Middle Trapezius Tendon Transfer for Augmentation of In Situ Superior Capsular Reconstruction–Reinforced Partial Rotator Cuff Repair

Short-term Outcomes of a Prospective Cohort Study

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Background: Middle trapezius tendon (MTT) transfer has been described for dynamic reproduction of supraspinatus function. For management of irreparable rotator cuff (RC) tears, this procedure can be coupled with in situ (long head of the biceps tendon–based) superior capsular reconstruction (SCR) and partial RC repair.

Purpose: To investigate the functional outcomes of augmentation of in situ SCR–reinforced partial RC repair with MTT transfer for the management of irreparable posterosuperior RC tears.

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

Methods: Conducted between September 2014 and March 2022, this study included 24 patients with irreparable posterosuperior RC tears who were allocated into 2 groups: patients managed with 2-layer tendon construct (in situ SCR–reinforced partial RC repair) (group A; n = 15) and patients managed with 3-layer tendon construct (MTT transfer–augmented, in situ SCR–reinforced partial RC repair) (group B; n = 9). Outcome measures included 2-year postoperative pain, range of motion (ROM) in forward flexion and external rotation, and the American Shoulder and Elbow Surgeons (ASES) and the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) scores. For data comparison, independent and paired *t* tests were used for parametric quantitative variables, and Mann-Whitney and Wilcoxon signed-rank tests were used for nonparametric quantitative variables; Fisher exact and McNemar tests were used for qualitative variables.

Results: The mean age of the patients was 58.40 ± 4.54 years in group A and 59.22 ± 4.46 years in group B; there were no between-group differences in baseline patient characteristics. Patients in both groups had significant preoperative to postoperative improvement on all outcome measures ($P < .05$ for all). Group B had a significantly higher magnitude of postoperative improvement compared with group A in forward flexion ROM (88.88° ± 29.34° vs 46.66° ± 20.93°; $P = .001$), external rotation ROM (32.22° ± 14.81° vs 16.0° ± 9.10°; $P = .002$), ASES score (71.07 ± 8.26 vs 57.87 ± 8.39; $P = .001$), and QuickDASH score (–70.20 ± 6.95 vs –58.34 ± 12.52; $P = .007$).

Conclusion: Augmentation of in situ SCR–reinforced partial RC repair with MTT transfer in a 3-layer tendon construct led to significantly greater improvement in postoperative ROM and functional scores compared with a 2-layer construct.

Keywords: irreparable rotator cuff tear; middle trapezius tendon transfer; partial rotator cuff repair; superior capsular reconstruction; tendon transfer for irreparable cuff tear

Over the past decade, different reconstructive techniques have been described for the management of irreparable rotator cuff (RC) tears. One technique is in situ/biological superior capsular reconstruction (SCR), which refers to transposition of the long head of the biceps (LHB) tendon out of its groove into a trough over the greater tuberosity where single-/double-row tenodesis of LHB is performed for structural and functional reconstitution of the superior glenohumeral (GH) capsule.[2,17-19]

When coupled with partial RC repair, in situ SCR has been reported to achieve satisfactory biomechanical (ie, static restraint of superior migration of the humeral head) and functional and radiological postoperative outcomes.[2,10,17-20] Nevertheless, in situ SCR has disadvantages

The Orthopaedic Journal of Sports Medicine, 11(2), 23259671221147537
DOI: 10.1177/23259671221147537
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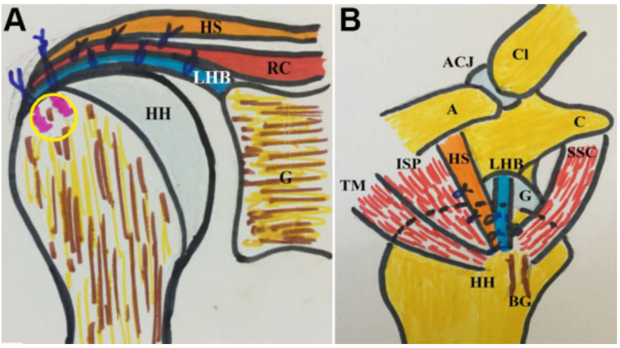

Figure 1. Technical principle of the 3-layer tendon construct of middle trapezius tendon transfer–augmented, in situ superior capsular reconstruction–reinforced partial rotator cuff (RC) repair in the right shoulder. (A) Coronal plane diagram showing suture anchors (yellow circle). (B) Oblique sagittal plane diagram. A, acromion; ACJ, acromioclavicular joint; BG, bicipital groove; C, coracoid; Cl, clavicle (lateral end); G, glenoid; HH, humeral head; HS, fashioned hamstring sheet used to lengthen the transferred middle trapezius tendon to the footprint of the RC; ISP, infraspinatus muscle; LHB, long head of the biceps tendon; SSC, subscapularis muscle; TM, teres minor muscle.

in terms of its static biomechanical nature and inability to dynamically reconstitute supraspinatus (SSP) function.[2,5,10,17-20,37]

Kandeel[15] has recently introduced transfer of the medial portion of the middle trapezius tendon (MTT) as a novel technical note for dynamic reproduction of SSP function in patients with irreparable posterosuperior RC tears. However, as MTT transfer is still a recently evolving technique, valid functional outcomes of this procedure are lacking.

