# Clinical Outcomes and Repair Integrity after Arthroscopic Full-thickness Rotator Cuff Repair: Traditional Suture-bridge Versus Novel Modified Suture-bridge Technique

**Zengshuai Han**
The Affiliated Hospital of Qingdao University
**Wenru Ma**
The Affiliated Hospital of Qingdao University
**Dongfang Zhang**
The Affiliated Hospital of Qingdao University
**Yi Zhang**
The Affiliated Hospital of Qingdao University
**Chao Qi**
The Affiliated Hospital of Qingdao University
**Tengbo Yu** (ytb1970@126.com)
The Affiliated Hospital of Qingdao University

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# Abstract

**Background:** This prospective study compared the clinical and radiologic outcomes of patients who underwent arthroscopic rotator cuff repairs by the traditional suture bridge technique and the modified suture bridge technique.

**Methods:** From December 2018 to December 2019, 50 consecutive cases of full-thickness medium rotator cuff tear, 1 to 3 cm in the coronal plane, for which arthroscopic rotator cuff repair was performed, were included. The TSB technique was used in 24 consecutive shoulders; and the MSB technique, in 26 consecutive shoulders. Clinical outcomes at 3 months, 6 months and a minimum of 1 years (mean, 11.92±1.92months) were evaluated postoperatively using range of shoulder, the visual analog scale score; University of California Los Angeles Shoulder Scale score; Constant-Murley shoulder score and American Shoulder and Elbow Surgeons Subjective Shoulder Scale score. All patients underwent preoperative MRI and B-US to identify the rotator cuff tear, and postoperatively at final follow-up to evaluate tendon integrity.

**Results:** At the final follow-up, the clinical outcomes improved in both groups. There were no significant differences in the results of the ROM between the two groups at 3 months, 6 months and the final follow-up. The average VAS score decreased from 6.12±0.95 to 1.04±0.45 in MSB Group and decreased from 6.29±0.91 to 1.33±0.48 at the final follow-up in TSB Group. The VAS score significantly differed between the two groups only at the final follow-up ($P$=0.03). The mean UCLA score increased from 12.23±3.47 to 30.96±2.54 in MSB Group and increased from 11.50±4.00 to 28.79±4.47 in TSB Group at the final follow-up; the mean Constant shoulder score increased from 40.54±5.61 to 92.08±7.21 in MSB Group and increased from 41.79±5.51 to 86.96±8.42 in TSB Group at the final follow-up. The average ASES score increased from 36.04±2.47 to 96.04±7.28 in MSB Group and increased from 35.04±3.10 to 91.50±7.33 in TSB Group at the final follow-up. The UCLA ($P$=0.044), Constant ($P$=0.025), ASES ($P$=0.033) score significantly differed between the two groups only at the final follow-up. At the final follow-up postoperatively, the MRI assessments showed no retear in MSB Group and two retears in TSB Group (8%) ($Z$=-1.538, $P$=0.124), B-US assessments showed no retear in MSB Group and one retear in TSB Group (4%)($Z$=-1.169, $P$=0.242). No significant difference was found between the 2 groups regarding cuff integrity in accordance with MRI assessments and B-US assessments

**Conclusion:** For medium-sized RCTs, the patients who underwent MSB repair had shown better shoulder functional outcomes and a lower but not significant re-tear rate with those who underwent TSB repair. Therefore, the MSB repair technique can be considered an effective treatment for patients with medium-sized full-thickness RCTs.

**ClinicalTrials.gov Identifier: NCT04825249**

**Level of evidence:** A prospective study, Level II.

# Background

Rotator cuff tears (RCTs) account for 22.1% of all shoulder injuries in older subjects[1]. Several arthroscopic techniques, including single-row and double-row methods, can be used to treat RCTs. In an effort to improve the biomechanics of rotator cuff repair constructs, suture bridge (tranosseous-equivalent) technique has been proposed and recently become a popular method for rotator cuff repair, which aim is to restore the natural anatomy and stability. However, the reported re-tear rates after repair remain remarkably high (10–36%)[2-6].

In the traditional knotted suture bridge (TSB) technique, medial row sutures are usually tied before bridging with lateral row anchors[3] [7-8]. Although this overcomes some of the shortcomings of single- and double-row repairs, increasing the contact area of the cuff footprint[9-11], reducing knot impingement, and narrowing the gap between the cuff and humeral head[12-13], the repair remains controversial. Several studies have shown that TSB repair triggers a unique re-tear pattern in the medial row, possibly because a tension overload disturbs the microcirculation[14-16], This has encouraged the development of a knotless suture bridge repair without medial row knot-tying, which not only avoids stress concentration at the medial row but also further increases tendon coverage in the footprint area and more evenly distributes tension at the bone-tendon contact surface[17-18].

However, the connection between the lateral row and bone is the only foundation of the knotless suture bridge. If the suture limbs loosen, or osteoporosis loosens the lateral row, loss of compression with the lateral aspect of the cuff tendon against the bone would occurred[19]. Thus, suture bridge repair procedures continue to evolve as instruments and related techniques improve. We have been combined the knotted suture bridge with the knotless suture bridge technique through two tendon sutures and refer to this procedure as a new modified suture bridge (MSB) technique.

The purpose of this prospective study was to evaluate the clinical and radiological outcomes after MSB repair. We hypothesized that this new technique would yield better radiological outcomes, with a reduced failure rate, compared with TSB repair wherein medial row knot-tying is bridged with lateral row fixation.

## Methods

# Study population

This study was prospective and included 60 consecutive patients with medium full-thickness RCTs who were treated with the TSB or MSB technique in our institute between December 2018 to December 2019. Of the 60 patients, 10 (17%) were lost to follow-up before 1 years after surgery, missed the radiologic evaluation at 1 year after surgery, or refused to participate in this study. The patients who met the inclusion criteria were assigned according to a table of random numbers to one of two groups depending on the surgical repair technique. The TSB technique was used in 24 of 30 consecutive shoulders and the MSB technique was used in 26 of 30 consecutive shoulders. All the surgeries were performed by the same surgeon. The study was approved by the local ethics committee (QYFYWZLL26271). Both verbal and written informed consent were obtained by all participants. We prospectively followed up the patients.

