SAS Journal of Surgery
Abbreviated Key Title: SAS J Surg
ISSN 2454-5104
Journal homepage: https://www.saspublishers.com

OPEN ACCESS

Orthopaedics

Is the Shoestring Bridge Technique an Effective Option to Treat Massive Rotator Cuff Tears?

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DOI: https://doi.org/10.36347/sasjs.2024.v10i12.007 | **Received:** 01.11.2024 | **Accepted:** 05.12.2024 | **Published:** 10.12.2024

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Abstract **Original Research Article**

***Objective*:** Numerous surgical strategies have been proposed to treat non-arthritic irreparable massive rotator cuff tears and the comparative efficacy of these treatments remains unclear. The purpose of our study is to clarify the role of this type of repair. ***Methods*:** We report the medium-term clinical outcomes of a retrospective study that includes 21 patients submitted to an arthroscopic side-to-side repair technique in the configuration of a shoestring using one single suture anchored to the tendon footprint, for large and retracted posterosuperior rotator cuff tears. ***Results*:** All the range of motion measurements have significantly improved after surgery, except external rotation. A mean Constant score of 68.8 was obtained (SD 15.46). Both functional scores (QuickDASH and ASES) have improved significantly (QuickDASH Z = -3.877, p = .001; ASES Z = -4.016, p = .001). The absence of symptomatic improvement was defined as failure and a rate of 20.8% was found. ***Conclusions*:** According to our findings, this technique can offer good results in terms of range of motion and functional scores. It should be seen as an effective option for large and retracted posterosuperior rotator cuff tears in which an anatomic primary repair cannot be achieved. Other advantages are its low potential for complications, low cost and not compromising future treatment options that may be required in case of failure.

Keywords: Arthroscopy, Massive Rotator Cuff Tear, Shoestring Suture.

INTRODUCTION

Rotator cuff tears (RCT) are a challenging and prevalent [1], condition with approximately 54% of individuals over the age of 60 having a partial or complete RCT [2]. Most RCT tend to be chronic and evolutive [3], ultimately leading to an irreparable tear.

The concept of an irreparable tear should be clarified and distinguished from a massive rotator cuff tear (MRCT) because they are often misused. Not all MRCTs are irreparable, and not all irreparable tears are MRCTs, although the latter is often a reality. MRCT have been historically described by Cofield [4], as tears with a diameter of 5 cm or more in the coronal plane, or as stated by Gerber [5], a full-thickness tear of at least two tendons. Later, Davidson *et al*., [6], defined it as a tear with a coronal length and sagittal width greater than or equal to 2 cm.

Irreparable RCT represent up to 30% of the total RCTs [7, 8]. They were defined as tears with an acromiohumeral interval of less than 7 mm [9], or as posterosuperior RCT that cannot achieve fixation of the torn tendons in <60° of abduction despite adequate releases [10]. Nowadays they are being described as lesions that cannot be repaired primarily to their insertion on the tuberosities despite conventional techniques of surgical release and mobilization, because of their size, retraction, and muscle impairment caused by atrophy and fatty infiltration [11–13].

Numerous surgical strategies have been proposed to treat non-arthritic irreparable MRCT, such as debridement, partial repair, graft interposition, tendon transfer, superior capsular reconstruction (SCR), balloon arthroplasty, and reverse shoulder arthroplasty (RSA). The comparative efficacy of these treatments remains unclear.

In this study, we focus on the treatment of large RCT involving supra and infraspinatus, reported in the literature as having high retear rates [14–16], by a specific repair technique.

Our purpose was to evaluate the medium-term clinical outcomes of an arthroscopic side-to-side repair technique in the configuration of a shoestring using one single suture anchored to the footprint, for large and retracted posterosuperior rotator cuff tears, and compare the results with previous reports of this technique. Evaluation of the timing of physical therapy, as well as its influence on the outcome, were a secondary goal. We hypothesise this technique could constitute an effective alternative treatment for this type of RCT.

