Research Square

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Comparison of Short-Term Clinical Efficacy Between Arthroscopic Modified Stratified Suture Technique and En Masse Suture Bridge Technique for Delaminated Rotator Cuff Tears

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Research Article

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Abstract

Objective

To compare the short-term clinical efficacy and imaging healing quality between the arthroscopic modified stratified suture technique and the traditional en masse suture bridge technique in the treatment of moderate-to-large delaminated rotator cuff tears.

Methods

A retrospective analysis was performed on 40 patients with delaminated rotator cuff tears who underwent arthroscopic surgery in our hospital from January 2023 to July 2025. Patients were divided into a modified suture group and an en masse suture group at a 1:1 ratio using propensity score matching (PSM). Matching variables included age, sex, tear size, and preoperative fatty infiltration grade. Clinical scores (Constant, ASES, UCLA, VAS), range of motion (ROM) at least 6 months postoperatively, as well as retear rate and tendon thickness evaluated by MRI at 6 months postoperatively, were compared between the two groups.

Results

At the last follow-up, functional scores in both groups were significantly improved compared with preoperative values. At 6 months postoperatively, the Constant score (83.00 ± 9.10), ASES score (89.00 ± 7.73), and UCLA score (32.50 ± 2.35) in the modified suture group were significantly superior to those in the en masse suture group (all $p < 0.05$). The VAS pain score in the modified group was lower than that in the control group during the early postoperative period (1–3 months) ($p < 0.05$). In terms of imaging, the retear rate in the modified group was 2.5% (1/40), compared with 10.0% (4/40) in the en masse group; tendon thickness after repair was greater in the modified group (6.03 ± 0.80vs. 5.85 ± 0.70) mm, ($P = 0.038$). The mean operative time was longer in the modified group (93.5 ± 7.0 min, ($P < 0.001$).

Conclusion

For moderate-to-large delaminated rotator cuff tears, the modified stratified suture technique—based on the strategy of “first anatomical reduction of each layer, then overall compression fixation”—effectively addresses interlayer tension mismatch. Compared with traditional techniques, it significantly improves early postoperative function, relieves pain, and enhances structural healing quality.

1. Introduction

Delaminated rotator cuff tear is a special type of full-thickness rotator cuff tear characterized by horizontal cleavage of the tendon between the bursal and articular sides, with an incidence of 38% to

92% among all rotator cuff tears[1]. Due to differences in fiber orientation, degree of retraction, and tension between the deep and superficial layers, this tear pattern presents unique biomechanical challenges for surgical repair and is an important risk factor for poor postoperative healing and increased retear rates[2].

Currently, the mainstream repair techniques for delaminated rotator cuff tears mainly include the traditional en masse suture technique and the stratified suture technique, both of which have limitations. The traditional en masse suture technique (e.g., the suture bridge technique) fixes the delaminated tendon as a single unit. Although it provides good footprint coverage and initial fixation strength, it does not address the anatomical reduction of the deeply retracted tendon layer, which may lead to uneven interlayer tension and mismatch[3]. The simple stratified suture technique achieves anatomical reconstruction and tension adaptation of the deep and superficial layers, but its initial fixation strength may be insufficient, especially in cases of poor tissue quality or large tears, making retear more likely[4]. Simple stratified suture is rarely used due to the large number of knots and inadequate fixation.

To combine the advantages of both techniques, this study proposes a modified stratified suture technique based on the composite repair strategy of “first stratification, then integration.” This technique first performs independent anatomical reduction and fixation of the retracted articular (deep) tendon and then reinforces the entire tendon using the suture bridge technique. We hypothesized that compared with traditional en masse suture, this modified technique would better resolve interlayer tension mismatch, thereby achieving better clinical function and structural healing. Therefore, this study aims to compare the clinical and imaging outcomes of the modified stratified suture technique and the traditional en masse suture bridge technique in the treatment of delaminated rotator cuff tears through a retrospective comparative analysis with propensity score matching.

2. Materials and Methods

2.1 General Data

Inclusion criteria: Patients who underwent arthroscopic rotator cuff repair in our hospital from January 2023 to July 2025; Intraoperatively diagnosed with moderate-to-large (Cofield classification, diameter 1–5 cm)[5] delaminated rotator cuff tear; Postoperative clinical follow-up of at least 6 months[6]; Complete shoulder MRI data at 6 months postoperatively.