The medium-sized RCTs were preoperatively diagnosed by magnetic resonance imaging (MRI) and the tear was identified and included in our research through direct intraoperative arthroscopic exploration (Fig.1). The inclusion criteria were (1) 1- to 3-cm tears in either the coronal plane, measured and confirmed intraoperatively, (2) failure of 3-month conservative treatment, (3) and completion of the 12-month follow-up with adherence to the rehabilitation plan. According to the classification of DeOrio and Cofield[20], tears with an anterior-to-posterior length of less than 1 cm, 1 to 3 cm, 3 to 5 cm, and greater than 5 cm were categorized as small, medium, large, and massive, respectively

The exclusion criteria were (1) history of an operation on the same shoulder; (2) any other pathological change that required attention during arthroscopic surgery (an RCT involving the subscapular tendon and biceps tendon injury); (3) and failure to follow the postoperative rehabilitation protocol and/or a lack of regular follow-up; (4) full-thickness supraspinatus tears with an anterior-posterior dimension of less than 1 cm or greater than 3 cm; (5) workers' compensation claims.

# Surgical procedures

All procedures were performed with patients in the lateral supine position under general anesthesia. A shoulder traction device (Spider 2; Smith & Nephew, Andover, MA, USA) was used to maintain the arm in 20° of flexion and 30° of abduction. A posterior portal was established for initial assessment of the joint. An anterior portal through the rotator interval was established as the working portal for intra-articular debridement. Posterior and posterolateral portals were used mainly for the standard 30 angled 4-mm arthroscope (the viewing portals), whereas anterior and anterolateral portals were used for the instruments (the working portals). After acromioplasty, adequate visualization, preparation, and tendon release, the upper surface of the greater tuberosity was widely abraded with a shaver; all soft tissue was removed to create a bleeding cancellous bone bed. Then, 1 4.5-mm bioabsorbable anchor (Smith & Nephew,USA) loaded with 2 No. 2 nonabsorbable braided sutures, was inserted in the medial side of the cuff footprint of the humeral head (medial row).

For the TSB repair, 4 suture limbs from the medial anchor were passed through the torn tendon using a Scorpion suture passer (Arthrex), and the limbs were tied in a horizontal mattress fashion to form 2 knots. To establish the lateral row, the suture limbs of the medial-row anchor were crossed over the tendon and fixed laterally by 1 knotless anchor (4.5-mm Bio-PushLock; Arthrex, USA). Lateral anchors were then inserted perpendicular to the cortical surface of the humerus 5 to 10 mm distallateral to the lateral edge of the greater tuberosity. The free suture tails were totally appressed to the side of the tendon synovial bursa (Fig. 2) (Fig. 4a).

For the MSB group, we created a new lateral portal; the Scorpion suture passer (Arthrex) with a No. 2 polydioxanone suture (PDS2) was passed through the torn tendon through the new lateral portal. The suture gripper was used to pull out the PDS2 and 1 limb of the medial anchor suture through the anterolateral portal, and the limb and tendon suture tail were tied to the PDS2. The PDS2 was then pulled out through the original portal, the anchor and tendon suture limbs thus passed together through the torn tendon in the articular-to-bursal direction (Fig. 3a). For the second passage, the Scorpion suture passer (Arthrex) with a PDS2 was passed through the cuff and another tail of the tendon suture and the unpassed limb of the medial anchor suture were retrieved through the lateral portal using the method described above (Fig. 3b). We repeated the above steps until 2 limbs of the second anchor suture and the second tendon suture passed together through the torn tendon (Fig. 3c). The medial-row suture limbs were temporarily untied. Before tying of the horizontal mattress stitch in the medial row, the 4 free limbs of the 2 tendon sutures pulled the torn tendon back to footprint and were fixed to the lateral aspect of the greater tuberosity using a lateral row. The limbs of the tendon sutures were separated and appressed to the side of the tendon synovial bursa (Fig. 3d). After confirming that the tension was sufficient and fixation was stable, the 2 sutures of the medial row were knotted and the free tails were cut off (Figs. 3e) (Fig. 4b).

# Clinical outcome evaluation

Evaluation indexs were monitored from the preoperative period until 12 months after operation by two independent observers. Range-of-motion was assessed through the shoulder turntable measuring instrument preoperatively and at 3, 6, and 12 months postoperatively. Clinical outcomes were evaluated with the visual analog scale (VAS) score for pain, University of California–Los Angeles (UCLA) score, Constant-Murley shoulder score and American Shoulder and Elbow Surgeons (ASES) score for functional outcomes in the form of a questionnaire preoperatively and at 3, 6, and 12 months postoperatively.

# Imaging studies

The routine preoperative diagnostic examinations included shoulder radiographs (anteroposterior, true anteroposterior, and axillary views), MRI, and B-US. Routine postoperative MRI and B-US were performed at 12 months postoperatively. Oblique coronal, oblique sagittal, and axial views were obtained with a 3.0-T MRI unit (Siemens Medical Solutions, Erlangen, Germany) and evaluated by a radiologist.

Rotator cuff integrity was evaluated with MRI using the radiographic grading criteria of Sugaya et al[21]. Grade I and II: RCTs have sufficient cuff thickness; grade III: RCTs have insufficient cuff thickness without discontinuity; and grade IV and V: RCTs have cuff discontinuity suggesting small tears and large tears, respectively. Rotator cuff integrity was evaluated by 3 sports medicine surgeons and was determined by a majority consensus.

Rotator cuff integrity was evaluated on B-US using the grading system proposed by Barth[22] et al as follows: grades I and II, sufficient thickness of >2 mm; grade III, insufficient cuff thickness of <2 mm without discontinuity; and grades IV and V, presence of discontinuity suggesting small and large tears, respectively.

# Postoperative rehabilitation

Postoperative rehabilitation was achieved equally for both groups. Routine postoperative outpatient follow-up visits were conducted at 2 weeks; 6 weeks; and 3, 6 and 12months postoperatively. In the first 4 to 6 weeks, shoulder immobilization was maintained with an abduction brace that limited internal rotation of the affected arm to 30° to 40° and abduction to 30°. Active elbow flexion and extension, active forearm supination and pronation, and active hand and wrist motions were encouraged on day 1 postoperatively. After 4 to 6 weeks, the brace was removed and therapist-supervised active and passive ROM was initiated. After 3 months, active resistance musclestrengthening exercises were begun. From the sixth month, full use of the shoulder was permitted.

