Republic of Korea

Background: Both superior capsular reconstruction (SCR) and middle trapezius tendon (MTT) transfer can be performed in non-arthritic young and active patients with isolated irreparable supraspinatus tendon tears (IISTTs). However, to our knowledge, no comparative clinical studies have been conducted on these procedures.

Purpose: To evaluate and compare the clinical and radiological outcomes of SCR and arthroscopic-assisted MTT transfer in patients with IISTTs.

Study Design: Cohort study; Level of evidence, 3.

Methods: A total of 60 patients with IISTTs were categorized into 2 groups according to the surgical procedure—Group S underwent SCR (n = 34); Group M underwent MTT transfer (n = 26). The clinical outcomes included the visual analog scale score for pain, active shoulder range of motion, American Shoulder and Elbow Surgeons score, and University of California, Los Angeles, shoulder score. Radiological outcomes included the assessment of the acromiohumeral distance, progression of cuff tear arthropathy (Hamada grade), subacromial bone erosion, and graft failure.

Results: The mean follow-up time was 39.3 ± 5.2 months (range, 26-59 months) and 37.6 ± 9.8 months (range, 27-54 months) in Group S and Group M, respectively. Significant improvements in clinical outcomes were observed in both groups, while the active forward flexion (148.2° ± 24.1° vs 165.9° ± 8.7°; $P = .003$) and abduction (131° ± 37.3° vs 152.5° ± 17.9°; $P = .035$) were significantly higher in Group M at the final follow-up. No significant differences were found in the postoperative Constant, American Shoulder and Elbow Surgeons, and University of California, Los Angeles, shoulder scores between the 2 groups. Radiologically, although no difference was found in the Hamada grade at the final follow-up between the 2 groups ($P = .143$), the rates of acromial wear (58.8% vs 15.4%; $P < .001$) and graft retear (47.1% vs 7.7%; $P < .001$) were significantly higher in Group S than in Group M.

Conclusion: Both SCR and MTT transfer improved the overall clinical outcomes of IISTTs postoperatively, whereas MTT transfer was superior to SCR in terms of active forward flexion and abduction range of motion. Although higher rates of graft failure and subacromial bone erosion were observed in Group S, no difference was found in the clinical scores between the 2 groups at the short-term follow-up. However, further well-structured, prolonged comparative trials should be conducted in the future.

Keywords: irreparable rotator cuff tear; irreparable supraspinatus tendon tear; middle trapezius tendon transfer; superior capsular reconstruction; tendon transfer

Isolated irreparable supraspinatus tendon tears (IISTTs) have remained an ongoing challenge for reconstructive shoulder surgeons, causing patients unendurable pain and diminishing shoulder function.[14,32] There are various treatment options for IISTTs, such as patch augmentation, interpositional bridging graft, superior capsular reconstruction (SCR), biceps rerouting, subacromial balloon spacer, supraspinatus (SSP) tendon advancement, and biological tuberoplasty.[12,20,31,37,44] However, the optimal approach for treating IISTTs continues to be debated. Among them, SCR has been commonly performed as a promising tool to manage young and active patients with IISTTs.[2,3,10,28,29,45,46] SCR provides static stability for superior translation of the humeral head with the reconstruction of the superior capsule. However, the

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dynamic stability that should have been obtained by the rotator cuff musculature cannot be achieved. Recent biomechanical studies revealed that SCR, which lacks dynamic stability, does not effectively depress the humeral head during the higher shoulder abduction angles.[18,35] Moreover, various complications such as higher rates of graft failure and reoperation,[10,45] graft elongation,[7,27] and subacromial bone erosion[1,42] have also been reported to compromise the superior stability of the humeral head and functional outcomes.

In recent decades, several tendon transfer procedures have been proposed as reasonable treatment options with satisfactory clinical outcomes for nonarthritic young and high-demand elderly patients with irreparable rotator cuff tears.[19,44] Recently, middle trapezius tendon (MTT) transfer has been introduced as an alternative and feasible transfer option for IISTTs with a focus on enhancing dynamic stability in the glenohumeral joint and potentially improving active forward flexion.[1,17,33,34] In contrast, lower trapezius tendon transfer has been utilized to address irreparable posterosuperior cuff tears, showing early promising outcomes, particularly in terms of enhancing active external rotation.[2,8,9,40] The MTT transferred from the medial half of the scapular spine to the SSP footprint with interpositional graft could reconstruct the SSP tendon by mimicking the SSP tendon vector and its muscle contraction, which provides the dynamic stability of the glenohumeral joint (Figure 1).[1,17,33] Moreover, the MTT with an interpositional graft could also be a biological subacromial spacer that provides static stability in the glenohumeral joint.[1] Nevertheless, despite the proven significance of the superior capsule through biomechanical and clinical studies, one limitation of the MTT could be its inability to contribute to the static stability offered by the superior glenohumeral capsule.

Although SCR and MTT transfer could be considered potential treatment options for nonarthritic young and active patients with IISTTs, to our knowledge, no clinical studies have been conducted to compare the 2 fundamentally different procedures. Therefore, this study evaluated and compared the minimum 2-year follow-up clinical and radiological outcomes between SCR and arthroscopic-assisted MTT transfer in patients with IISTTs. We hypothesized that MTT transfer would have better clinical and radiological outcomes compared with SCR at a minimum 2-year follow-up.