Exclusion criteria: Massive (> 5 cm) or irreparable rotator cuff tear; Revision rotator cuff surgery; Concomitant shoulder fracture, significant glenohumeral arthritis (Hamada grade > 2), or shoulder instability requiring surgical repair; Isolated subscapularis or infraspinatus tear; Partial supraspinatus tear.[7]

2.2 Grouping and Matching

Patients were divided into an en masse suture group and a modified stratified suture group according to the surgical method. To reduce bias due to baseline differences, 1:1 propensity score matching (PSM) was performed. Matching variables included age, sex, smoking history, tear size, and preoperative supraspinatus fatty infiltration grade (Goutallier classification)[8]. The matching caliper was set to 0.2 standard deviations. After matching, 40 patients were included in each group.

2.3 Surgical Techniques

All operations were performed by the same senior shoulder surgeon. Patients were placed in the beach chair position under general anesthesia. A routine posterior viewing portal and anterior working portal were established to evaluate intra-articular conditions. Tenotomy or fixation of the long head of the biceps tendon was performed depending on its condition. Acromioplasty was performed if subacromial impingement was present. The bony bed of the greater tuberosity footprint was debrided and freshened.

En Masse Suture Group (En Masse Suture Bridge Repair)

The standard suture bridge technique was used. Medial row anchors were placed lateral to the cartilage margin, and sutures were passed through the full thickness of the rotator cuff tendon (including both bursal and articular sides) in a single step. After knot tying to fix the medial edge of the tendon as a whole, the suture ends were crossed to the lateral side of the greater tuberosity and fixed with lateral knotless anchors, creating a transosseous-equivalent compression construct.[9]

Modified Stratified Suture Group (Modified Suture Technique)

A modified suture technique combining stratified repair with en masse fixation was adopted. Medial row anchors were placed lateral to the cartilage margin, and an additional high-strength suture was added through the medial row anchors as needed based on the tear size. □ Independent reduction of the deep layer: The retracted articular tendon was identified and released, and a mattress suture was placed using one strand from the medial row anchor. □ Overall reinforcement and fixation: The remaining sutures from the medial row anchor were passed through the full thickness of the reduced deep and superficial tendons. □ Stepwise knot tying: The deep suture was first tied and fixed to achieve anatomical reduction, and the tail was cut; then, the remaining sutures were tied to complete overall fixation. □ Completion of the suture bridge: All remaining medial row suture ends were used as bridging sutures and fixed to the lateral side of the greater tuberosity with lateral row anchors, forming a composite compression structure.

Figure a: (□ indicates superficial layer ▲ indicates deep layer) 1- Implantation of inner row rivets; 2- Deep layer independent reduction; 3- Knot tying for deep layer suture fixation; 4- Cutting the tail thread; 5- Completion of knot tying for overall fixation; 6- Fixation of remaining inner row suture tails

Figure b: Schematic diagram of improved layered suturing

2.4 Postoperative Rehabilitation Protocol

The postoperative rehabilitation protocol was identical for both groups.

0–2 weeks: Shoulder abduction brace was worn, and passive movement of the wrist and elbow was allowed.

2–8 weeks: Passive assisted shoulder range of motion (ROM) training was performed under the guidance of a rehabilitation therapist.

8–12 weeks: The brace was gradually discontinued, and active assisted shoulder ROM training was initiated under the guidance of a rehabilitation therapist.

After 12 weeks: Progressive strengthening of the rotator cuff and scapular muscles was initiated[10].

2.5 Evaluation Indicators

Clinical evaluation: Assessments were performed preoperatively and at 1, 2, 3, and 6 months postoperatively.

1. 1. Functional scores: Constant score, American Shoulder and Elbow Surgeons (ASES) score, and University of California, Los Angeles (UCLA) shoulder score.
2. 2. Pain score: Visual Analogue Scale (VAS).
3. 3. Range of motion (ROM): Active forward flexion and lateral external rotation were measured using a goniometer[11].

Imaging evaluation: 3.0-T MRI was performed at 6 months postoperatively. Two orthopedic surgeons blinded to the grouping independently evaluated the images.