# Statistical analysis

All results are expressed as mean ± standard deviation. The reliability of postoperative indexs were tested by the intraclass correlation coefficient with the 95% confidence interval, which was used to evaluate the reproducibility of measurements. An intraclass correlation coefficient of 0.80-1.00 was considered excellent agreement; 0.60-0.79, good agreement; 0.40-0.59, moderate agreement; 0.20-0.39, weak agreement; and 0.00-0.19, no agreement. Normality tests (Kolmogorov-Smirnov test and Shapiro-Wilk test) were used to determine whether all measurement data were in accordance with a normal distribution. Preoperative and postoperative range of shoulder motion and clinical scores were compared by paired t tests. Postoperative outcome scores were compared between groups using analysis of variance and independent-samples t test. For the cuff integrity grade distribution on MRI and B-US, rank sum test was used for statistical analysis. All of the contrasts were considered significant when $p < 0.05$. The data were processed and analysed using the SPSS (IBM) v.25 program.

## Results

# Preoperative demographic characteristics

A total of 50 patients were included (Table I); The MSB technique was performed in 26 patients (52%), whereas the TSB technique was performed in 24 (48%). The reproducibility for inter-reliabilities was excellent; the data are presented in Table II. In total, The average age of the patients was 59.04±9.54 years. There were 16 men (10 in the TSB Group and 6 in the MSB Group) and 34 women (14 in the TSB Group and 20 in the MSB Group). The average body mass index (BMI) was 25.50±2.64 kg/m^2 and the average size of the tear was 2.67± 0.36 cm. There were 32 right (15 in the TSB Group and 17 in the MSB Group) and 18 left (9 in the TSB Group and 9 in the MSB Group). The average symptom duration of the patients was 6.00±0.80 months and the average follow-up time was 11.92±1.92 months. No significant differences were found in preoperative abduction, forward flextion, external rotation, VAS, UCLA , Constant and ASES scores. There were no significant differences between the TSB and MSB groups regarding the demographic characteristics.

# Functional outcomes

All patients were followed up at 3, 6 and 12 months postoperatively. The overall postoperative ROM and scoring systems indicated significant improvements in both the TSB and MSB groups at final follow-up. The mean ROM and scores in the 2 groups at the same follow-up time points are shown in Figure 5 and Figure 6. There were no significant differences in the results of the ROM between the two groups at 3 months, 6 months and final follow-up. The VAS score significantly differed between the TSB and MSB groups at final follow-up postoperatively ($P$=0.03) but not at 3 months ($P$=0.181) and 6 months ($P$=0.228) postoperatively. Similarly, the UCLA ($P$=0.044), Constant-Murley shoulder ($P$=0.025), and ASES ($P$=0.033) scores at final follow-up postoperatively significantly differed between the TSB and MSB groups. However, these scores did not significantly differ between the 2 groups at 3 and 6 months postoperatively (all comparative data, $P > 0.050$; Fig. 5, Fig. 6).

# Radiological outcomes

In MSB group, 21 cuffs were classified as grade I or II, 5 were classified as grade III,  there were no type IV or V retears detected on MRI. In TSB group, 15 cuffs were classified as grade I or II, 7 were classified as grade III and there were 2 grade IV or V retears. There were no significant differences between the 2 groups in accordance with the Sugaya grading system ($Z$=-1.538, $P$=0.124) (Table III).

Cuff integrity evaluated on B-US in the MSB and TSB groups is shown in Table IV. There were no significant difference between the 2 groups regarding cuff integrity in accordance with the Barth grading system ($Z$=-1.169, $P$=0.242).

## Discussion

This study evaluated the clinical and radiologic results of arthroscopic repair with the TSB or MSB technique in patients with medium-sized full-thickness rotator cuff tears. Both groups afforded satisfactory postoperative clinical outcomes. Our research did not show any significant differences in the range of shoulder motion at 3, 6, 12 months postoperatively. Similarly, functional scores did not show any difference between 3 and 6 months postoperatively, and only at 12 months postoperatively did MSB repair perform better than TSB repair. Radiologic outcomes were determined by evaluating for retears on MRI and B-US. The retear rates in the MSB group was lower than that in the TSB group (8%/4%). However, the difference was not significant. The superiority of MSB repair of rotator cuff arthroscopic reconstruction could not be established with certainty except better shoulder function. This might be limited by the sample and the final time of follow-up we followed.

Current suture-bridge methods include the knotted suture bridge (TSB) and knotless suture bridge. The suture-bridge technique is known to improve biological healing by enhancing footprint coverage, reducing gap formation, and increasing ultimate load to failure by equally distributing pressure on the footprint[23]. On the basis of these theoretical benefits, the suture-bridge technique is currently widely used in arthroscopic rotator cuff repair, but the retear rate has varied among studies[3] [8] [24–25]. Frank et al[24]reported a retear rate of 12% for the traditional suture-bridge technique and asserted that their study showed a better outcome than other studies. However, their study was limited with regard to the small sample size and small-sized tears mainly included. Boyer et al[26] compared the functional and structural outcomes of knotted and knotless suture-bridge techniques and the re-tear rate trended to be higher in knotted repair (23.4%) than in knotless repair(17.1%). Similarly, Hirokazu Honda et al[27] compared arthroscopic suture bridging with and without medial tying, the number of incompletely healed tendons in suture bridge with medial tying was significantly larger at 24 months after surgery. In addition, in a study by Christoforetti et al[14] that measured blood flow in repaired rotator cuffs in patients who received the TSB repair, blood flow decreased significantly (44.6%) after the completion of the construct with lateral anchors. This phenomenon is representative of the weakness of TSB repair because reduced blood flow can lead to tissue necrosis and produce medial cuff failure. Several studies have called this new type of tear "medial re-tear"[28–29]. In addition, marginal dogear deformities on repaired rotator cuffs are common as seen in our TSB repair series. These deformities, caused by excessive compression of the lateral row, may induce insufficient healing by causing gap formation at other cuff sites and poor coverage of the footprint[30]. In our study, the retear rate was higher in the TSB group (8%, 2 of 24) than in the MSB group. To reduce repair failure of TSB repair, Rhee and colleagues[31] reported a knotless suture-bridge technique, which showed a lower retear rate than the TSB technique. However, according to a recent study that used 11 pairs of fresh-frozen cadaveric shoulders (22 specimens), the footprint contact area and interface pressure were lower in the knotless suturebridge group than in the TSB group[32]. Another disadvantage of knotless suture-bridge repair is that as all fixation tension is borne by the lateral row, there is a risk of anchor pullout. In addition, medial footprint leakage has been reported when the medial sutures are untied. Nassos et al[33] identified the type of rotator cuff repair that best isolated the healing zone interface from synovial fluid in vitro. They found that the in vitro, tied, suture-bridge repair technique best prevented leakage onto the rotator cuff footprint compared to knotless repairs. Therefore the optimal arthroscopic repair technique for rotator cuff tears is still controversial.