MATERIAL AND METHODS

Study Design and Participants

This is a retrospective cohort study, involving the patients from one institution. Surgeries were performed from 01/01/2015 to 31/12/2019, by two surgeons. Inclusion criteria were as follows: patients submitted to arthroscopic side-to-side repair of symptomatic large posterosuperior RCT diagnosed by MRI, that intraoperatively could not be attached to their original footprint; non-successful conservative treatment for at least 6 months, including corticoid injection and rehabilitation. Exclusion criteria were age under 18 or above 90 years old, a follow-up period under 6 months, rheumatoid arthritis, history of oral corticosteroids, glenohumeral arthritis, incomplete passive range of motion, external rotators insufficiency (positive Horn blower or Lag sign), concomitant non repairable subscapularis tendon tear and previous shoulder surgery. The study had the Ethical Committee approval of our institution and all the patients gave their written informed consent.

Patient electronic files were analysed by two different investigators. The obtained data consisted of comorbidities, including smoking habits, the preoperative range of motion (ROM) in terms of active shoulder flexion, abduction, external and internal rotation (all movements were measured in degrees except Internal Rotation in which a sequential and progressive scale was used: Hip, S1; L5, L1, D6), the preoperative QuickDASH and ASES Scores.

All patients considered eligible were summoned for new clinical evaluation and ROM assessment. Portuguese validated versions [17–19], of the QuickDASH, ASES and Constant scores were obtained.

Time from surgery to rehabilitation was obtained, as well as the duration of the physiotherapy period.

Patients were asked about their satisfaction with the surgical outcome, in two ways: (1) “Would you be operated again?” and (2) rating their satisfaction from 0 to 10, where 10 means total satisfaction.

The complication rate was evaluated for the first 3 months after surgery. We defined complication as an unintended or undesirable diagnosis directly related to the procedure, such as infection or suture dehiscence. We defined failure as the absence of symptomatic improvement in relation to an ineffective result. For this purpose, was assumed as failure, patients with a combination of: (1) variations of both ASES and QuickDASH scores below the standard deviation and (2) patients who claim not improving after surgery, saying they would not undergo surgery again.

Surgical Technique

The patient is placed in *beach-chair* position under a combination of interscalene block and balanced general anaesthesia. Three standard portals are used: posterior, lateral, and anterior. An additional antero-lateral portal is used, as necessary, to repair the subscapularis tendon.

The arthroscope is introduced through the posterior portal, for initial assessment of the intra-articular space. The subscapularis tendon is evaluated and if a tear classified as II or above on the Lafosse classification [20], is identified, a direct repair is performed. A tenotomy of the long head of biceps (LHB) is also performed.

An evaluation of the supraspinatus tear is made according to its configuration, and its direct reparability to the footprint area.

Debridement of the supraspinatus tendon edges and preparation of the footprint area on the great tuberosity is made, until a bleeding appearance is obtained.

Further on, the subacromial space is visualized using the lateral portal. After a large subacromial bursectomy and tendon release (Fig. 1), we confirm the suitability of the tear for a shoestring configuration repair (U or V shaped tear with a central area irreducible to the footprint).

The defect is closed using a No.2 non-absorbable suture, FiberWire (Arthrex, Naples, FL), with a suture passer Scorpion (Arthrex, Naples, FL) or Truepass (Smith&Nephew, Watford, UK), starting from the anterior edge of the tendon apex, from articular to bursal side. We repeat the same on the other suture limb through the posterior edge of the tendon. The posterior suture limb is now passed through the anterior edge more laterally, as well as the anterior suture limb is passed through the posterior edge, in a side-to-side shoestring fashion as performed by Van der Zwaal *et al*., [21]. Sutures are passed several times until the base of the tendon tear is reached (Fig. 2). The two limbs of the

suture are passed through a knotless absorbable anchor, SwiveLock (Arthrex, Naples, FL) or Multifix (Smith&Nephew, Watford, UK), and are gently tensioned, bringing together the anterior and posterior tendon edges and the anchor is placed in the lateral part of the greater tuberosity.