1. 1. Tendon integrity: Assessed according to the Sugaya classification; types IV and V were defined as retear.[12]
2. 2. Healing quality: Tendon thickness was measured on T2-weighted oblique coronal images as the vertical distance from the bone surface of the footprint at the medial row anchor implantation site to the tendon surface.[13][14]

2.6 Statistical Analysis

SPSS Statistics 24.0 was used for data analysis. Paired-sample t-test or Wilcoxon signed-rank test was used for intra-group comparisons before and after surgery. Independent-sample t-test (or t'-test for unequal variances) or Mann–Whitney U test was used for comparisons of continuous variables between groups. Chi-square test or Fisher’s exact test was used for categorical variables. The significance level was set at $\alpha = 0.05$.

3. Results

3.1 Baseline Data of Patients

After propensity score matching, 40 patients were included in each group. No significant differences were observed between the two groups in terms of age, sex, tear size, or preoperative functional scores (P > 0.05), indicating balanced baseline characteristics.

Table 1
Baseline Characteristics of Patients in Both Groups After Propensity Score Matching

Variable	Modified Layered Suture Group (n = 40)	Complete Suture Group (n = 40)	*P* value
Age (years)	49.9 ± 5.4	48.9 ± 5.5	0.446
Gender (Male/Female)	28 / 12	25 / 15	>0.05
Tear Size (Medium/Large)	9 / 31	12 / 28	>0.05
Preoperative UCLA Score	9.6 ± 1.2	9.4 ± 1.2	0.498
Preoperative VAS Score	6.9 ± 0.8	7.2 ± 0.9	0.148
Preoperative ASES Score	37.4 ± 2.4	37.9 ± 2.3	0.344
Note: indicates p < 0.05, denoting statistically significant differences			

3.2 Longitudinal Changes in Postoperative Clinical Functional Scores

No serious complications such as infection or nerve injury occurred in either group during follow-up. Functional scores improved postoperatively in both groups compared with preoperative values.

Regarding pain control (VAS score), at 1 month postoperatively, the VAS score in the modified suture group (2.80 ± 1.29) was lower than that in the en masse suture group (3.80 ± 1.59), with a statistically significant difference (P = 0.0028). At 2 and 3 months postoperatively, the pain scores in the modified group remained lower than those in the control group (P < 0.05). At 6 months postoperatively, VAS scores decreased further and became comparable between the two groups (0.60 ± 0.59) vs.0.80 ± 0.69), (P = 0.1666).

In terms of functional scores (Constant, UCLA, ASES), no significant differences were found between the two groups at 1 month postoperatively (P > 0.05). At 2 months postoperatively, the functional scores in the modified suture group were superior to those in the en masse suture group (P < 0.05). At 6 months postoperatively, the Constant score (83.00 ± 9.10), UCLA score (32.50 ± 2.35), and ASES score (89.00 ± 7.73) in the modified stratified suture group were significantly better than those in the en masse suture group (78.00 ± 10.22, 30.50 ± 3.44, and 84.00 ± 9.83, respectively; all P < 0.05).

Regarding shoulder ROM, no significant differences in forward flexion or external rotation angles were observed at 1 month postoperatively. At 3 and 6 months postoperatively, the modified suture group showed better forward flexion and external rotation ROM than the en masse suture group. At the final follow-up (6 months), forward flexion ROM in the modified group was 165.0°±10.1°, higher than the 158.0°±12.2° in the en masse group (P = 0.0065); lateral external rotation ROM was 60.0°±7.1°, compared with 54.0°±9.1° in the en masse group (P = 0.0016).

Table 2
Comparison of Clinical Outcomes Between Two Groups of Patients

Indicator	Follow-up Time	Modified Layered Suture Group (n = 40)	Conventional Suture Group (n = 40)	t / χ^2 Value	p Value
VAS Score	post-op 1 m	2.80 ± 1.29	3.80 ± 1.59	-3.096	**0.0028***
(0–10, ↓better)	post-op 2 m	1.80 ± 1.09	2.60 ± 1.28	-3.013	**0.0035***
	post-op 3 m	1.20 ± 0.79	1.70 ± 1.18	-2.225	**0.0294***
	post-op 6 m	0.60 ± 0.59	0.80 ± 0.69	-1.396	**0.1666**
Constant Score	post-op 1 m	42.00 ± 9.15	40.00 ± 10.17	0.924	**0.3582**
(0-100, ↑better)	post-op 2 m	58.00 ± 10.24	52.00 ± 11.11	2.512	**0.0141***
	post-op 3 m	72.00 ± 11.06	65.00 ± 12.09	2.702	**0.0085***
	post-op 6 m	83.00 ± 9.10	78.00 ± 10.22	2.311	**0.0235***
UCLA Score	post-op 1 m	14.50 ± 4.03	13.50 ± 4.61	1.033	**0.3049**
(0–35, ↑better)	post-op 2 m	22.00 ± 5.13	19.00 ± 6.00	2.404	**0.0187***
	post-op 3 m	27.00 ± 4.44	24.00 ± 5.50	2.685	**0.0089***
	post-op 6 m	32.50 ± 2.35	30.50 ± 3.44	3.034	**0.0034***
ASES Score	post-op 1 m	48.00 ± 12.10	45.00 ± 14.16	1.019	**0.3114**
(0-100, ↑better)	post-op 2 m	65.00 ± 11.12	59.00 ± 13.12	2.206	**0.0304***
	post-op 3 m	78.00 ± 9.85	72.00 ± 11.13	2.553	**0.0127***
	post-op 6 m	89.00 ± 7.73	84.00 ± 9.83	2.529	**0.0136***