For the drawback of knotless and knotted repair, our new MSB technique forms a bridge between the medial and lateral rows via two tendon sutures. It can be viewed as a combination of knotted and knotless suture bridging, characterized by bridging suture startpoints that are transferred from knots to the hole which the suture-passing instruments and suture materials entered on their way through the tendons. The MSB technique is beneficial because it evenly distributes the force on the bursa side of the tendon, resulting in better tendon attachment, as well as increased contact area for healing by restoring a wider footprint. In other words, it eliminates 'dog ear' deformities, evenly increasing better footprint compression to help promote healing (disadvantage of knotted suture bridge technique). In addition, by providing two knots of medial-row, the biomechanical strength of fixation and the intensity of the repair construct are increased, and reduce the stress on the suture-cuff point. Meanwhile, the medial knots also show smallest gap formation and prevent synovial fluid leakage in the medial area.(disadvantage of knotless suture bridge technique). Many studies have shown that when the contact area is maximized and mechanical stability ensured at the healing interface, clinical function is improved and the re-tear rate is significantly reduced[34–37]. To our knowledge, no studies have demonstrated this novel suture bridge technique and evaluated its clinical outcomes and biomechanical advantages. Our study was based on the hypothesis that compared with TSB method, the MSB technique would result in greater biomechanical strength and a larger footprint area after restoration of the repaired rotator cuff, which would lead to increased biological healing, thereby reducing the retear rate. This technique showed a lower retear rate than the TSB technique, though not significantly.

Furthermore, the steps of operation also solved the “medial re-tear” characteristic of TSB repair. We believe that the medial knot-tying after suture-bridge lateral row repair contributed to decreased stress concentration to the medial row sutures. If medial row sutures are tied before suture-bridging, bidirectional forces may be applied to the medial row sutures: cuff muscles apply a force in the medial direction, and suture-bridging applies a force in the lateral direction. In MSB technique, the tension of the repaired cuff is initially controlled via lateral anchor. After the lateral anchor pierces the great tubercle of the humerus, the medial knots do not add extra tension during anatomical reduction, thus avoiding strangulation and subsequent necrosis of the tendon at the medial row. Yasutaka Takeuchi[38] et al explored medium tear repair integrity when performing medial knot-tying after suture-bridge lateral row repair. Two medial anchors featuring 3 No. 2 high-strength sutures were placed, two of which were incorporated into a knotless bridge and then the other was knotted. The repair failure was lower than that of the TSB repair, which is consistent with our findings. Our strengths are, for medium tears, this MSB repair replaces a medial anchor with two tendon sutures. This not only reduces the tendon damage caused by suture instruments, but also the cost and surgical difficulty of surgery. We may need biomechanical studies to elucidate the differences between the forces applied to medial row sutures in TSB technique and MSB technique.

Our study had several limitations. First, despite the prospective design, the number of patients was small and the follow-up was short. Second, since this is our new refinement of the suture bridge repair, there is a lack of biomechanical datas and evidence on the molecular level of tendon healing, which is our further study. Third, confounders such as acromioplasty, synovectomy, and metabolic factors may have influenced the results. Finally, bias cannot be entirely ruled out, although all dates were performed twice by highly experienced experts.

# Conclusion

The two techniques provided satisfactory clinical outcomes in the patients with symptomatic medium-size full-thickness RCTs. The shoulder functional outcomes were better and retear rates were lower but not significant in the patients who underwent MSB repair, compared with those of the patients who underwent TSB repair. Longer follow-up is needed to confirm the potential differences between the two techniques. Therefore, the MSB repair technique can be considered an effective treatment for patients with medium-sized full-thickness RCTs.

## Abbreviations

TSB: traditional suture bridge; MSB: modified suture bridge; RCTs: rotator cuff tears; VAS: visual analog scale; UCLA: University of California–Los Angeles; ASES: American Shoulder and Elbow Surgeons

## Declarations

# Ethics approval and consent to participate

This research was approved by Ethics Committee of Qingdao University Hospital. Informed consent was obtained from all individual participants included in the study.

# Consent for publication

Written informed consent was obtained from the patients for publication of this research and any accompanying images.

# Availability of data and materials

The final dataset will be available from the corresponding author.

# Competing interests

The authors declare that they have no competing interests

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# Authors' contributions

ZSH and YZ contributed to the study conception and design. ZSH and WRM contributed to the data collection and analysis. Material preparation were performed by ZSH, WRM and DFZ. The first draft of the manuscript was written by ZSH, TBY and CQ commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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# Tables

Table 1

Preoperative Demographic Data

| | The MSB Group(n=26) | The TSB Group(n=24) | *P* value |
|---|---|---|---|
| Age, yr | 60.65±8.99 | 57.29±9.98 | 0.216 |
| BMI, kg/m^2 | 25.21±2.47 | 25.81±2.82 | 0.432 |
| Size of tear,cm | 2.64±0.38 | 2.70±0.33 | 0.554 |
| Sex, female/male | 20/6 | 14/10 | 0.371 |
| Side of involvement, | | | |
| Right/Left | 17/9 | 15/9 | 0.832 |
| Symptom duration, mo | 6.1±0.8 | 5.9±0.83 | 0.489 |
| Time of follow-up，mo | 11.53±1.67 | 12.33±2.09 | 0.144 |
| Preoperative Shoulder ROM | | | |
| Abduction, | 88.54±28.54 | 75.63±31.25 | 0.133 |
| Forward flextion, | 96.12±21.14 | 103.25±30.03 | 0.333 |
| External rotation, | 28.92±11.32 | 23.13±11.96 | 0.085 |
| Preoperative Functional Scores | | | |
| VAS score | 6.12±0.95 | 6.29±0.91 | 0.507 |
| UCLA score | 12.23±3.47 | 11.5±4.00 | 0.492 |
| Constant score | 40.54±5.61 | 41.79±5.51 | 0. 430 |
| ASES score | 36.04±2.47 | 35.04±3.10 | 0.213 |