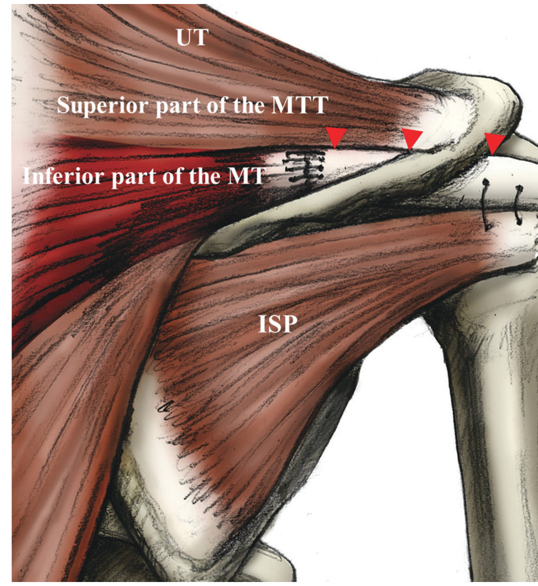

Figure 1. Schematic outline of middle trapezius tendon (MTT) transfer. The inferior part of the MTT is harvested and transferred to the supraspinatus footprint beneath the undersurface of the acromion using an interpositional graft (red arrowheads). ISP, infraspinatus; UT, upper trapezius. (Reprinted from Baek CH, Kim JG. Shoulder superior capsular reconstruction hybrid graft thickness greater than preoperative acromiohumeral distance increases graft retear rate and subacromial erosion. *Arthroscopy*. 2022;38(6):1784-1792. Permission obtained from Springer Ltd.).

METHODS

Patient Selection

This study was approved by the institutional review board (IRB) of the Ministry of Health and Welfare (IRB approval No. P01-202301-01-010). We conducted a retrospective comparative clinical study between April 2017 and July 2020. The indications for SCR were as follows: (1) incapacitating pain and loss of shoulder function that disrupts daily activity; (2) irreparable SSP tendons with or without irreparable infraspinatus (ISP) tendon tears, with poor muscle condition (Goutallier classification[11] grades 3 or 4) and severe retraction of the SSP tendon (Patte classification[36] grade 3) on magnetic resonance imaging (MRI); (3) other intact or reparable rotator cuff tendons, such as the subscapularis (SSC) and the teres minor (Tm) tendons; and (4) little or no arthritic change (Hamada grades[13] $\leq$2). The indications for MTT transfer were as follows: (1) incapacitating pain and/or loss of shoulder function that disrupts daily activity; (2) isolated, irreparable SSP tendons with poor muscle condition (Goutallier classification grades 3 or 4) and severe retraction (Patte classification grade 3) on MRI; (3) other intact or reparable rotator cuff tendons, such as the SSC, ISP, and Tm; and (4) little or no arthritic change (Hamada grades $\leq$2) (Figure 2). The reparability of other rotator cuff tendons (SSC, ISP, and

†Address correspondence to Chang Hee Baek, MD, Department of Orthopaedic Surgery, Yeosu Baek Hospital, Jeollanam-do, 59709, Republic of Korea (email: yeosubaek@gmail.com).

*Department of Orthopaedic Surgery, Yeosu Baek Hospital, Jeollanam-do, Republic of Korea.

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Tm) was evaluated using diagnostic arthroscopy. Irreparable cuff tendons were defined based on both preoperative MRI scans and diagnostic arthroscopy if the retracted cuff tendon could not be pulled to its footprint area despite the use of mobilization techniques and soft tissue release. We excluded patients who underwent SCR for surgically confirmed irreparable SSP and ISP tears (n = 16), those who underwent SCR using a dermal allograft (n = 2), and those who underwent MTT transfer using an Achilles allograft (n = 2). In addition, patients who were unavailable for a preoperative and 2-year postoperative radiological and clinical assessment (n = 3) were excluded. Finally, 34 patients who underwent SCR using a fascia lata (FL) autograft (Group S) and 26 patients who underwent MTT transfer using an FL autograft (Group M) for IISTTs were included (Figure 2). The decision to choose SCR or MTT transfer in patients with an isolated SSP tear or an SSP tendon with a reparable ISP tear was based on the patient's overall condition, including willingness for rehabilitation, return to work, desired activity level, medical comorbidities, and more. We provided detailed explanations about the mechanism, surgical procedure, skin incision, and efficacy of each procedure before the operation. In most cases, SCR or MTT transfer was performed according to the patient's decision. However, because a patient's preoperative reparable ISP tear may be found to be irreparable during surgery, we obtained prior consent for proceeding with SCR in case of surgically irreparable ISP tendons, even if the patient expressed a preference for MTT transfer preoperatively. Conversely, in cases where an ISP tear was considered irreparable preoperatively but found to be surgically reparable, we discussed SCR or MTT transfer options and obtained prior consent.

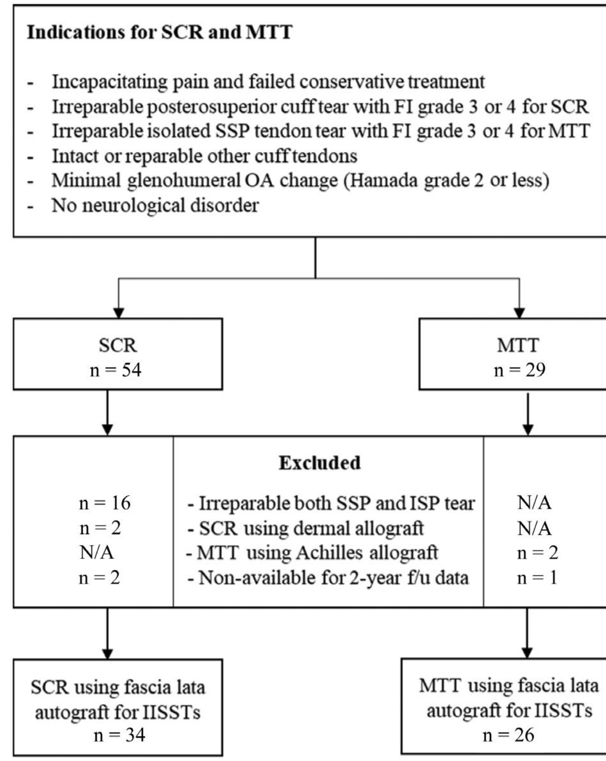

Figure 2. Flowchart showing the patient selection for this study. FI, fatty infiltration; f/u, follow-up; IISST, isolated irreparable supraspinatus tendon tear; ISP, infraspinatus; MTT, middle trapezius transfer; N/A, not applicable; OA, osteoarthritis; SCR, superior capsular reconstruction; SSP, supraspinatus.