Based on the presumed dynamic nature of MTT transfer in the management of irreparable posterosuperior RC tears, the author has been using a novel 3-layer tendon construct in which partially repaired RC is augmented with/sandwiched between in situ SCR and hamstring sheet–lengthened MTT transfer. Figure 1 illustrates the technical principle of this 3-layer tendon construct.

The purpose of this study was to compare outcomes of the novel 3-layer tendon construct with those of a 2-layer tendon construct (in situ SCR–reinforced partial RC repair) in the management of irreparable posterosuperior RC tears. The hypothesis was that the 3-layer construct would show significant superiority in postoperative functional outcomes compared with its 2-layer counterpart.

METHODS

The protocol for the current study, conducted between September 2014 and March 2022, received institutional review board approval, and all included patients provided written informed consent. At first, the present work was designed as a prospective case series of in situ SCR–reinforced partial RC repair (2-layer construct); however, upon introduction of MTT transfer in 2019, it was modified into a prospective cohort study with the addition of a consecutive comparison group with MTT transfer–augmented, in situ SCR–reinforced partial RC repair (3-layer construct). A total of 56 patients with a diagnosis of irreparable posterosuperior RC tear were enrolled. Criteria of irreparability included massive tears (ie, tear length >5 cm in sagittal plane) with tendon stump retraction (Patte grade 2 to 3), marked muscle fatty infiltration on magnetic resonance imaging (MRI) (Goutallier grade 3 to 4), profound muscle atrophy (Thomazeau grade 3 to 4), or intraoperative poor soft tissue quality of the cuff tendon.[7,26,30] Other criteria of enrollment were healthy contralateral shoulder and completion of 24-month postoperative follow-up.

However, 25 patients were excluded according to the following criteria; age >70 years, advanced RC arthropathy (Hamada grade >2), history of GH infection, shoulder stiffness (<90° of passive forward flexion [FF]/abduction) whether responding or not to manipulation under anesthesia, nonfunctioning deltoid muscle (eg, dehiscence, axillary nerve injury), trapezius muscle paralysis, diagnosis of unstable superior labral anchor/partial tearing/total rupture of LHB tendon, irreparable subscapularis (SSC)/infraspinatus (ISP) tear, or torn teres minor.[9]

Accordingly, this study included 31 patients. Initially, 20 patients were allocated to receive the 2-layer tendon construct (group A). Starting in July 2019, 11 patients were allocated to receive the 3-layer tendon construct (group B). Ultimately, 15 patients in group A and 9 patients in group B were available for statistical analysis of the final outcome measures. Figure 2 demonstrates a flowchart of patient enrollment and inclusion.

Preoperative Evaluation

Preoperatively, the included patients were evaluated by the author (A.A.K.), who has >19 years of experience in the fields of orthopaedic surgery, sports medicine, and upper limb reconstruction. Patient and clinical characteristics were recorded (ie, age, occupation, history of trauma, duration of complaint, comorbidities, modalities of nonoperative management, related previous operative interventions). Preoperative pain was evaluated with a 10-point visual analog scale (VAS), in which higher scores indicated worse

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Final revision submitted September 29, 2022; accepted October 21, 2022.

The author declared that he has no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Menoufia University (reference No. 10/2020ORTH).