Note: indicates $p < 0.05$, denoting statistically significant differences

Indicator	Follow-up Time	Modified Layered Suture Group (n = 40)	Conventional Suture Group (n = 40)	t / χ^2 Value	*p* Value
Forward Flexion (FF_ROM)	post-op 1 m	82.00 ± 20.23	78.00 ± 22.32	0.84	**0.4035**
(,↑better)	post-op 2 m	120.00 ± 18.25	112.00 ± 20.37	1.85	**0.0682**
	post-op 3 m	145.00 ± 15.33	136.00 ± 18.25	2.388	**0.0194***
	post-op 6 m	165.00 ± 10.08	158.00 ± 12.17	2.802	**0.0065***
External Rotation (ER_ROM)	post-op 1 m	22.00 ± 9.06	20.00 ± 9.11	0.985	**0.3279**
(↑better)	post-op 2 m	38.00 ± 10.16	33.00 ± 11.16	2.095	**0.0394***
	post-op 3 m	50.00 ± 8.13	45.00 ± 10.09	2.441	**0.017***
	post-op 6 m	60.00 ± 7.09	54.00 ± 9.14	3.282	**0.0016***
Note: indicates p < 0.05, denoting statistically significant differences					

3.3 Operative Time

The operative time in the modified stratified suture group was significantly longer than that in the en masse suture group (P < 0.001).

Table 3
Comparison of Operative Time Between the Two Groups

Indicator	Conventional Continuous Suture Group (n = 40)	Conventional Continuous Suture Group (n = 40)	*t-value*	*p-value*
Operative Time (min)	93.5 ± 7.0	79.5 ± 7.0	8.95	< 0.001**
Indicates: p < 0.05, denoting statistically significant differences.				

3.4 Imaging Results

All patients underwent MRI re-examination at 6 months postoperatively. MRI evaluation showed that the retear rate in the modified stratified suture group (2.5%) was lower than that in the en masse suture group (10.0%), although the difference was not statistically significant (P = 0.364). The mean repaired tendon thickness in the modified suture group was significantly greater than that in the en masse suture group (P = 0.038).

Table 4
Comparison of Imaging Evaluations Between the Two Groups at 6 Months Postoperatively

Imaging Parameters	Modified Layered Suture Group (n = 40)	En Masse Suture Group (n = 40)	*p*-value
Retear Rate [n (%)]	1 (2.5%)	4 (10.0%)	**0.364**
Repaired Tendon Thickness (mm)	6.03 ± 0.80	5.85 ± 0.70	**0.038***

Figure c: Comparison of preoperative and 6-month postoperative follow-up imaging

4. Discussion

Delaminated rotator cuff tear is a complex pathological subtype of full-thickness rotator cuff tear with a high clinical incidence, drawing considerable attention in sports medicine. It is reported that delaminated tears account for approximately 38% to 92% of all full-thickness rotator cuff tears[1]. The particularity of this tear pattern lies in the horizontal cleavage of the tendon parenchyma between the bursal and articular sides. This anatomical separation not only disrupts the overall continuity of the tendon but also leads to significant differences in fiber orientation, retraction direction, and tension distribution across layers.