Surgical Technique

The patients were placed in the lateral decubitus position under general anesthesia with an interscalene block. The diagnostic arthroscopy was performed to evaluate the reparability of the cuff tendons and debride any residual scar tissue. The tenotomy, tenodesis, or debridement of the biceps long head was performed according to the arthroscopic finding of biceps pathologies, such as a tear, subluxation, or degenerative change. In cases where SSC and/or ISP tendons were reparable, the repair was attempted. To prevent postoperative graft attrition between the acromion and humeral head, acromioplasty was routinely performed.

SCR Procedure. To determine the size of the FL graft, the distance from the medial glenoid to the footprint of the lateral greater tuberosity and the anteroposterior (AP) area of the cuff defect was measured at 45° of shoulder abduction. After the FL was harvested according to the measured defect size, the harvested FL was folded 2 or 3 times to obtain a minimal graft thickness of 6 mm and prepared using the Krakow method (Figure 3, A and B). The graft thickness was measured using a caliper at the lateral one-third of the thickest part of the graft.[22] After graft preparation, the superior glenoid and SSP footprints were decorticated to the attachment site. Two 4.5-mm anchors (Corkscrew FT; Arthrex) were inserted into the superior portion of the glenoid rim and the greater tuberosity of the lateral humerus. The graft was shuttled through the lateral portal to the subacromial space using anchor sutures, and the medial margin of the graft was positioned between the remnant SSP tendon and the glenoid. Medial glenoid fixation was performed using the mattress-tying technique, while the lateral portion of the graft was fixed on the footprint using the double-row suture bridge technique. Finally, side-to-side suturing was performed between the graft, the posterior rotator cuff, and the capsular portion (Figure 3C).

Arthroscopic-assisted MTT. After the FL was harvested ≥4 cm in width and 15 cm in length, the harvested FL was folded lengthwise, including the thick intermuscular septum portion to make the graft thicker. A No. 2 nonabsorbable suture material (Ethicon Inc) was then sutured along the edge of the graft (Figure 4). The graft thickness was also measured using a caliper at the lateral one-third of the thickest part of the graft.

A 5-cm transverse skin incision was made laterally from the medial half of the scapular spine. After superficial dissection, the medial half of the upper lip of the scapular spine was identified where the inferior portion of the MTT was attached. The inferior portion of the MTT was released from the scapular spine to the medial scapular

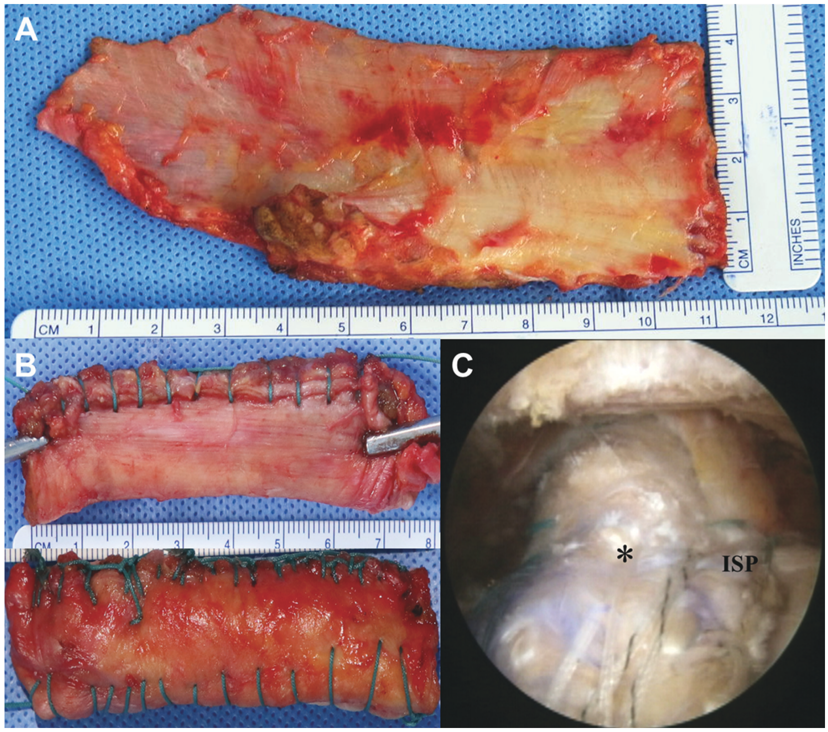

Figure 3. (A) The fascia lata (FL) involving the thicker intermuscular septum and posterior tissue was harvested. (B) The FL was then folded twice to obtain a minimal graft thickness of 6 mm and was prepared and sutured using the Krackow method. (C) An arthroscopic image (asterisk) with side-to-side suturing between the graft and the infraspinatus (ISP) tendon.