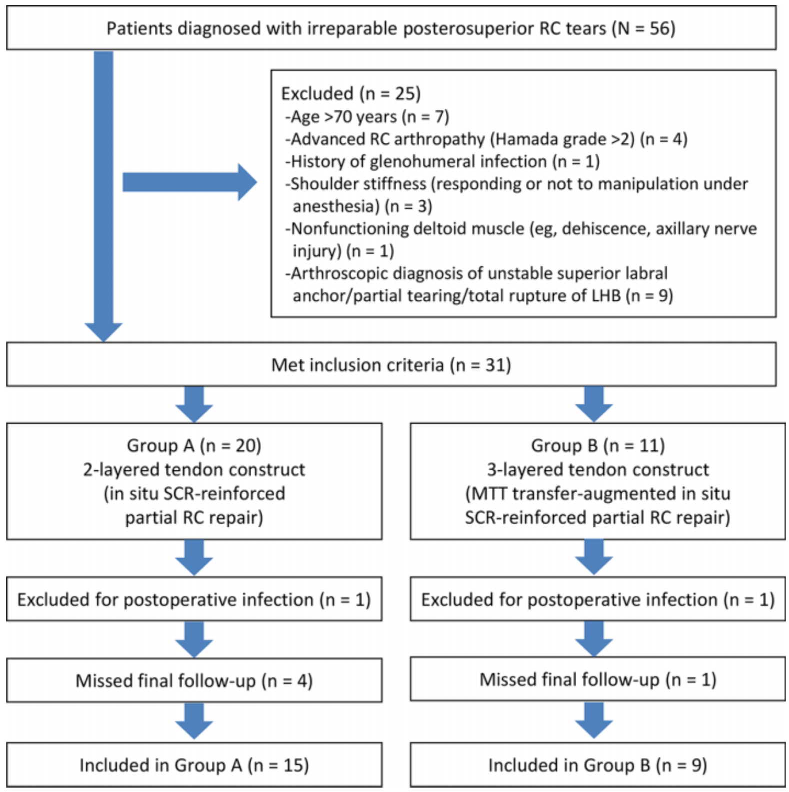

Figure 2. Flowchart of patients enrolled in the current study. LHB, long head of the biceps tendon; MTT, middle trapezius tendon; RC, rotator cuff; SCR, superior capsular reconstruction (using LHB).

pain. Patients were also examined for points of local tenderness; goniometer-based measurements of active range of motion (ROM) of the shoulder (notably FF and external rotation [ER] at 0° of abduction); and arm-drop sign.

For the primary outcome of the study, shoulders of interest were functionally evaluated using the American Shoulder and Elbow Surgeons (ASES) and the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) scores. Imaging evaluation included standard anteroposterior and axillary plain radiographic views and MRI for measurement of the acromiohumeral distance, assessment of the RC status, and exclusion of concurrent pathology.

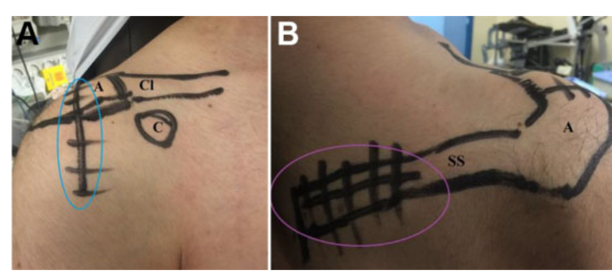

Figure 3. Anatomic bony landmarks marked with a pen and surgical approaches for the 3-layer tendon construct (ie, middle trapezius tendon transfer–augmented superior capsular reconstruction–reinforced partial rotator cuff repair) in the right shoulder. (A) Anterior aspect of the shoulder showing the McKenzie approach (blue oval). (B) Posterior aspect of the shoulder showing the scapular approach (violet oval). A, acromion; C, coracoid; Cl, clavicle (lateral end); SS, scapular spine.

Operative Procedure

Setup. The patient was seated in the beach-chair position. After administration of general anesthesia and antibiotic prophylaxis and marking of the related anatomic landmarks, passive ROM of the operated shoulder was assessed in order to exclude concurrent shoulder stiffness. Figure 3 demonstrates pen-marked anatomic bony landmarks and surgical approaches for the 3-layer tendon construct.

Diagnostic Arthroscopic GH Examination. Arthroscopic GH examination was performed via standard posterior and anterior midglenoid portals to confirm the diagnosis of RC irreparability, assess LHB and SSC integrity, and preclude concomitant intra-articular pathology (eg, detachment of the superior labrum–biceps anchor complex and advanced GH arthritis).

First Layer of Tendon Construct: SCR (Both Groups). First, the subacromial space was decompressed via the standard McKenzie approach (ie, a 4 to 5 cm–long skin incision was made starting from the acromioclavicular joint and extending inferolaterally over the anterolateral corner of the acromion; this incision was followed with longitudinal 4 cm–long deltoid splitting between its anterior and middle thirds). Next, the LHB tendon was mobilized out of its groove and transposed into a 2 cm–long trough created at the midportion of the greater tuberosity for single-row suture anchor biceps tenodesis.

Then, LHB was tenotomized distal to its tenodesis site by about 1 cm, and the free stump of the LHB tendon was then reattached to the SSC via simple stitches (ie, soft tissue tenodesis). Figure 4 demonstrates in situ SCR using an LHB tendon.

Second Layer of Tendon Construct: Partial RC Repair (Both Groups). Afterward, ISP was suture bridge anatomically repaired using a combination of another suture anchor, transosseous No. 5 nonabsorbable sutures (Ethibond Excel; Ethicon), and suture limbs of the anchor used for LHB tenodesis. When evident, a concurrent SSC tear was anatomically reduced and single-row suture anchor repaired. For further reinforcement, the repaired cuff was side to side sutured to the reconstructed superior capsule (ie, LHB) using No. 2 absorbable sutures (Vicryl; Ethicon) and suture limbs of the implanted anchors. Figure 5 demonstrates partial RC repair after in situ SCR (using the LHB tendon).