The quality of reconstruction and covering of the humeral head is confirmed both in the subacromial (Fig. 3) and intra-articular space (Fig. 4).

Postoperative Protocol

All patients were provided with an arm sling for 5 weeks but encouraged to perform passive shoulder exercises including pendulum exercises and passive forward flexion from day one after surgery. Active elbow and wrist exercises were also allowed.

Physiotherapy should begin 6 weeks after surgery with active assisted mobilization exercises, and at week 10-12 patients start muscle strengthening of deltoid, scapulothoracic and rotator cuff muscles.

Rehabilitation starting time wasn´t the same in all patients because it depended on the institution limitations. However, we were able to study the impact of the timing of rehabilitation on clinical outcomes.

Statistical Analysis

Statistical analysis involved measures of descriptive statistics and inferential statistics.

The level of significance for rejecting the null hypothesis was fixed at $\alpha \leq .05$. In this, as the quantitative variables did not have a normal distribution (analysed with the Shapiro-Wilk) non-parametric statistics were used, namely the Mann-Whitney, Wilcoxon test and Spearman's correlation coefficient. Statistical analysis was performed using the SPSS (Statistical Package for the Social Sciences) version 27.0 for Windows.

RESULTS

Participants

Regarding the period between 2015 and 2019 we had 28 eligible patients being submitted to this procedure; 2 patients refused to participate in the study, 1 patient had deceased at the time of evaluation, 1 patient was untraceable, 3 patients had additional surgery (reverse arthroplasty) to the affected shoulder (motivated by recalcitrant pain and/or loss of function and re-rupture confirmed with MRI) and were therefore considered as treatment failures. Therefore, a total of 21 shoulders in 21 patients were enrolled in this study. The most common comorbidity identified was hypertension (47.6%), and we found no correlation with the ROM nor functional outcome. Patients´ demographics are listed in Table 1.

Range of Motion (ROM)

All the ROM measurements have significantly improved except external rotation which improvement was almost statistically significant. Values in Table 2.

Functional Scores

A mean Constant score of 68.8 was obtained (SD 15.46).

Both functional scores, QuickDASH and ASES, have improved significantly (QuickDASH Z = -3.877, p = .001; ASES Z = -4.016, p = .001). Values in Table 3.

Results According to Gender

We did not find any significant influence of gender in the outcome in terms of ROM nor functional score (Table 4).

Correlations between Functional Scores and ROM

Postoperative QuickDASH score negatively correlated with postoperative ASES and Constant score. This means that the lower the values on QuickDASH scores (correspond to better results), the bigger the values will be in the ASES and Constant scores.

Both postoperative QuickDASH and ASES scores significantly correlated with their own variation measures.

In this univariable analysis, we found that the only ROM variation measurement, that has a consistent significant correlation with Functional scores at the final follow-up, is Abduction variation (Table 5).

Satisfaction Evaluation

Most of the patients agree that they would want to have surgery again (90.5%), with 19 patients considering they have improved their condition after surgery. Patients reported a mean satisfaction value of 8.7 (SD 1.87; max 10; min 4).

A positive correlation between Constant score and Satisfaction with surgery results was found ($p<0.001$).

Complications and Failures

According to our definition of complication, none was found.

Regarding our failure definition, we had 2 evaluated patients (Fig. 5 and Table 3), and 3 patients that had been submitted to additional surgery (reverse shoulder arthroplasty) at the time of the evaluation. Therefore, we assume a total of 5 failures out of a total of 24 patients (20.8%).

Time until the Start of Physiotherapy:

A significant negative correlation was found between the time until the start of physiotherapy after surgery and the Flexion and External rotation variations. No correlation was found between the time until

physiotherapy and the total duration of physiotherapy performed (Table 6).