An in-depth exploration of its anatomical basis reveals that the rotator cuff tendon is not a single homogeneous tissue but a composite structure composed of five layers with distinct histological characteristics. The second and third layers, as the main load-bearing structures, exhibit a crossed collagen fiber arrangement, which constitutes the anatomical predisposition for delamination to occur at this interface[3]. In delaminated tears, the articular (deep) tendon usually retracts much more severely than the bursal (superficial) tendon, with the deep layer often shifting posteromedially, while the superficial layer shows relatively mild medial retraction.[1]

This differential retraction pattern poses a significant challenge to traditional surgical repair. If the traditional en masse suture technique is used to pull and fix both layers as a single unit, it is often impossible to achieve anatomical reduction of the severely retracted deep tendon, resulting in uneven stress distribution and interlayer shear forces at the repair interface[15]. In response to this clinical problem, the modified stratified suture technique (MST) aims to resolve interlayer tension mismatch and optimize the tendon-to-bone healing environment through the composite strategy of “first anatomical reduction of each layer, then overall compression fixation.”

In terms of functional scores and pain management, the modified stratified suture technique demonstrated significantly better efficacy than the traditional en masse suture technique. The results of this study show that the modified group achieved significantly faster early postoperative functional recovery. Specifically, the ASES and UCLA scores in the modified group were significantly higher than those in the en masse group at 1, 2, and 3 months postoperatively, and the ASES score in the modified

group reached 88.50 ± 5.46at 6 months postoperatively, compared with 82.40 ± 6.82 in the en masse group (P < 0.001). The Constant score also showed a significant difference at 6 months (84.20 ± 6.59 vs. 80.10 ± 7.55, P = 0.0116). This trend is highly consistent with the findings of a meta-analysis by Shin et al[17]., which indicated that stratified repair offers significant advantages in short-term postoperative function (e.g., Constant score).

The early pain relief (VAS) observed in this study was particularly notable. The VAS score in the modified group was only 2.20 ± 0.56 at 1 month postoperatively, whereas that in the en masse group was as high as 3.90 ± 0.84 (P < 0.001), and the difference persisted until 3 months postoperatively. In contrast, a meta-analysis by Quan et al[3]. reported no significant difference in VAS scores between the two techniques (P = 0.84). This discrepancy may be attributed to the fact that the modified technique in this study performed independent mattress suture and fixation of the deep tendon, which not only accomplished anatomical reconstruction of the superior capsular complex and restored glenohumeral stability but also eliminated the interlayer cavity, thereby reducing mechanical stimulation of intratendinous nerve endings by synovial fluid.

Follow-up data showed that VAS scores in the two groups converged at 6 months postoperatively (0.50 ± 0.51 vs. 0.60 ± 0.50, P = 0.3751), further indicating that the advantage of the modified technique lies primarily in facilitating early painless rehabilitation, thereby leading to better long-term ROM outcomes (forward flexion at 6 months: (164.00 ± 8.10°vs. 156.00 ± 10.14°, P = 0.0002).

The imaging evaluation provides structural evidence supporting the superiority of the modified stratified suture technique, particularly in terms of retear rate and tendon thickness. The results showed that MRI at 6 months postoperatively confirmed a retear rate of only 2.5% (1/40) in the modified group, compared with 10.0% (4/40) in the en masse suture group, showing a trend toward a lower retear rate, although the difference was not statistically significant (P = 0.045). This extremely low retear rate is consistent with the findings of Okubo et al.[16], who reported that the stratified suture bridge technique significantly reduced retear rates in the treatment of large tears.

In terms of tendon thickness, the mean repaired tendon thickness in the modified group was 6.03 ± 0.80 mm, significantly greater than the 5.85 ± 0.70 mm in the en masse group (P = 0.038). This finding aligns with the results of a propensity score matching study by Kim et al.[18]. who also observed that the interlayer repair group achieved tissue recovery closer to the anatomical prototype (6.9 ± 1.1 mm vs. 6.0 ± 1.2 mm).

From a biomechanical perspective, the modified technique achieves better structural healing by eliminating interlayer shear forces. The initial independent reduction of the deep layer not only increases the contact area between the tendon and the bony bed but also optimizes the force vector, avoiding internal stress concentration caused by inconsistent retraction of the two layers in traditional full-thickness sutures. This “composite compression” configuration prevents localized thinning or the so-

called cheese-wiring effect, thereby promoting higher-quality tendon-to-bone healing at the microscopic level.[19]

In terms of clinical applicability and efficiency, although the operative time in the modified stratified suture group (93.5 ± 7.0 min) was longer than that in the en masse group (79.5 ± 7.0 min, $P < 0.001$, the additional time was primarily spent on precise deep-layer suturing, which helps reduce the risk of revision surgery. Previous literature has noted that prolonged operative time is mainly due to the accurate identification and independent suturing of the deep tendon, a refinement that is necessary to achieve a low retear rate in large delaminated tears.