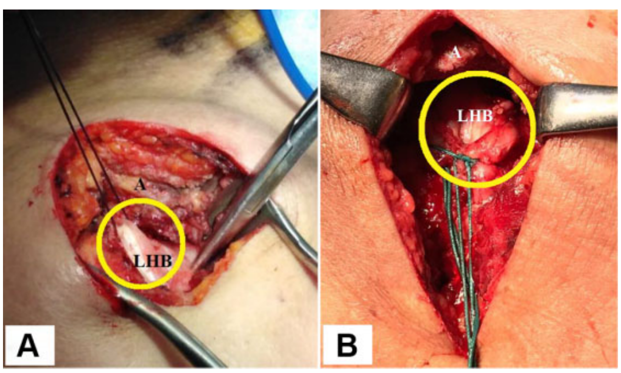

Figure 4. In situ superior capsular reconstruction using the long head of the biceps tendon (LHB) via the McKenzie approach in the right shoulder. (A) Mobilization of the LHB out of the bicipital groove (yellow circle). (B) Suture anchor tenodesis of the transposed LHB into a trough created at the midportion of the greater tuberosity (yellow circle); this tenodesis was then followed with tenotomy of the LHB 1 cm distal to its tenodesis site. *A*, acromion.

Third Layer of Tendon Construct: MTT Transfer (Group B). For patients in group B, in situ SCR and partial RC repair were followed with MTT transfer. Initially, a part (ie, the most medial 5 cm) of scapular spine insertion of the MTT was tagged with No. 2 absorbable sutures and released using a diathermy probe. Figure 6 demonstrates the technique of harvesting the medial portion of scapular spine insertion of the MTT.

Thereafter, hamstring (both semitendinosus and gracilis) tendons were harvested and fashioned as a sheet of about 12 to 14 cm in length. Then, a long straight artery clamp was used to establish a subtrapezius/subacromial corridor for passage of the hamstring sheet from the scapular approach (ie, scapular side) to the McKenzie approach (ie, humeral side), where the sheet was reattached to the native footprint of the RC (ie, SSP) via suture bridge repair configuration using transosseous No. 5 nonabsorbable sutures. Moreover, the sheet was sutured to the repaired cuff and reconstructed superior capsule (ie, LHB) using No. 2 absorbable sutures and suture limbs of the implanted anchors. On the scapular side, the sheet was sutured to the released MTT using No. 5 nonabsorbable sutures while the shoulder was placed in 45° of abduction and 45° of ER. Figure 7 demonstrates sheet-fashioned hamstring tendons, and subtrapezius/subacromial passage, and reattachment (ie, to the RC footprint on the humeral side and to the released MTT on the scapular side) of the hamstring sheet.

Under dynamic conditions, the whole tendon construct was evaluated for integrity, tension, and smooth subtrapezius/subacromial gliding motion. The Video Supplement provides a technical description of the currently reported 3-layer tendon construct of MTT transfer–augmented, in situ SCR–reinforced partial RC repair.

Figure 5. Partial rotator cuff repair after in situ superior capsular reconstruction using the long head of the biceps (LHB) tendon (yellow circles) in the right shoulder. (A) Suture bridge anatomic repair of the infraspinatus tendon (ISP) (white arrow) using a combination of a suture anchor, transosseous No. 5 nonabsorbable sutures, and suture limbs of the anchor used for LHB tenodesis. (B) Single-row suture anchor anatomic repair of the subscapularis tendon (SSC) (green arrow). (C) For further reinforcement, the partially repaired cuff was side to side sutured to the reconstructed superior capsule (ie, LHB tendon) using No. 2 absorbable sutures and suture limbs of the implanted anchors.

Postoperative Rehabilitation (Both Groups)

For 6 weeks after surgery, the operated shoulder was placed in a regular shoulder immobilizer; however, within-the-sling cis-cross shoulder exercises were encouraged. Thereafter, the sling was discarded to allow resumption of light activities of daily living and practice of pendulum and active-assisted shoulder exercises for 2 weeks. After the eighth postoperative week, a 12-week standardized shoulder rehabilitation protocol cosupervised by the surgeon (A.A.K.) and physical therapist was initiated; this protocol included 4 weeks of passive/stretching ROM exercises, 4 weeks of active/strengthening exercises, and 4 weeks of neuromuscular coordination exercises. Return to heavy duty and overhead activities was allowed by the end of the fifth postoperative month.