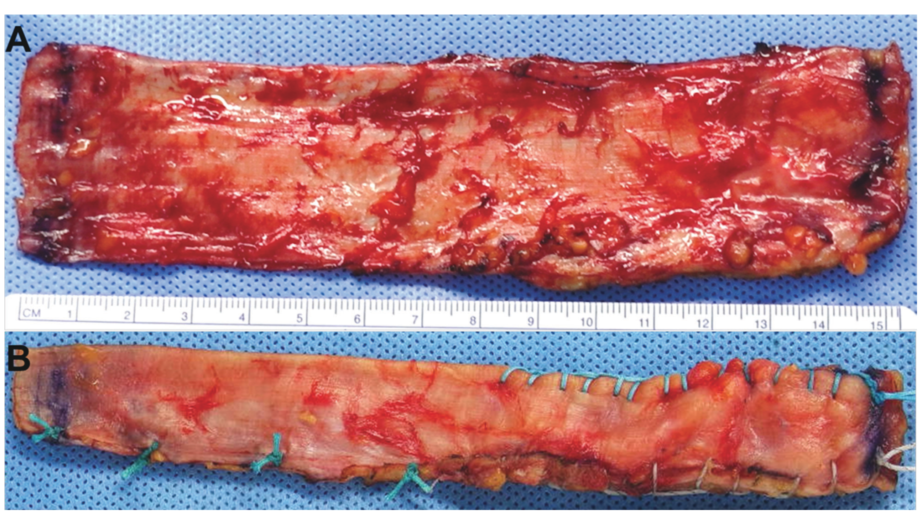

Figure 4. (A) The fascia lata (FL) strip is harvested ≥4 cm and 15 cm in width and length, respectively, involving the intermuscular septum and posterior thicker tissue. (B) The harvested FL was folded once lengthwise, and No. 2 nonabsorbable sutures were applied on both edges of the graft.

border. We did not release the lateral scapular border and acromion at which the superior portion of the MTT was attached to avoid injuring the posterior acromioclavicular joint capsule. Moreover, care was taken not to release it too medially to prevent the iatrogenic injury of the spinal accessory nerve that runs vertically, parallel to the medial border of the scapula. Nevertheless, a previous anatomic study has indicated that the risk of spinal accessory nerve damage is minimal because of a significant separation between the inserted tendon and the nerve pedicle[33]

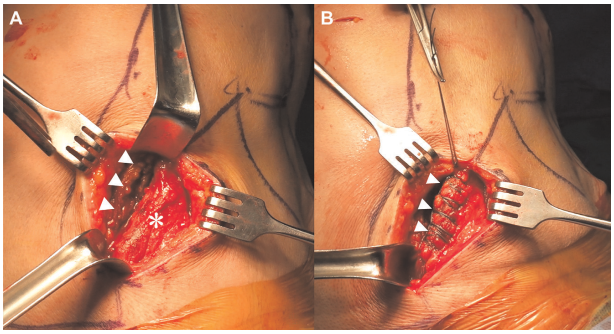

Figure 5. (A) The exposed inferior part of the middle trapezius tendon (MTT) (asterisk) and the scapular spine (arrowheads) of the left shoulder. (B) Subsequently, the harvested MTT is prepared using nonabsorbable suture material along the inferior edge of the tendon.

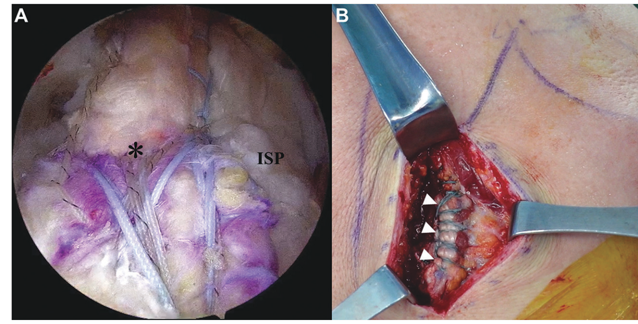

Figure 6. (A) Arthroscopic image of the left shoulder from the lateral portal showing fascia lata (FL) interpositional graft (asterisk) and side-to-side suturing to the infraspinatus (ISP) tendon. (B) The FL and the middle trapezius tendon were secured together using No. 2 nonabsorbable sutures with continuous locking fashion, indicated by the arrowheads.

(Figure 5A). Subsequently, traction sutures were placed at the end of the harvested MTT using No. 2 nonabsorbable suture material (Figure 5B).

After the MTT preparation, 1 triple-loaded and 1 double-loaded suture anchor (4.5-mm PEEK Corkscrew FT; Arthrex Inc) were inserted at the footprint of the SSP tendon. With use of a long grasping clamp, the FL graft was grabbed and pulled out from the lateral portal to the skin incision of the scapular spine. After the FL graft was placed on the SSP footprint, 4 strands of the triple-loaded suture anchor were passed through the intact or repaired ISP tendon using a Suture Lasso (Arthrex Inc) for side-to-side suturing with the FL graft. The remaining 2 strands of the triple-loaded and 4 of the double-loaded suture anchors were used to fix the FL graft to the SSP footprint with the double-row suture bridge technique (Figure 6A). After fixing the FL graft to the SSP footprint, we attached the medial portion of the FL graft to the harvested MTT with the continuous-locking suture fashion (Figure 6B) in 45° of external rotation and 45° of abduction of the shoulder for physiologic tensioning.

Postoperative Rehabilitation

Postoperatively, both groups of patients were secured utilized to a shoulder abduction brace with the shoulder maintained in a neutral position for 6 weeks. During this time, patients could intermittently move their elbows, wrists, and fingers. After 6 weeks of immobilization, patients started active-assisted range of motion (ROM) exercises in every direction. Subsequently, the patients progressed to full ROM and gentle strengthening exercises after 3 months. Based on the patients' preoperative activity levels, labor and sporting activities were initiated 6 months postoperatively.

Clinical Assessments

Patient data—including age, sex, body mass index, smoking status, and medical comorbidities—were collected. Pre- and postoperative clinical outcomes were evaluated using the visual analog scale for pain, shoulder active ROM (aROM), Constant, American Shoulder and Elbow Surgeons (ASES), and University of California, Los Angeles (UCLA), shoulder scores. The shoulder aROM was measured, including forward flexion, abduction, external rotation at 0° and 90° of abduction, and internal rotation. Internal rotation was measured as the level that could be reached by the thumb (0, greater trochanter; 2, buttock; 4, lumbosacral junction; 6, L3; 8, T12; and 10, T7). The aROM was assessed at each follow-up visit, and a research coordinator recorded all clinical scores. A minimal clinically important difference and Patient Acceptable Symptom State were evaluated based on the points determined for rotator cuff repair.[5,21] Complications—such as graft failure, nerve injury, hematoma formation, adhesive capsulitis, and infection—were documented.