Table 2 Reliabilities of range of shoulder motion, VAS, ASES, CS, and UCLA scores

| | First vs. second assessment by the examiner | |
|---|---|---|
| | ICC | 95% CI |
| Abduction | 0.899 | 0.826-0.942 |
| Forward Flexion | 0.922 | 0.802-0.963 |
| External Rotation | 0.885 | 0.805-0.933 |
| VAS Score | 0.920 | 0.863-0.954 |
| UCLA Score | 0.930 | 0.880-0.960 |
| Constant Score | 0.935 | 0.888-0.962 |
| ASES Score | 0.888 | 0.811-0.935 |

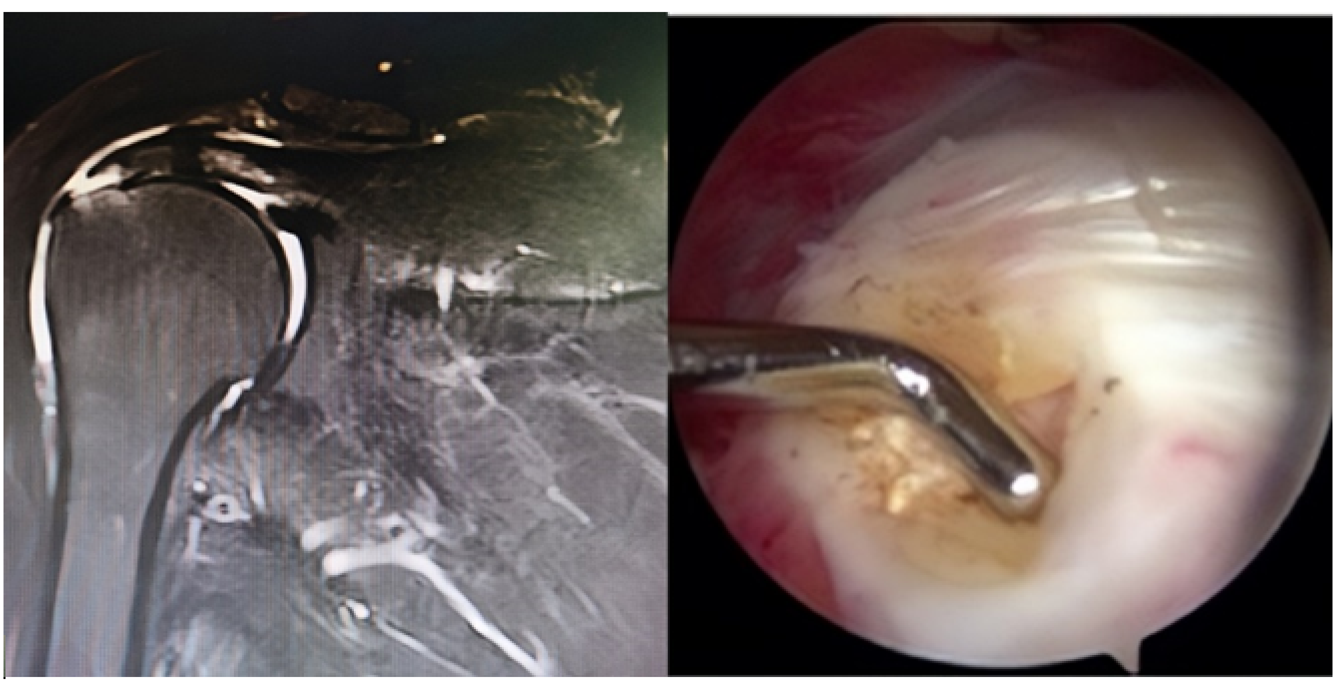
Table 3 Cuff integrity grade distribution at 12 months follow-up

| | Sugaya MRI grade | | | | *Z* value | *P* value |
|---|---|---|---|---|---|---|
| | n | I or II | III | IV or V | | |
| The MSB repair | 26 | 21 | 5 | 0 | -1.538 | 0.124 |
| The TSB repair | 24 | 15 | 7 | 2 | | |
| Total | 50 | 36 | 12 | 2 | | |