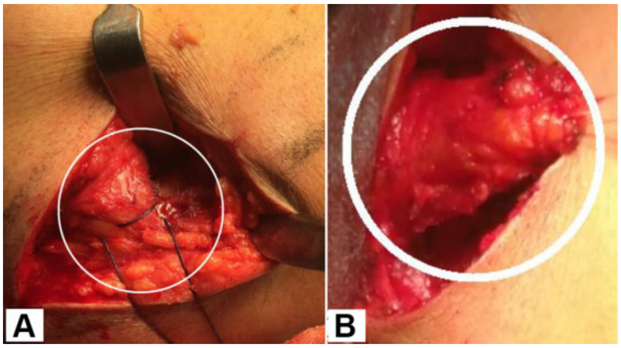

Figure 6. Harvesting the medial portion of the scapular spine insertion of the middle trapezius tendon in the right shoulder. (A) Tendon (white circle) identification and tagging with No. 2 absorbable sutures before tendon release using a diathermy probe. (B) Testing adequacy of excursion of the released tendon (white circle).

Postoperative Outcome Measures

Patients included in the current study were followed up at 1, 2, 6, 8, and 20 weeks postoperatively for wound care, supervision of patient compliance with postoperative rehabilitation, advice regarding return to work/sports activity, and management of complications. The final (ie, 2 years postoperative) evaluation included assessment of the clinical outcomes (ie, pain as assessed with VAS score, goniometer-based measurement of active ROM, arm-drop sign, complications). In addition, evaluation included rating of the functional outcomes using ASES and QuickDASH scores. Data from the 2-year postoperative evaluation (as assessed by the surgeon/author) were used for statistical analysis of the outcomes.

Statistical Analysis

Based on the findings of Valenti and Werthel[32] indicating improvement in the mean Constant-Murley score from 35 ±15 preoperatively to 60 ±9 postoperatively, sample size calculation of 80% study power with a 95% CI rendered allocation of ≥7 patients into group B with a 10% dropout rate.

Data (in both groups) were prospectively collected, tabulated, and analyzed by an independent statistician using IBM Statistical Package of Social Science (SPSS) software Version 28 (IBM Corp). The Shapiro-Wilk test was used to check normality of data distribution. For data comparison, independent and paired *t* tests were used for parametric quantitative variables, and Mann-Whitney and Wilcoxon

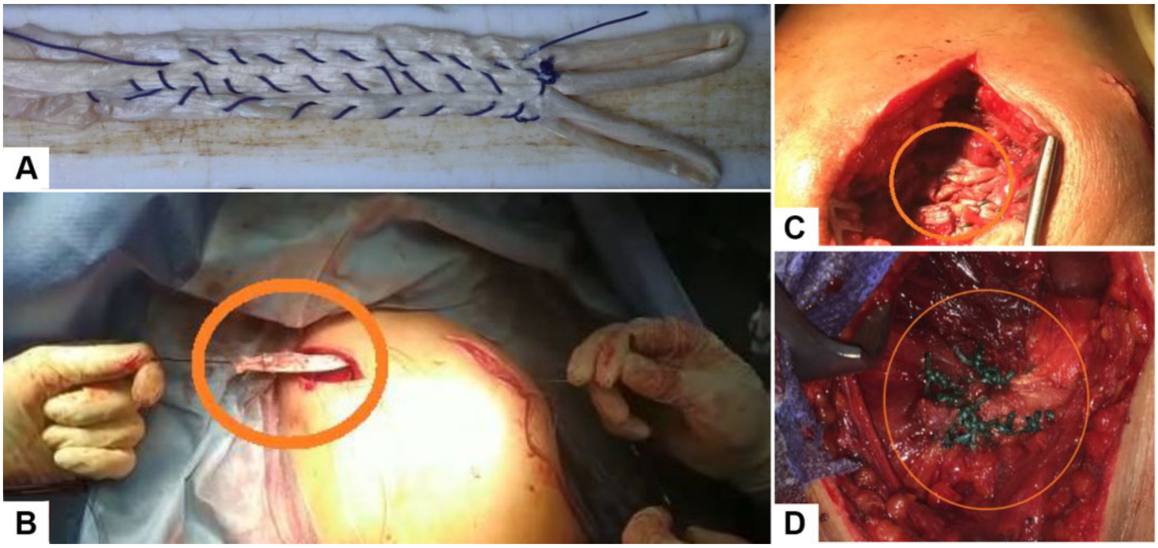

Figure 7. (A) Sheet-fashioned hamstring tendons. (B) Subtrapezius/subacromial passage of the hamstring sheet (orange circle). (C) Reattachment of the hamstring sheet (orange circle) to the rotator cuff footprint (on the humeral side) via a suture bridge repair configuration using transosseous No. 5 nonabsorbable sutures. (D) Reattachment of the hamstring sheet (orange circle) to the released middle trapezius tendon (on the scapular side) using No. 5 nonabsorbable sutures.