Radiological Assessments

The patient's true AP, lateral scapular, and axillary lateral radiographical views were taken pre- and postoperatively. To assess the radiological outcomes, the acromiohumeral distance (AHD) was measured in the true AP view while the patient was standing. The shortest distance between the inferior border of the acromial undersurface and the apex of the humeral head was measured at the 2-year follow-up. The cuff tear arthropathy in the glenohumeral joint was also evaluated pre- and postoperatively using the Hamada grade in the true AP view with the patient standing. The subacromial bone erosion was investigated at the 2-year follow-up using a true AP view of plain radiographs and MRI scans. It was defined as >2 mm of osteolysis of the acromial undersurface, according to previous studies.[4,42] The radiological assessment was conducted by 2 physicians (1 shoulder surgeon and 1 board-certified musculoskeletal radiologist), blinded in this study. The fatty infiltration grades of the rotator cuff muscles (SSC, SSP, ISP, and Tm) were determined from sagittal oblique images (ie, Y-view) using the Goutallier grading system,[11] as follows: 0, no fat; 1, fatty streaks within the muscle; 2, less fat than muscle; 3, as much fat as muscle; 4, more fat than muscle. To evaluate graft integrity, patients underwent MRI preoperatively and at 6 weeks, 1 year, and 2 years postoperatively. The transferred graft was assessed and classified into 5 categories, according to the classification of Sugaya et al[41]; types IV and V were regarded as graft failures.

Statistical Analysis

The interobserver reliability of the AHD and Hamada grades was evaluated by 2 other authors (J.G.K. and B.T.K.) using the intraclass correlation coefficient (ICC) of the radiographical measurements. The Cohen kappa statistic was used to determine the degree of agreement between the 2 authors (J.G.K. and B.T.K.) for the incidence of subacromial bone erosion. Pre- and postoperative clinical and radiological outcomes were compared using the nonparametric Wilcoxon signed-rank test and the McNemar test for continuous and categorical data, respectively. Clinical and radiological outcomes were compared between the 2 surgical techniques using the nonparametric Mann-Whitney *U* test and the Fisher exact test for continuous and categorical data, respectively. All statistical analyses were performed using SPSS for Windows Version 25.0 (SPSS Inc), and the significance level was set at 95%.

RESULTS

Overall, 60 patients were retrospectively enrolled in this study. Of these, 34 and 26 patients were in Group S and Group M, respectively. The mean follow-up time was 39.3 ± 5.2 months (range, 26-59 months) and 37.6 ± 9.8 months (range, 27-54 months) in Group S and Group M, respectively (P = .742). No significant differences were found in the preoperative demographic and clinical characteristics between the 2 groups (Table 1).

Significant improvements in the clinical outcomes were observed in both groups except for rotational ROM. Moreover, 28 (82.4%) and 22 (84.6%) patients in Group S and Group M (P = .816), respectively, achieved a minimal clinically importance difference of 11.1 in the ASES score improvement, as established for rotator cuff repair.[5] In addition, 21 (61.8%) and 18 (69.2%) patients in Group S and Group M (P = .182), respectively, achieved a Patient Acceptable Symptom State of 86.7 in the ASES score improvement, as established for rotator cuff repair.[5] Although there was no significant difference in postoperative active external and internal rotation, the forward flexion ($P < .003$) and abduction ($P < .035$) were significantly higher in Group M. Furthermore, no significant differences were found in the postoperative Constant, ASES, and UCLA shoulder scores between the groups (Table 2).

The mean graft thicknesses of Group S and Group M were 8.1 ± 2.4 mm (range, 7-14 mm) and 7.2 ± 1.6 mm (range, 6-11 mm), respectively. No significant difference was found in graft thickness between the 2 groups (P = .146). The interobserver reliability for measuring the pre- and postoperative AHD ($ICC_{pre\text{-}AHD}$ = 0.94 [0.91-0.97], $P < .001$; $ICC_{post\text{-}AHD}$ = 0.95 [0.92-0.97], $P < .001$) and the pre- and postoperative Hamada grade ($ICC_{pre\text{-}Hamada}$ = 0.94 [0.90-0.96], $P < .001$; $ICC_{post\text{-}Hamada}$ = 0.88 [0.80-0.93], $P < .001$) was excellent. There was a almost perfect agreement between the 2 raters regarding the incidence of subacromial bone erosion, measured with a Cohen kappa value (k = 0.831).[23] An increased AHD was found in Group M between pre- and postoperatively at the 2-year follow-up. Still, no significant changes were observed in Group S. Group M had a larger AHD at the final follow-up compared with Group S. No significant cuff tear arthritic changes (Hamada grade) were confirmed in either group (Group S [P = .174] vs Group M [P = .185]), and no significant difference at the final follow-up. However, the rate of subacromial bone erosion was significantly higher in Group S than in Group M (20 patients [(58.8%] in Group S and 4 patients [15.4%] in Group M; $P < .001$) (Figure 7, A and B).