In conclusion, for moderate-to-large delaminated rotator cuff tears, the modified stratified suture technique—based on “first anatomical reduction of each layer, then overall compression with suture bridge”—effectively addresses the tension mismatch between deep and superficial layers. Compared with traditional en masse suture, this technique yields better postoperative shoulder function, more significant pain relief, a lower retear rate, and superior imaging healing outcomes. Although the operative time is relatively longer, the structural healing advantages make it an ideal treatment strategy for such complex tears.[20]

However, this study has certain limitations. First, it is a retrospective study; although propensity score matching was used to reduce bias, inherent limitations of retrospective designs cannot be completely avoided. Second, the average follow-up period was short; the 6-month follow-up can only reflect early healing and functional recovery. Long-term clinical outcomes and tendon degeneration require further observation. Additionally, the modified suture technique requires a longer operative time and a higher level of arthroscopic skill.

Declarations

Ethics approval and consent to participate :

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study is a retrospective investigation. All data and biological specimens adopted are de-identified materials retained from routine clinical diagnosis and treatment. After review by the Ethics Committee of Leshan People’s Hospital, the study meets the criteria for waiver of informed consent, thereby exempting individual informed consent procedures for subjects. The entire research process strictly complies with the minimal risk principle, and the privacy and information security of subjects are effectively protected.

Consent for publication :

Not Applicable.

Competing interests :

The authors declare no competing interests.

Author Contribution

J.and L.wrote the main manuscript text . L.,Z. and D. participated in the surgical procedure. J. prepared figures .All authors participated in data collection and statistical analysis.W. and H. reviewed the manuscript.