TABLE 1
Comparison of Demographics, Preoperative Evaluation Data, and Intraoperative Findings Between the Study Groups[a]

Variable	Group A, n = 15	Group B, n = 9	*P*
Demographic data			
Age, y	58.40 ± 4.54	59.22 ± 4.46	.670
Sex			>.999
Male	12 (80.0)	7 (77.8)	
Female	3 (20.0)	2 (22.2)	
History of trauma			>.999
Yes	13 (86.7)	8 (88.9)	
No	2 (13.3)	1 (11.1)	
Duration, mo	8.93 ± 4.81	8.66 ± 5.0	.584
Clinical data			
VAS pain	7.60 ± 1.12	7.55 ± 1.33	.888
FF ROM, deg	59.33 ± 12.79	55.55 ± 15.09	.519
ER ROM at 0° of abduction, deg	18.0 ± 6.76	18.88 ± 7.81	.969
Imaging data			
Tendon retraction			.615
Patte grade 2	2 (13.3)	2 (22.2)	
Patte grade 3	13 (86.7)	7 (77.8)	
Fatty infiltration			>.999
Goutallier grade 3	9 (60.0)	5 (55.6)	
Goutallier grade 4	6 (40.0)	4 (44.4)	
Muscle atrophy			.635
Shimizu grade 3	12 (80.0)	6 (66.7)	
Shimizu grade 4	3 (20.0)	3 (33.3)	
Acromiohumeral distance on MRI, mm	4.13 ± 0.74	4.0 ± 0.86	.693
Preoperative functional scores			
ASES	17.84 ± 7.82	16.82 ± 6.01	.872
QuickDASH	77.43 ± 7.25	79.53 ± 6.80	.490
Intraoperative findings			.678
Reparable subscapularis tear	5 (33.3)	4 (44.4)	
No tear	10 (66.7)	5 (55.6)	

[a]Data are reported as mean ± SD or n (%). ASES, American Shoulder and Elbow Surgeons; ER, external rotation; FF, forward flexion; MRI, magnetic resonance imaging; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand; ROM, range of motion; VAS, visual analog scale.

signed-rank tests were used for nonparametric quantitative variables. The Fisher exact and McNemar tests were used for qualitative variables. Statistical significance was set at $P < .05$.

RESULTS

A comparison of patient characteristics, preoperative evaluation data, and intraoperative findings between groups A and B is provided in Table 1. There were no statistically significant differences in baseline preoperative data between the groups.

In terms of postoperative outcomes, both groups showed significant improvement in VAS score, ROM, and ASES and QuickDASH scores ($P < .05$ for all). Postoperative outcomes are summarized in Table 2. With the exception of the VAS score, which was similar between groups, postoperative improvement in outcome measures was significantly greater in group B compared with group A ($P < .05$ for all) (Table 2 and Figure 8).

The most common postoperative complication was hypertrophic scars, occurring in 7 and 4 patients in group A and group B, respectively. In addition, each group had 1 patient with a deep-seated infection; these 2 patients were not included in the study.

DISCUSSION

The most important finding of the current study was that for management of irreparable posterosuperior RC tears, the 3-layer tendon construct led to greater improvement in short-term postoperative outcomes compared with its 2-layer counterpart. Group B patients had a significantly higher magnitude of postoperative improvement compared with group A patients in FF ROM (88.88° ± 29.34° vs 46.66° ± 20.93°; $P = .001$), ER ROM (32.22° ± 14.81° vs 16.0° ± 9.10°; $P = .002$), ASES score (71.07 ± 8.26 vs 57.87 ± 8.39; $P = .001$), and QuickDASH score (–70.20 ± 6.95 vs –58.34 ± 12.52; $P = .007$).

The superiority of the 3-layer tendon construct in the current study might be attributed to its third component (ie, the transferred MTT). However, this attribution cannot be further supported with conclusions from other studies, as the current study is the first evaluation, to the author's

TABLE 2
Comparison of Postoperative Outcomes and Magnitude of Improvement Within and Between Study Groups[a]

Variable	Group A, n = 15			Group B, n = 9			*P*, Group A vs B	
	Postop	$\Delta_{preop\text{-}postop}$	*P*	Postop	$\Delta_{preop\text{-}postop}$	*P*	Postop	$\Delta_{preop\text{-}postop}$
Clinical data								
VAS pain	1.0 ± 1.06	–6.60 ± 1.40	**<.001**	0.66 ± 0.70	–6.88 ± 1.16	**.007**	.571	.61
FF ROM, deg	106.0 ± 18.43	46.66 ± 20.93	**<.001**	144.44 ± 33.58	88.88 ± 29.34	**<.001**	**.009**	**.001**
ER ROM at 0° of abduction, deg	34.0 ± 6.32	16.0 ± 9.10	**<.001**	51.11 ± 10.54	32.22 ± 14.81	**.010**	**<.001**	**.002**
Functional scores								
ASES	75.72 ± 4.91	57.87 ± 8.39	**<.001**	87.90 ± 5.58	71.07 ± 8.26	**.007**	**<.001**	**.001**
QuickDASH	19.09 ± 6.85	–58.34 ± 12.52	**<.001**	9.33 ± 5.28	–70.20 ± 6.95	**.008**	**.001**	**.007**

[a]Data are reported as mean ± SD. Boldface *P* values indicate a statistically significant difference between groups compared ($P < .05$). ASES, American Shoulder and Elbow Surgeons; ER, external rotation; FF, forward flexion; postop, postoperative; preop, preoperative; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand; ROM, range of motion; VAS, visual analog scale.