Graft failure developed in 16 (47.1%) patients (at footprint in 5, at midsubstance in 7, and at glenoid area in 4 patients) and in 2 (7.7%) patients (at footprint area in both patients) in Group S and Group M, respectively (Figure 8). The graft failure rate was significantly higher in Group S ($P < .001$) (Table 3). However, in the 2 groups, no significant difference was observed between the graft failure and intact groups in terms of the final follow-up

TABLE 1
Demographic and Clinical Characteristics of Patients[a]

Parameters	Group S	Group M	*P*
No. of patients	34	26	NA
Age, y	64.1 ± 5.8	63.5 ± 7.3	.570
Sex, male:female	22:12	16:10	.956
BMI, kg/m^2	24.2 ± 3	23.8 ± 3.1	.488
Diabetes mellitus	6	5	≥.999
Hypertension	14	8	.433
Hamada grade			.501
Grade 1	32	26	
Grade 2	2	0	
SSC fatty infiltration grade			.081
Grade 1	28	23	
Grade 2	6	3	
SSP fatty infiltration grade			.438
Grade 3	19	16	
Grade 4	15	10	
ISP fatty infiltration grade			.784
Grade 1	15	14	
Grade 2	19	12	
Tm fatty infiltration grade			.817
Grade 1	31	24	
Grade 2	3	2	
Previous rotator cuff repair			
SSP repair	4 (11.8)	4 (15.4)	.485
Reparable concomitant cuff tear[b]			
SSC tear	5 (14.7)	3 (11.5)	.724
ISP tear	7 (20.6)	4 (15.4)	.740
Biceps tenotomy[b]	4 (11.8)	2 (7.7)	.472
Biceps tenodesis[b]	7 (20.6)	4 (15.4)	.433
Used graft thickness[b]	8.1 ± 2.4	7.2 ± 1.6	.146
Mean follow-up, months	39.3 ± 5.2	37.6 ± 9.8	.742

[a]Data are presented as mean ± SD, n (%), or n. BMI, body mass index; ISP, infraspinatus; Group M, middle trapezius transfer; NA, not applicable; Group S, superior capsular reconstruction; SSC, subscapularis; SSP, supraspinatus; Tm, teres minor.
[b]During surgery.

TABLE 2
Comparisons in Clinical Outcomes Between the 2 Surgical Groups[a]

Parameters	Group S	Group M	P
VAS score			
Preop	4.6 ± 1.5	4.4 ± 1.7	.754
Postop	1.9 ± 1.4	1.7 ± 0.7	.981
P	**<.001**	**<.001**	
Active FF, deg			
Preop	122.8 ± 29.2	123.8 ± 20.8	.798
Postop	148.2 ± 24.1	165.9 ± 8.7	**.003**
P	**<.001**	**<.001**	
Active ABD, deg			
Preop	100.6 ± 30.3	101.4 ± 25.2	.922
Postop	131 ± 37.3	152.5 ± 17.9	**.035**
P	**<.001**	**<.001**	
Active ER at 0°ABD			
Preop	55.3 ± 10.2	54.2 ± 9	.676
Preop	59.3 ± 8.9	58.9 ± 9.5	.611
P	.108	.232	
IR at back			
Preop	6.4 ± 1.4	6.9 ± 1.3	.159
Postop	6.74 ± 1.4	6.9 ± 0.8	.194
P	.234	.862	
Constant shoulder score			
Preop	50.4 ± 9.7	52.9 ± 11.1	.399
Postop	69.9 ± 10.9	70.5 ± 5.7	.964
P	**<.001**	**<.001**	
ASES score			
Preop	56.5 ± 10.4	58.1 ± 12.9	.577
Postop	81.5 ± 10.9	83.2 ± 11.1	.549
P	**<.001**	**<.001**	
UCLA shoulder score			
Preop	19.2 ± 3.4	20.3 ± 6.1	.111
Postop	29.1 ± 4.8	28.1 ± 2.1	.333
P	**<.001**	**<.001**	

[a]Values are shown as mean ± SD. Bold *P* values indicate statistical significance. Internal rotation was measured as the level that could be reached by the thumb (0, greater trochanter; 2, buttock; 4, lumbosacral junction; 6, L3; 8, T12; and 10, T7). ABD, abduction; ASES, American Shoulder and Elbow Surgeons; ER, external rotation; FF, forward flexion; IR, internal rotation; Group M, middle trapezius transfer; Postop, postoperative; Preop, preoperative; Group S, superior capsular reconstruction; UCLA, University of California, Los Angeles; VAS, visual analog scale.

AHD (Group S: mean AHD, 9.3 ± 2.5 mm in graft intact and 8.6 ± 3.4 mm in graft failure [*P* = .675]; Group M: mean AHD, 11.5 ± 2 mm in graft intact and 9.1 ± 3.8 mm in graft failure [*P* = .113). After MTT surgery, 1 patient had superficial infections in the early postoperative period, which were treated with open debridement and intravenous antibiotics. No nerve complications were observed. In Group S, 3 patients experienced superficial infections, but all were managed with arthroscopic irrigation and intravenous antibiotics. Two patients in the graft tear subgroup required additional procedures; namely, tendon transfer and reverse total shoulder arthroplasty. No complications such as hematoma, infection, or fascia dehiscence at the donor site for the FL autograft harvest were observed in the 2 groups.

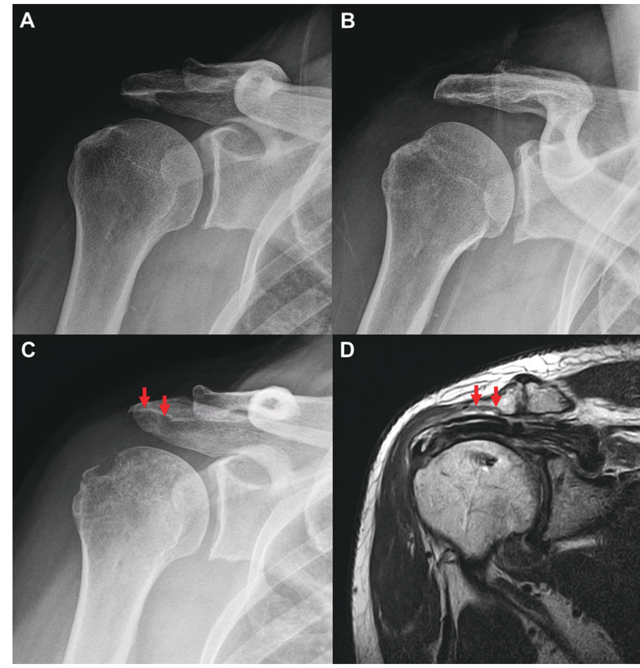

Figure 7. (A) Preoperative plain radiography and (B) immediate operative radiography reveal no signs of bony erosion in the subacromial region. (C) Plain radiography and (D) MRI at 2 years postoperatively demonstrate the subacromial bone erosion (arrows) after SCR. MRI, magnetic resonance imaging; SCR, superior capsular reconstruction.