Table 4. Cuff integrity grade distribution at 12 months follow-up

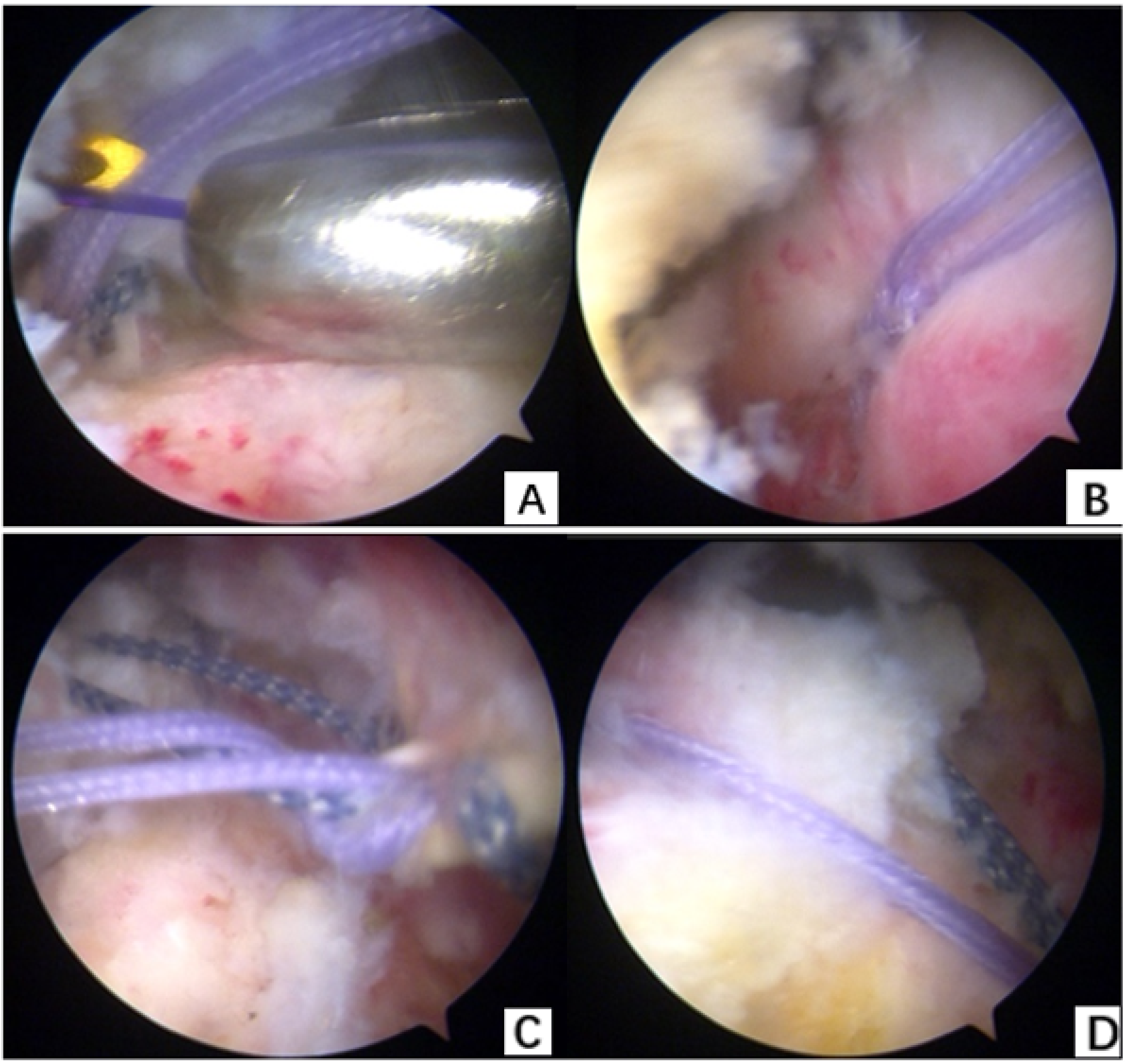
| | Barth B-US grade | | | | *Z* value | *P* value |
|---|---|---|---|---|---|---|
| | n | I or II | III | IV or V | | |
| The MSB repair | 26 | 20 | 6 | 0 | -1.169 | 0.242 |
| The TSB repair | 24 | 15 | 8 | 1 | | |
| Total | 50 | 35 | 14 | 1 | | |

## Figures



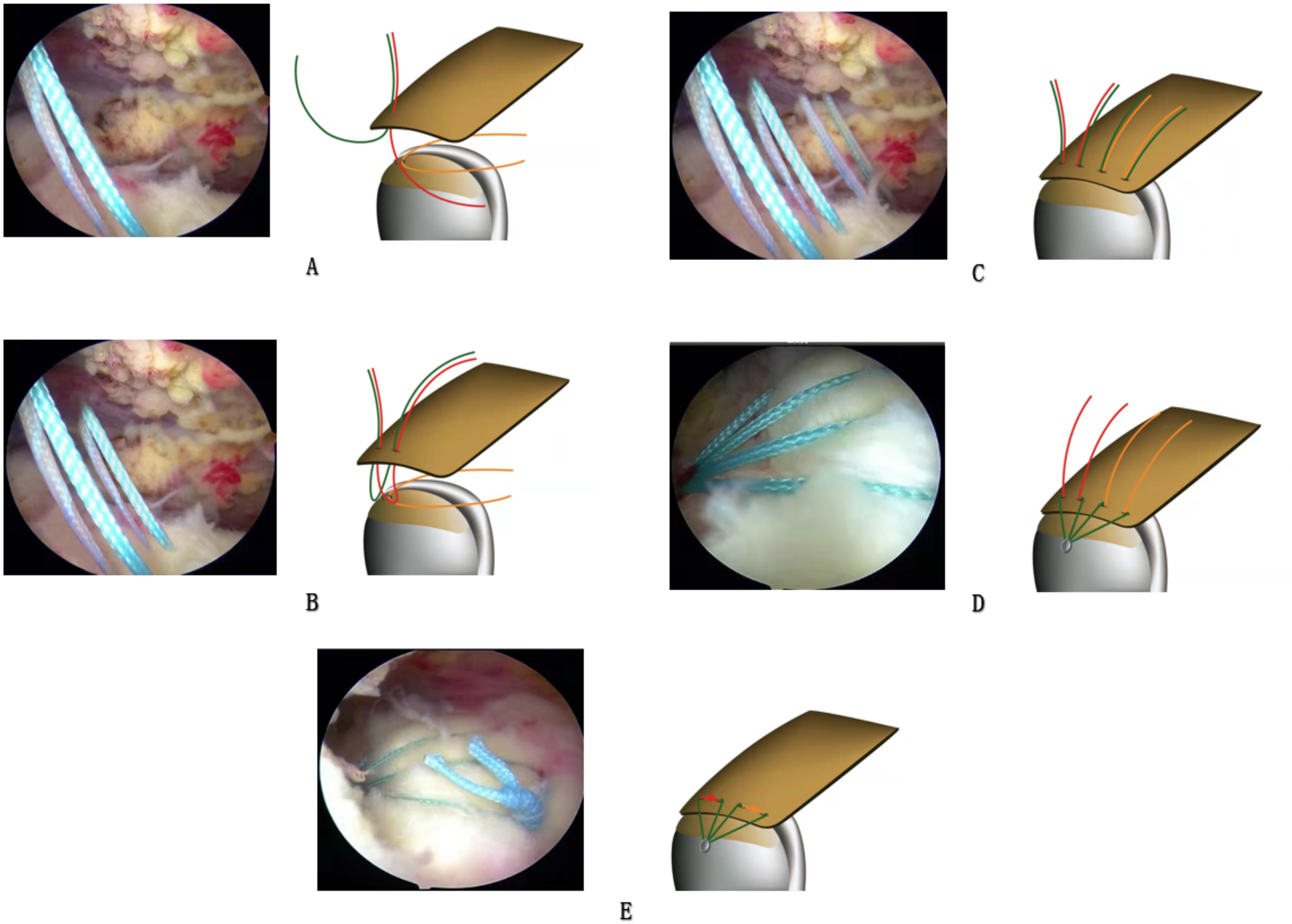
## Figure 1

The medium-sized RCTs were preoperatively diagnosed by magnetic resonance imaging (MRI) and the tear was identified and included in our research through direct intraoperative arthroscopic exploration (Fig.1).