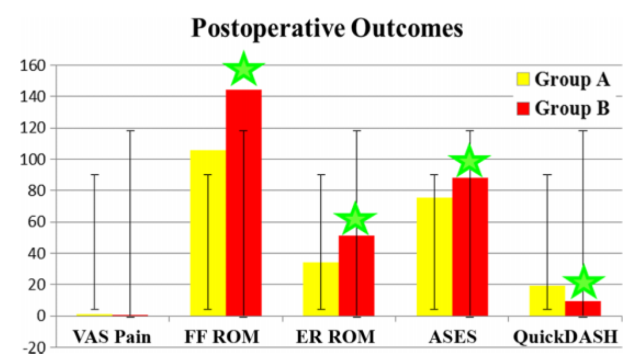

Figure 8. Comparison of postoperative outcomes between groups A and B. Green stars indicate a significant difference between groups ($P < .05$). ASES, American Shoulder and Elbow Surgeons; ER, external rotation at 0° of abduction; FF, forward flexion; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand; ROM, range of motion; VAS, visual analog scale.

knowledge, on outcomes after MTT transfer. Nevertheless, the inclusion of MTT transfer might be justified with the following 5 points.

The first point is that biomechanically, MTT transfer is assumed to dynamically reproduce SSP function via its anatomic features and force vector, which closely simulate those of SSP.[8,24] Therefore, MTT transfer per se might have the potential to recentralize the humeral head over the glenoid via a dynamic mechanism (ie, its reproduction of SSP function), and static mechanisms (ie, the subacromial spacer effect, and the countervailing force of the tensioned hamstring tendon sheet).[15,24,25]

Recentralization of the humeral head (via the aforementioned mechanisms) enhances the effectiveness of the transverse plane GH force couple mechanism (reconstituted via repaired ISP and intact/repaired SSC) needed to stabilize the GH fulcrum during elevation. In turn, this force couple further counteracts superior translation of the humeral head; hence, a positive feedback loop of GH restabilization mechanisms is established.[15,24,25]

In addition, scapular kinematics (ie, trapezius force couple mechanism) remain unviolated, as the upper, lower, and major bulk of the middle segments of the trapezius are kept intact.[15]

Likewise, the multilayered tendon construct described here might herald the potential of load-sharing mechanics across the tendon-tendon-bone interfaces at the native RC footprint; this, in turn, reduces tension loads over every individual layer of the tendon construct. Thus, the local biomechanical environment for the construct healing is optimized.[3,20-22,28]

The second point is that anatomically, atrophied SSP might allow its corresponding fossa to offer capacious anatomically convenient room for gliding motion of the transferred tendon. Another anatomic feature might be the combined soft tissue/bony (subtrapezius/subacromial) corridor, which could ease motion of the transferred tendon. Those anatomic features in conjunction with a horizontally oriented force vector of the medial portion of MTT can overcome the possibility of subacromial block of the transferred tendon, which was reported by Moroder et al[24] in a cadaveric description of transferring the lateral portion of the MTT.[15,16]

As a third point, transfer of the medial portion of the MTT offers considerable safety, as it does not violate the acromioclavicular joint. In addition, use of an intervening hamstring sheet (to lengthen the released medial MTT) minimizes subperiosteal dissection of the trapezius, tension across interfaces of the tendon construct, and displacement of trapezius-related neurovasculature.[8,15,24,27] Fourth, enriched vasculature of the transferred MTT can enhance local biology for healing of the tendon construct.[35] The fifth point is that electrophysiologically, phasic recruitment of MTT might accelerate postoperative rehabilitation and consequently reduce the risk of subtrapezius-subacromial scarring.[4,36]

Another finding of the current study was that the 2-layer tendon construct, in itself, was able to yield significant postoperative improvement in outcome measures. This finding might come in accordance with satisfactory outcomes of different studies examining SCR. In the earliest description of SCR, Mihata et al[22] reported significant functional improvement after arthroscopic SCR (using fascia lata) in 24 shoulders with irreparable RC tears, attributing these favorable outcomes to restoration of superior GH stability, as demonstrated with a significant (ie, 4 mm) postoperative increase in acromiohumeral distances on radiography.[1,10-12,21-23,31]

However, the inconsistency of postoperative outcomes of SCR-reinforced partial RC repair remains a major concern, especially with dermal allograft use, nonhealing of the grafts, heavy smoking, and revision surgery.[5,6,29,37] In a recent publication of a prospective study of 21 irreparable RC tears managed with partial RC repair reinforced with SCR (using human acellular dermal allograft), Shin et al[29] pointed out that 1-year postoperative minimal clinically important differences were reached in 19 (90.5%) and only 7 (33.3%) patients for VAS and Constant scores, respectively; in addition, postoperative improvement in shoulder ROM was insignificant.