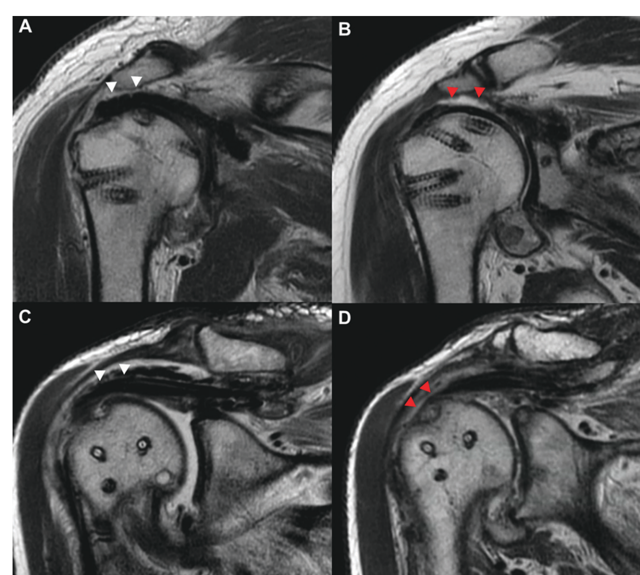

Figure 8. (A, C) MRI scans of immediate postoperative intact graft (arrowheads) and (B, D) 2-year postoperative retear graft (arrowheads) of SCR and MTT transfer, respectively. MRI, magnetic resonance imaging; MTT, middle trapezius tendon; SCR, superior capsular reconstruction.

TABLE 3
Comparison of Radiological Outcomes Between the 2 Groups[a]

Parameters	Group S	Group M	*P*
AHD, mm			
Preop	9.9 ± 2.5	9.8 ± 1.5	.737
2-year follow-up	8.9 ± 2.9	11.2 ± 2	**.001**
P	<.127	**<.001**	
Hamada grade			
Preop	1.07 ± 0.17	1.03 ± 0.19	.474
2-year follow-up	1.20 ± 0.46	1.05 ± 0.20	.143
P	.174	.185	
Subacromial bone erosion			**<.001**
No erosion	14 (41.2)	22 (84.6)	
Erosion	20 (58.8)	4 (15.4)	
Graft integrity			**<.001**
Graft intact	18 (52.9)	24 (92.3)	
Graft failure	16 (47.1)	2 (7.7)	

[a]Data are presented as mean ± SD or n (%). AHD, acromiohumeral distance; Group M, middle trapezius transfer; Preop, preoperative; Group S, superior capsular reconstruction. Bold *P* values indicate statistical significance.

DISCUSSION

To our knowledge, this is the first comparative clinical study of the 2 fundamentally different procedures as SCR utilizing a static stabilizer and MTT transfer utilizing a dynamic stabilizer[8,16,25,43] in patients with IISTTs. The main finding of this study is that although SCR and MTT transfer improved overall clinical outcomes for IISTTs postoperatively, MTT transfer was superior to SCR in terms of active forward flexion and abduction of the shoulder ROM. Moreover, graft failure and subacromial bone erosion rates were significantly higher in SCR compared with MTT transfer.

The basic concept of the SCR procedure has been theorized such that the proximal migration of the humeral head can be prevented by recreating the superior capsule between the glenoid and humeral greater tuberosity.[2,28] Although the static stability to superior translation of the humeral head can be restored, the dynamic stability that should have been derived by contraction of the superior cuff musculature could not be obtained. Several clinical and biomechanical studies have confirmed the favorable clinical results.[2,3,10,28,29,45] In contrast, various complications have also been reported—such as higher graft failure rates and reoperation.[1,7,10,42,45] Although no difference was found in clinical scores between the 2 groups in this comparative study, a higher 47.1% graft failure rate were confirmed in Group S, compared with 7.7% in Group M ($P <$ .001). Notably, this high graft failure rate in Group S is consistent with the previous clinical studies[1,15,24] that noted graft failure rates of >40%. Some studies[6,26,30] have reported that either graft thickness or graft stiffness may be considered contributing factors to graft failure and outcomes after SCR. In this study, relatively thick and stiff FL autografts were also used in both groups, and there was no difference in terms of graft thickness (SCR, 8.1 ± 2.4 mm; MTT transfer, 7.2 ± 1.6; P = .146) and graft type between the 2 groups.

One explanation for the difference in the graft failure rates between the 2 surgical procedures may be focused on the concentration and distribution of stress on the graft. Stress concentration on the graft may contribute to graft failure after SCR. Because both ends of the graft were firmly fixed to the SSP footprint and glenoid side, higher stress could be concentrated at the graft and attachment site during shoulder abduction, adduction, and rotational motion. Ding et al[7] found that the FL autograft became stretched and deformed on a 2-year postoperative MRI after SCR, and the superiorly migrated humeral head with the stretched FL autograft was also confirmed. They named this phenomenon of a graft getting stretched "patch creep" and described that this stretched graft might result in SCR failure. Mihata et al,[27] in a comparative biomechanical study on the FL and the human dermal allograft, also reported that the graft was elongated by approximately 14% of the anterior and 15% of the posterior length. In addition, a tendency (P = .05) toward a more elongated posterior length of the FL allograft was also documented in the posttest condition compared with the pretest condition. The authors indicated that shoulder ROM was the cause of elongation of the graft and reported that the partially restored superior translation of the humeral head using the human dermal allograft might be attributed to graft elongation that occurs with the shoulder ROM. Moreover, the superior translation of the humeral head and loss of superior stability because of an elongated graft may lead to abrasion of the graft under the acromion, resulting in graft failure.