Table 1: Patient Demographics

Patients	**21**
Male/ Female	7/14
Age (yr)	60.7 (± 7.8)
Length of follow-up (mo)	37.6 (± 17.7)
Right/left	14/7

NOTE: Data are n or mean (range).

Table 2: Range of motion (ROM)

Measurement	**Preoperative**	**Final follow-up**	**variation**	**Sig**
Abduction (º)	93.8 (28)	149.5 (42)	+ 55.7 (44)	.001
Flexion (º)	109.2 (34)	168.8 (29)	+ 53.5 (37)	.001
ER(º)	29.7 (19)	38.1 (10)	+ 8.3 (19)	0.058
IR (levels)	2.81 (0.9)	4 (0.8)	+ 1.2 (1)	0.003

NOTE: Data are mean (range). ER: external rotation; IR: internal rotation. Levels adopted for IR used a sequential and progressive scale: Hip, S1; L5, L1, D6.

Table 3: Functional scores and Satisfaction with the surgical outcome

Measurement	**Preoperative**	**Final follow-up**	**variation**	**Sig**	**N var. under SD**
QuickDASH score	64.6 (19)	23.3 (18)	- 41.2 (23)	.001	3
ASES score	31 (13)	76.8 (19)	+ 45.8 (20)	.001	4
Constant score	-	68.8 (15)	-	-	-
OA (yes/no)	-	19/2	-	-	-
Satisfaction	-	8.7 (min.4, max.10)	-	-	-

NOTE: Data are mean (range). OA: patients questioned "Would you be operated again?"; Satisfaction: patients rating surgical outcome from 0 to 10; N var. under SD: patients whose outcome variation was under the SD.

Table 4: Results according to Gender

Measurement	**Female**	**Male**	**Sig**
Var. Abduction	42.8 (47)	81.4 (24)	.079
Var. Flexion	49.2 (42)	62.1 (27)	.224
Var. ER	5.3 (22)	14.2 (12)	.172
Var. IR	1.2 (0.9)	1.1 (2)	.856
Var. QuickDASH score	- 42.1 (24)	- 39.4 (22)	.743
Var. ASES score	47.6 (21)	42.1 (18)	.322
Constant score	65.6 (16)	75.1 (10)	.149

NOTE: Data are mean (range). Var: Variation between preoperative and final follow-up. ER: external rotation; IR: internal rotation.

Table 5: Correlations between Functional Scores and ROM

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Final QuickDASH score								
2. Final ASES score	-.900*							
3. Constant score	-.901*	.887*						
4. Var Quick DASH score	.681*	-.726*	-.674*					
5. Var. ASES score	-.584*	.686*	.630*	-.939*				
6. Var. Abduction	-.626*	.572*	.545*	-.420	.368			
7. Var. Flexion	-.356	.430	.391	-.430	.433*	.654*		
8. Var. ER	.030	.001	-.214	-.003	-.088	.132	.070	
9. Var IR	-.379	.474*	.363	-.214	.160	.359	.316	.052

NOTE: Columns 1-8 represent the same variables listed as the rows; Var: Variation between preoperative and final follow-up. ER: external rotation; IR: internal rotation.* $p < .05$

Table 6: Correlation between Time till Physiotherapy and Functional Scores, ROM, and Physiotherapy duration

Measurement	Time till Physiotherapy
Constant score	.074
Var. Quick DASH score	-.044
Var. ASES score	.032
Var. Abduction	-.176
Var. Flexion	-.449*
Var. ER	-.491*
Var IR	.010
Physiotherapy duration	.018

NOTE: Var: Variation between preoperative and final follow-up. ER: external rotation; IR: internal rotation.
* $p < .05$

Table 7: Studies Comparation

Author		Final follow-up					
	Follow-up (mo)	Abduction (º)	Flexion (º)	ER (º)	Constant score	QuickDASH	Failure/ Retear rate (N)
Present study	37.6 (17.7)	149.5º (42)	162.8º (29)	38º (10)	68.8 (15)	23 (18)	20.8% (2+3)
Van der Zwaal *et al*., 2012	26.5 (2.3)	-	139° (39)	-	-	21 (14) *	19% (6)
Rousseau *et al*., 2012	38 (7)	-	-	-	69.3 (12.3)	-	44% (22)
Kim *et al*., 2019	38.3 (min.25, max.72)	141.3º (10.5)	164.5º (9.5)	58.6º (6.3)	77.8 (6.9)	-	54.2% (32)

NOTE: Data are mean (range) for Range of Motion. ER: external rotation. * Authors used DASH score, instead of QuickDASH.