## Figure 2

The TSB repair: (A) Limbs of sutures from the medial row were passed through torn tendon (B) the suture limbs were tied in a horizontal mattress suture pattern (C) the lateral row pressed the free tails of the knotted suture on the greater tubercle of the humerus (D) the effect after completion of the TSB repair




### Figure 3

The MSB repair: (A) one limb of anchor suture and tendon suture tail pass through the tore tendon together (B) another tail of the tendon suture and unpassed limb of medial-row suture pass through the cuff (C) repeated the above steps (D) The limbs of 2 tendon sutures were scattered and pressurized on the side surface of the tendon synovial bursa (E) After confirming that the tension was sufficient and fixation was stable, the 2 sutures of the medial row were knotted and the free tails were cut off

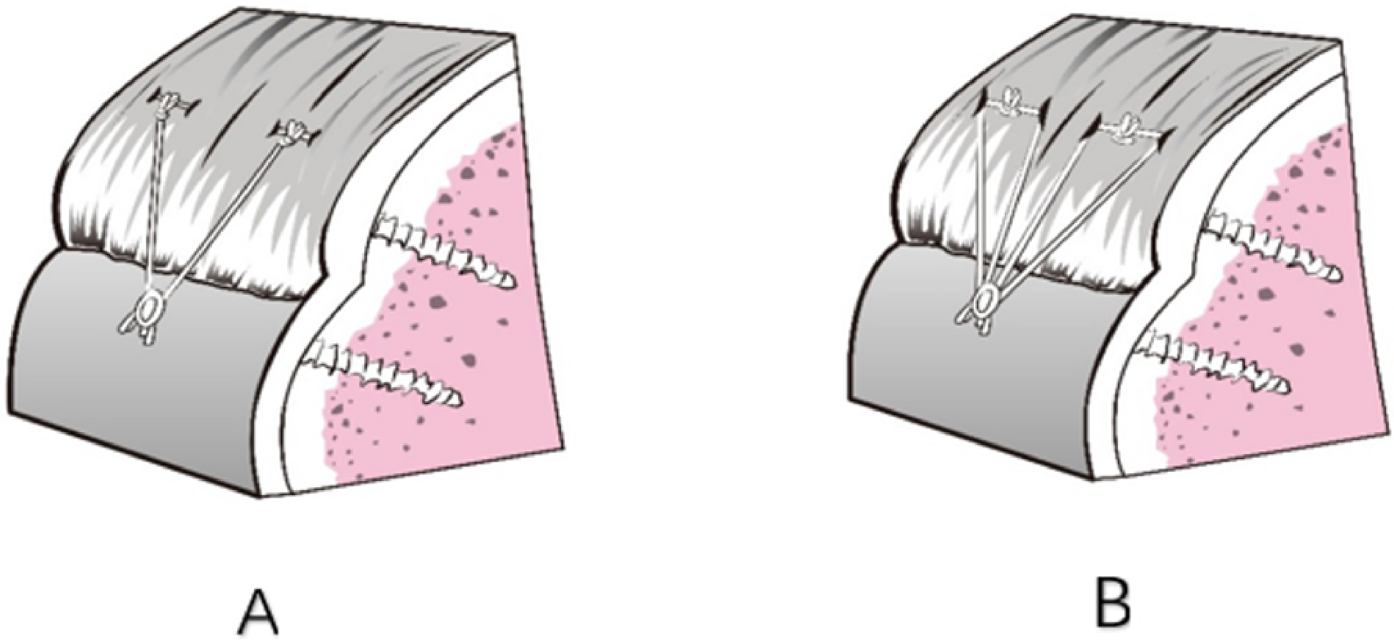
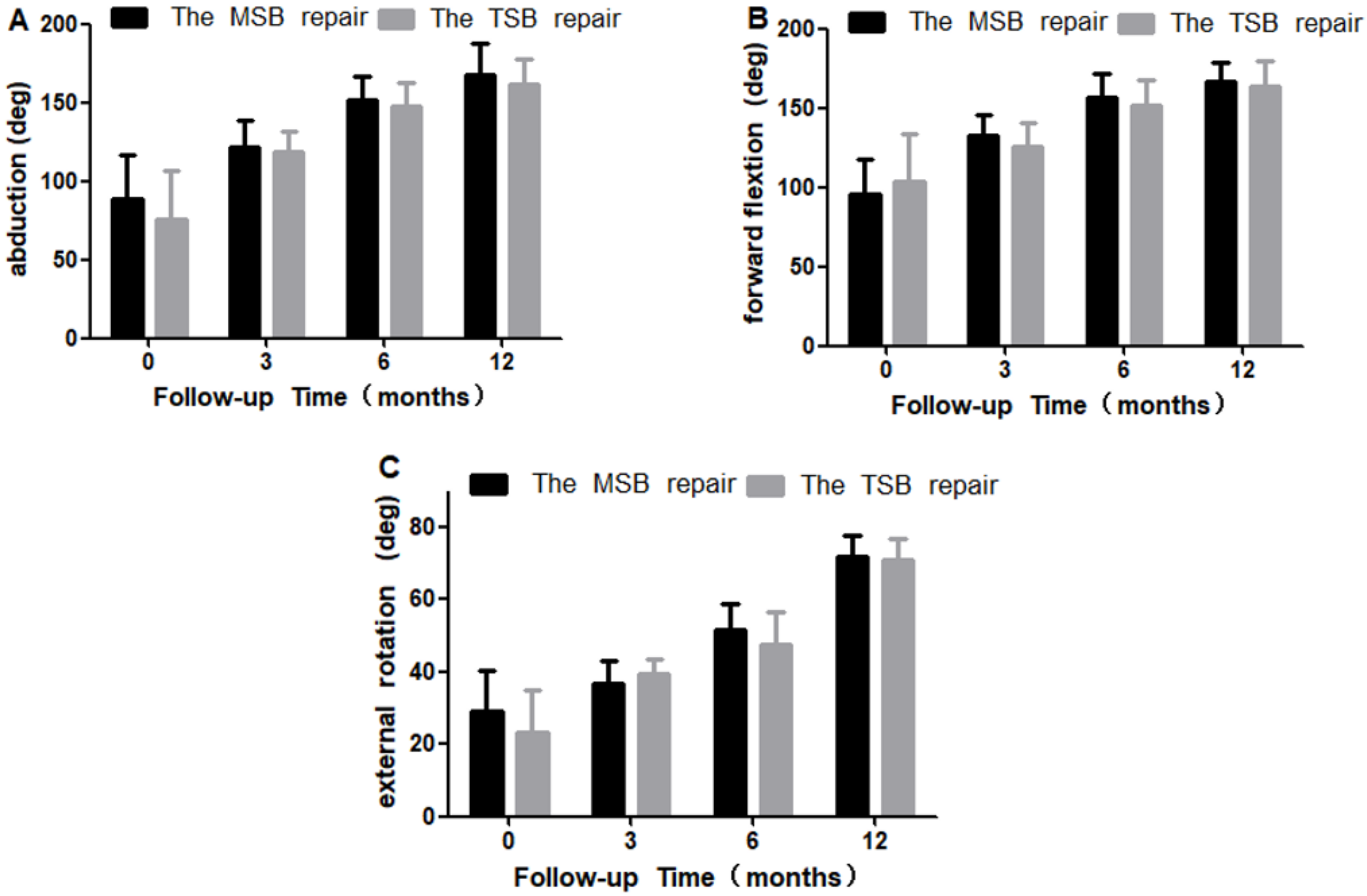