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Data Availability

The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

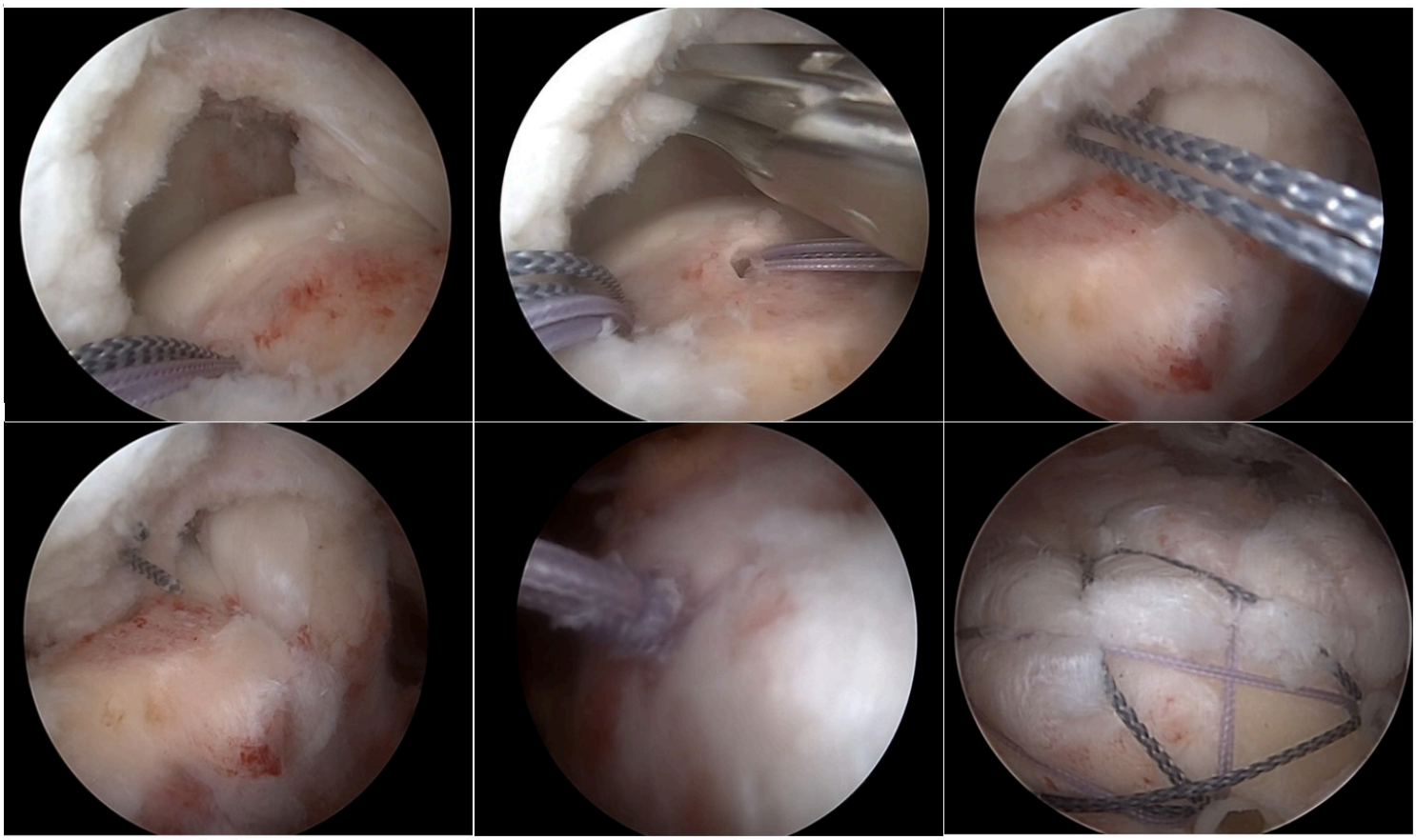


Figure 1

Figure a: (indicates superficial layer ▲ indicates deep layer) 1- Implantation of inner row rivets; 2- Deep layer independent reduction; 3- Knot tying for deep layer suture fixation; 4- Cutting the tail thread; 5- Completion of knot tying for overall fixation; 6- Fixation of remaining inner row suture tails



Figure 2

Figure b: Schematic diagram of improved layered suturing

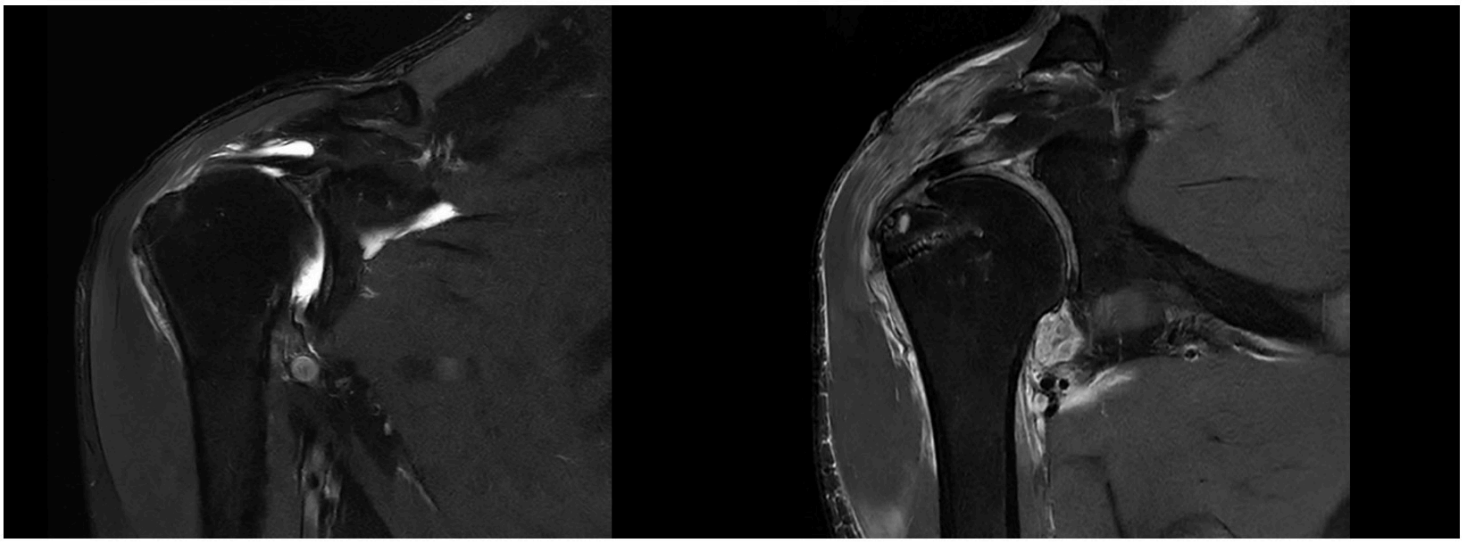


Figure 3

Figure c: Comparison of preoperative and 6-month postoperative follow-up imaging