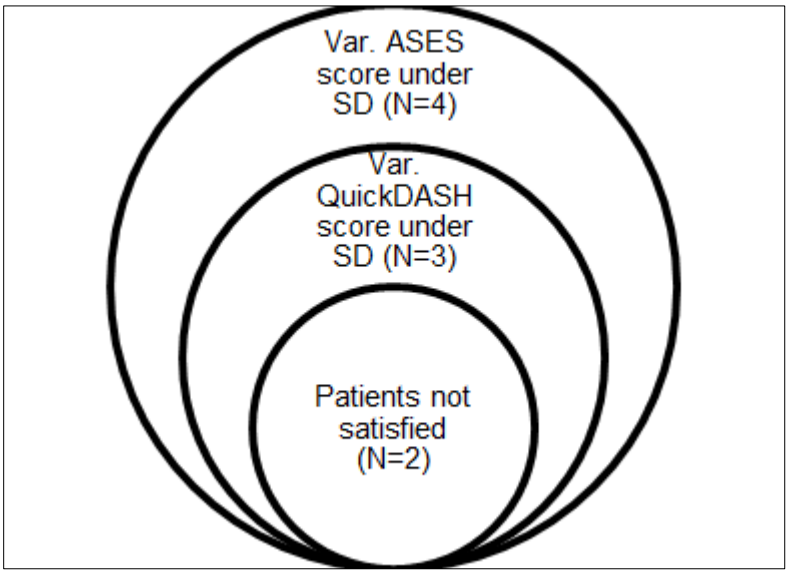

Figure 1: Venn diagram - Treatment failures assessed.

NOTE

We define as failures patients with a combination of: (1) variations of both ASES and QuickDASH scores below the standard deviation and (2) patients who claim not improving after surgery, saying they would not have surgery again. Other 3 patients were considered as having treatment failures, because they had been reoperated at the time of this study. Failures: 2+3= 5 failures, out of a total of 24 patients.

DISCUSSION

Results of our study suggest that at a mean follow-up of 3 years, shoestring bridge technique can offer good results in terms of ROM, functional scores, and patients' satisfaction. This technique can represent an effective treatment option for the patients with large and retracted posterosuperior RCTs (which cannot be anatomically repaired at the footprint), integrity of

external rotators, complete passive ROM and no glenohumeral arthritis.

Even with a failure rate of 20.8%, we consider it to be advantageous and a valuable alternative to SCR, which has a similar biomechanical effect as humeral head depressor [22]. When comparing these two techniques, we believe that the shoestring technique has the advantages of being less expensive (single anchor and suture), taking less surgical time, and it doesn't imply the risk of morbidity related to the donor site (in case of fascia lata graft). This technique did not show major complications [21], and keeps more invasive solutions like RSA as an alternative resource in case of failure. It has the disadvantage of only being useful in U and V shape tears [21].

Arthroscopic techniques described in 2012 [21-25], reported a side-to-side repair for large and retracted RCT, with attachment of the rotator cuff to the footprint without complete anatomic reconstruction, which was referred as the shoestring bridge technique [21]. This intended, in one hand, to restore the rotator cable principle described by Burkhart *et al*., [26]. On the other hand, it keeps the humeral head depressed and centred into the glenoid fossa allowing an improvement of the shoulder musculature kinetics and a single centre of rotation, which we believe to have a major role in the optimization of the rehabilitation results and on the success of this technique.