On the contrary, MTT transfer may have an advantage in terms of not only stress distribution on the graft but also the achievement of shoulder joint stability compared with SCR. MTT transfer has recently emerged as an alternative tendon transfer to manage patients with IISTTs characterized by transferring the middle trapezius tendon from its medial half of the scapular spine to the SSP footprint using an interpositional graft, which could reconstruct the function of the SSP tendon biomechanically (mimicking the SSP vector) and contribute to the biological subacromial spacer effect.[17,33,34] Therefore, considering this conceptual framework, MTT transfer could provide the combined effects of dynamic joint-centering stability and subacromial spacers in the glenohumeral joint.

According to the concept of MTT transfer, the glenoid side of the interpositional graft continues to be unfixed, whereas the humeral attachment side is firmly fixed. Consequently, static stability resulting from the superior capsular portion could not be effectively obtained. Nevertheless, because the middle trapezius muscular portion is anastomosed to the interpositional graft, the dynamic joint-compressive force derived by the middle trapezius muscle could be transmitted to the shoulder joint providing dynamic stability. From this, overall joint stability of the shoulder joint can be obtained. Furthermore, because 1 side of the graft was left unsecured and connected to the middle trapezius muscular portion, the stress or strain induced by the repetitive shoulder ROM may be effectively distributed to and absorbed within the muscular portion.

This is thought to be the reason that the higher rates of graft failure observed in Group S are less likely to occur in Group M. Moreover, this appears to be a fundamental difference in how the stress concentration on the graft is addressed in SCR and MTT transfer. However, despite the differences in graft failure rates between the 2 procedures, there was no difference in clinical outcomes in our short-term comparative study, except for forward flexion and abduction. The reason may be that the remnant graft could be occupying the subacromial space similar to a balloon, thereby acting as a mechanical depressor after a graft failure, as studied by Singh et al.[39] Therefore, further studies are needed to determine whether these differences in rates of graft failure contribute to a difference in clinical outcomes in a mid- or long-term follow-up study.

In this comparative study, a higher 58.8% rate of subacromial bone erosion was confirmed in Group S. Given no significant difference in graft thickness (P = .146) and graft type between the 2 groups, this result might be ascribed to the stress concentration on the graft resulting from repetitive shoulder ROM. This stress concentration may result in graft elongation or graft failure, eventually leading to the loss of superior stability of the shoulder joint. Furthermore, because the loss of superior stability of the humeral head gradually progresses, superior translation of the humeral head resulting from the deltoid muscle could also continue to accelerate.[38] The graft between the acromion and the humeral head could be subjected to continuous compression and friction force during repetitive shoulder ROM. Thus, because the loss of stability would have been more likely to occur in Group S, where the graft failure rate was higher, the subacromial bone erosion due to friction wear may have also appeared in Group S. However, despite the difference in bone erosion rates between the 2 groups, no difference was found in the short-term clinical scores based on the presence of bone erosion in the 2 groups in this study. Moreover, despite differences in bone erosion rates, there were no observed changes in the Hamada grade between the 2 groups. In our study, the final follow-up Hamada grades for the 2 groups were confirmed to be 1.2 for SCR and 1.05 for MTT on average. Considering that both groups exhibited Hamada grades in the 1-point range, it is necessary to distinguish erosion at this level, which maintains a relatively preserved AHD, from the marked decrease in the AHD seen at higher Hamada grades accompanied by subacromial erosion and acetabularization. Given that no mid- and long-term comparative clinical studies have been done on the 2 surgical procedures with fundamentally different concepts, further well-structured prolonged clinical studies should be conducted to elucidate the correlation between graft failure, bone erosion, and clinical scores.

This study has several inherent limitations. First, this study was retrospective, and the patients were not randomized into groups according to whether they underwent SCR or MTT transfer. Therefore, the decision to perform SCR or MTT transfer was based on the patient's overall condition, such as one's willingness for rehabilitation and return to his or her previous work, desired activity level, and medical comorbidity, among others. Although no significant difference was observed in the preoperative characteristics between the 2 groups, this limitation may have resulted in a performance or selection bias. Second, the small sample size limited the validity of the study for clinical practice. Third, the results were only evaluated in the short term. Therefore, it is still unclear whether MTT transfer would yield better results than SCR in the mid- and long-term follow-ups. Fourth, the results could have been influenced by potential biases that may have been present in the procedures involved—such as biceps tenotomy or tenodesis and the SSC or ISP tendons repair. Fifth, because we did not compare patients with IISTTs with those who received alternative treatments, such as biceps rerouting, balloon spacers, or biological tuberoplasty, we could not determine which surgical technique was the most viable alternative. Finally, our SCR employed exclusively FL autografts, whereas in certain countries, dermal allografts were extensively used in SCR. Consequently, the outcomes derived from this study may lack generalizability.

CONCLUSION

Both SCR and MTT transfer improved the overall clinical outcomes of IISTTs postoperatively, whereas MTT transfer was superior to SCR in terms of active forward flexion and abduction ROM. Although higher rates of graft failure and subacromial bone erosion were observed in SCR, no difference was found in the clinical scores between the 2 groups at the short-term follow-up. However, further well-structured, prolonged comparative trials should be conducted.

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