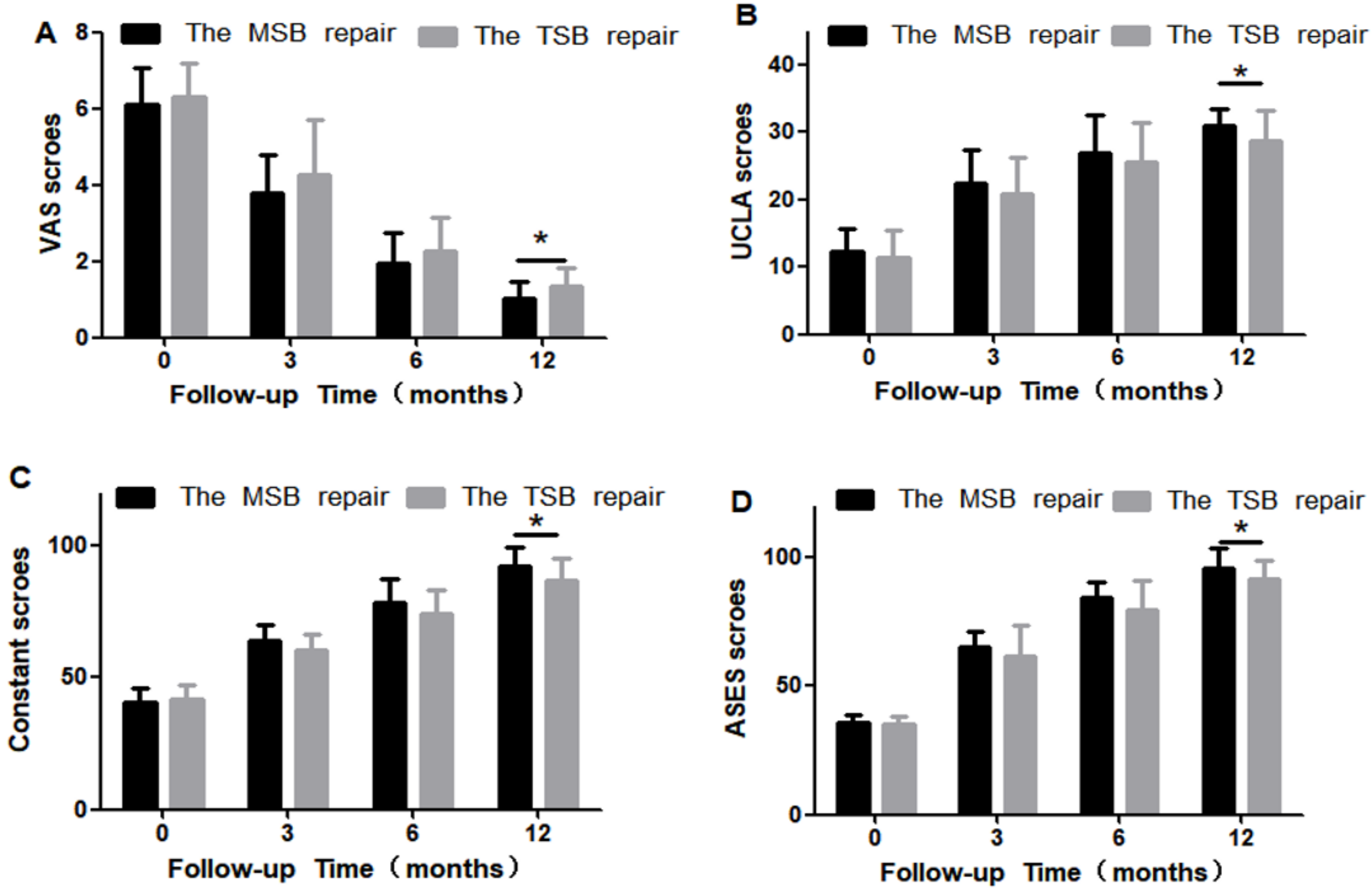

**Figure 4**

(A) Traditional suture bridge technique, (B) Modified suture bridge technique




## Figure 5

(A) The range of abduction (B) forward flexion (C) external rotation preoperatively and at 3, 6, 12 months after MSB and TSB repairs. No statistically significant differences were found.




## Figure 6

(A) VAS score (B) UCLA score (C) Constant score (D) ASES score preoperatively and at 3, 6, 12 months after MSB and TSB repairs. *Significant difference (P <0 .05).