Limited published outcomes exist regarding this technique. Van der Zwaal *et al*., [21], described his shoestring bridge technique using a single uninterrupted FiberTape suture (Arthrex®) and titanium anchors. We use the same surgical technique, with a different non-absorbable suture (FiberWire suture (Arthrex)) and anchor (SwiveLock (Arthrex) or Multifix (Smith&Nephew)). Our results show slightly better forward flexion than Van der Zwaal *et al*., and both studies demonstrated significant improvements in range of motion and functional outcome scores.

Several other studies have reported outcomes with modifications to the shoestring bridge technique. Rosseau *et al*., [25], also in 2012, reported his arthroscopic side-to-side repair technique using five portals and performing acromioplasty with release of the coracoacromial ligament. Lall *et al*., [27], described his technique using a double-row repair with a suture bridge configuration. Kim *et al*., [28], presented his results for arthroscopic side-to-side repair in 40 patients using a medial anchor, while in 19 patients performed a simple side-to-side repair. Despite the challenges of direct comparison due to variations described in surgical technique and outcome measures, our results are consistent with previous findings in the literature [21-28]. (Table 7) [21-28]. In our study, we used several outcome scores to reduce the bias related to the assessment process. All the functional scores assessed are in harmony, correlating significantly with each other. Both postoperative QuickDASH and ASES scores significantly correlated with their own variation measures, which means that a better functional result is associated with a bigger functional improvement. The same reasoning is also valid when evaluating the Constant score.

An interesting evidence found was the significant negative correlation between the time until the start of physiotherapy after surgery and the Flexion and External rotation variations. We may say that patients whose physiotherapy start was delayed, may be less likely to improve flexion and external rotation. This data, to our knowledge, had never been described before for this type of surgical technique.

Regarding the limitations of our study, we were unable to include the 3 patients with failure in the clinical evaluation. This is explained by the fact that this was a retrospective study, and at the time of evaluation those patients had already been reoperated. Tenotomy of LHB was systematically performed as an accessory procedure, and we are aware that this can itself contribute to improvement of pain since the LHB is a well-known contributor to shoulder pain, particularly in massive rotator cuff tears [29–31]. Other limitation is that we did not evaluate the repair integrity at the final follow-up, using MRI or ultrasound, so we assumed as failures only the patients with clinical manifestations of an ineffective surgical result or recurrent complaints. However, since the functional outcome was overall good, we do not consider that evaluation of the repair integrity is mandatory, since it would not change the treatment in those patients who may have an asymptomatic retear. Kim *et al*., [28], reported an overall 54.2% retear rate on MRI and found no significant outcome difference between the healing and retear groups. Rousseau *et al*., [25], found on the ultrasound performed at the time of follow-up, a 44% retear rate, and report that these patients had lower Constant scores and strength recovery, however they conclude that those patients were not disadvantaged since they experienced pain relief and functional improvement. Van der Zwaal *et al*., [21], reported 6 patients (19%) with a retear on ultrasound, but only 3 of those 6 patients were not satisfied with the result.

Arguably the major limitations are the small sample size, and the absence of a control group comparing different types of operative vs. nonoperative treatment. Nevertheless all patients had a preoperative physiotherapy for at least 6 months without relief of symptoms which can be considered as a failure for conservative treatment. Additional studies, with more statistical power, are needed to investigate the effectiveness of this technique at long term.

CONCLUSION

Arthroscopic shoestring bridge technique, with side-to-side repair and using one single suture anchored to the footprint can offer good results in terms of ROM, functional scores, and patients' satisfaction at a mean follow-up of 3 years. This technique should be seen as an effective option for large and retracted posterosuperior RCT which cannot be primarily anatomically repairable, with low potential for complications, low cost and not compromising future treatment options that may be required in case of failure.

Conflict of Interests: There are no conflicts of interest to declare.

Financial Support: There was no financial support from public, commercial, or non-profit sources.

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