In the present study, LHB was chosen for SCR because of its local availability, ready attachment to the superior labrum/glenoid, native vascularization and proprioception, saved operative time, and relatively lower risk of infection and cost. This choice might be further supported with different publications reporting favorable clinical, biomechanical, and histological outcomes of in situ SCR.[2,10,17-19,34] In an animal (rabbit) model, Xu et al[34] demonstrated time-dependent histologic remodeling (ie, dense, well-organized, mature collagen fibers) of the intra-articular portion and progressively ongoing healing of the extra-articular portion of the rerouted LHB. Besides, in comparison with its contralateral native counterparts, in situ SCR showed significantly more superior 9- and 12-week postreconstruction biomechanical performance (ie, higher load to failure and stiffness).

In the current study, transposition and tenodesis of LHB was followed with biceps tenotomy to reduce early (ie, 3-4 months) postoperative biceps-related pain. Otherwise, the second (soft tissue) LHB tenodesis was routinely exercised in order to lower postoperative risk of a Popeye deformity.[13,17,18]

The satisfactory outcomes reported here, in addition to the technical reproducibility, simplicity, and safety of MTT transfer, might offer a rationale to broaden the versatility of its indications to include RC retears not amenable for revised repair, as well as patients with isolated suprascapular nerve injury.[15] Although the open approach was used in the current study, MTT transfer can be technically modified to be performed arthroscopically and with use of tendon allografts. Likewise, it can be performed in conjunction with other GH reconstructive procedures, for example, the extra-articular soft arthroscopic Latarjet technique and latissimus dorsi transfer.[14,15,33]

Disadvantages of the 3-layer tendon construct, such as longer operative time, more surgical wounds, bulkier reconstructed tissues, more suture use, seroma formation on top of the roomy SSP fossa, and an abundance of sebaceous cysts (habitat of *Propionibacterium acnes*) over the scapula, might predispose patients of this construct to a relatively higher incidence of postoperative deep-seated infection.[15]

In spite of their good response to extensive debridement, anchor removal, and antibiotic therapy, patients with deep-seated infection (in both groups) were excluded from this study to negate the impact of this complication on study outcomes.

In addition, this 3-layer tendon construct cannot be used in patients with superior labral detachment, extensive tearing or rupture of LHB tendon, or paralysis of the spinal accessory nerve.[15,28]

Strengths and Limitations

To strengthen the current study, certain points were thoroughly considered, including the prospective study design. All included patients were managed by the same surgeon to ensure consistency of the exercised techniques. Also, all patients were evaluated by the same examiner (the author) to ascertain consistent assessment of the postoperative outcomes. However, this study is not without limitations; for example, the small number of included patients, short-term follow-up, undefined criteria of minimal clinically important differences, and unblinded assessment of outcomes. Therefore, further studies are recommended in order to crystallize long-term outcomes of MTT transfer, especially with regard to its effectiveness in counteracting progression of RC arthropathy.

Another limitation was abandonment of radiological outcomes of the study because of the inconsistent standardization of plain radiographic protocols for measurement of the acromiohumeral distance. Also, assessment of healing of the tendon construct on MRI was not always feasible because of lack of insurance coverage, cost, and patient refusal. This limitation might be further justified with the conclusions of Denard et al,[5] who reported that after SCR, there was no correlation between postoperative acromiohumeral distance and functional outcomes. In addition, this study did not consider the clinical impact of MTT transfer on the cervical spine, especially in light of the common prevalence of cervical spondylosis in the middle-aged patient population addressed with this tendon transfer.

CONCLUSION

Augmentation of in situ SCR–reinforced partial RC repair with MTT transfer in a 3-layer construct led to significantly greater postoperative ROM and functional scores compared with a 2-layer construct. Further biomechanical analysis and longer-term clinical studies are needed to validate the 3-layer tendon construct.

A Video Supplement for this article is available at https://journals.sagepub.com/doi/full/10.1177/23259671221147537#supplementary-materials

ACKNOWLEDGMENT

Special acknowledgment goes to Mohammed Dawood, Mahmoud Abbas, and Mohammed Asfour (residents of the

Department of Orthopedics & Traumatology, Faculty of Medicine, Menoufia University, Egypt) for their efforts during perioperative management of the patients included in the current work. Deep appreciation goes to Dr Zeinab Kasemy for her invaluable contribution to statistical analysis.

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