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Arthroscopic Side-to-Side Repair of Massive and Contracted Rotator Cuff Tears Using a Single Uninterrupted Suture: The Shoestring Bridge Technique

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ABSTRACT

Purpose
This study was performed to evaluate the clinical effectiveness of a new side-to-side repair technique for massive rotator cuff tears using a single uninterrupted suture in the configuration of a shoestring in a medial to lateral progression.

Methods
Thirty-one consecutive patients with a mean age of 59 years (SD 4.7) years had a primary arthroscopic repair of their massive U-shaped, contracted supraspinatus and infraspinatus tear using the Shoestring Bridge technique. Pre- and postoperatively active forward flexion, VAS pain, Simple Shoulder Test (SST) and Disabilities of the Arm, Shoulder and Hand (DASH) scores were collected. Repair integrity was evaluated by an ultrasonogram.

Results
At a mean follow up of 26.5 months all scores significantly improved: active forward flexion preoperative mean of 70º (SD 29º) to a mean of 139º (SD 39º) (P< 0.001); VAS pain preoperative mean of 8.0 ±1.4 points to 2.5 (SD 1.8) points (P<0.001); SST preoperative mean of 15% (SD 19%) to 72 % (SD 23%) (P<0.001); DASH preoperative mean of 62 (SD 17) points to 21 (SD 14) points (P<0.001). Ultrasound evaluation showed that 25 out of 31 patients (81%) had heeled tendons. 6 out of 31 patients (19%) had a complete re-tear. Only 3 of these 6 patients were not satisfied with the result.

Conclusion
Arthroscopic side-to-side repair using the Shoestring Bridge technique is effective in the treatment of massive U-shaped, contracted supraspinatus and infraspinatus tears. It provides the shoulder surgeon a treatment modality with significant improvement in pain and function, high patient satisfaction and a low re-tear rate.
INTRODUCTION

Over the past decade arthroscopic repair has become the preferred treatment for symptomatic small- to medium-sized rotator cuff tears with good results in the orthopaedic shoulder practice.\textsuperscript{1,2} In contrast, the clinical outcome of primary repair of massive and contracted supraspinatus and infraspinatus tears is inconsistent and associated with a high retear rate.\textsuperscript{3-7} The torn tendons are difficult to mobilise onto the footprint because of retraction and a lack of elasticity, and there usually is a significant deterioration in tissue quality as a result of fatty muscle infiltration. When performed successfully, repair of massive cuff tears can be associated with good long-term results and halted or decelerated progression of joint degeneration.\textsuperscript{8-10} Several techniques have been described for the treatment of these tears including the interval slide technique, partial repairs and repair with biologic substitutes.\textsuperscript{7,11-18}

We performed a prospective study in 31 patients with a massive U-shaped rotator cuff tear of the supraspinatus and infraspinatus tendons with a mean follow-up of 26.5 months. They were treated using an arthroscopic side-to-side repair with a single uninterrupted suture and fixation to the bone with a single anchor, the Shoestring Bridge technique. The purpose of our study was to evaluate the clinical effectiveness of this technique. Our hypothesis was that the Shoestring Bridge side-to-side repair using a single running suture can restore the functional integrity of massive and contracted rotator cuff tears and improve clinical outcome scores with a low retear rate.

METHODS

Patients. We performed a prospective study of 31 consecutive cases with massive, contracted tears of the supraspinatus and infraspinatus tendons. These patients were treated arthroscopically using the Shoestring Bridge technique as described later. Mean age was 59 years (SD 4.7). None of the patients had diabetes, rheumatoid arthritis or used oral corticosteroids. Patients older than 70 years and with a fatty muscle degeneration stage 4 were not considered candidates for the repair procedure, but for conservative treatment or reversed arthroplasty instead. Therefore
we did not see older patients in our study. 8 out of 31 patients used nicotine on a regular basis. The mean follow-up period was 26.5 months (SD 2.3). Patient characteristics are depicted in Table 1. All patients had symptomatic tears and were initially treated non-operatively with an active physical therapy program for at least 6 months. Most patients received 1 or 2 corticosteroid injections in this time period. The affected shoulders were evaluated by MRI examination at least three months before surgery. Average tear size was 3.3cm (SD 0.6) in the sagittal plane and 3.2cm (SD 0.5) in the coronal plane. All tears involved both the supraspinatus and infraspinatus tendons. The tears were massive, contracted U-shaped and could not be mobilised onto the greater tubercle without tension. The subscapularis tendon was intact in all cases. The muscles of the involved tendons had a muscle fatty infiltration stage 2 or 3 according to the Goutallier classification.\textsuperscript{19} Patients had a full passive range-of-motion at the time of surgery. Patients with glenohumeral arthritis, SLAP lesions or previous shoulder surgery were excluded from the study.

| Table 1. Patient characteristics |
|---------------------------------
| Number of patients | 31 |
| Age (years ±SD) | Mean 59 ± 4.7 |
| Sex | 15 male / 16 female |
| Affected side | 24 right / 7 left |
| Dominant side | 28 right / 3 left |
| Smoker | 8 out of 31 |
| Follow up (months ±SD) | mean 26.5 ± 2.3 |
| Tear size | sagittal: 3.3 cm (± 0.6) coronal: 3.2 cm (± 0.5) |
| Muscle atrophy | Goutallier 2: 8 patients Goutallier 3: 23 patients |
| Concomitant procedures | acromioplasty: 4 patients biceps tenotomy: 15 patients |
**Surgical technique.** The procedure is performed under general anaesthesia, interscalene block, or a combination of both. Prophylactic intravenous antibiotics are administered. We prefer placement in the beach chair position with the affected arm in an upper extremity positioner. This allows the arm to be manipulated and maintained in any desired position. The procedure commences with a range-of-motion and ligamentous examination of both shoulders. The shoulder is prepped and draped in the usual sterile fashion. Standard posterior, anterior and lateral portals are established and the scope is introduced through the posterior portal. The whole glenohumeral joint and the subacromial space are assessed. 15 patients had biceps tendinopathy and received biceps tenotomy. 4 patients had a large subacromial spur with intraoperative impingement on the cuff and received an acromioplasty. After bursectomy, with the arthroscope in the lateral portal the dimensions and geometry of the cuff tear are determined. The torn tendons are probed and manipulated with a soft tissue gasper to assess lateral, anterior and posterior mobility and elasticity. Anterior and posterior adhesions between tendons, bursa and deltoid muscle are removed to increase mobility. No specific releases between the tendons and the glenoid were performed. It is sometimes useful to create a fourth posterolateral portal for optimal exposure, especially with these large lesions. The edges of the tear are debrided and the insertion site for the suture anchor is prepared using a shaver.

In the Shoestring Bridge technique we use a FiberTape suture (Arthrex, Naples, Florida). FiberTape is a 2-mm wide and 7-inch long multistranded high strength polyethylene suture that provides broad compression and has high tissue cut-through resistance. The suture is passed through the anterior tear limb using a suture lasso starting at the apex of the tear from the bursal side to the articular side at least 1 cm away from the tear edge. The same suture thread is passed through the posterior limb using a suture passer from the articular side to the bursal side (Figure 1.1). The posterior thread is now passed back through the anterior limb more laterally and, in the same manner, the anterior thread is passed through the posterior limb. This should be performed from the bursal side to the articular side (Figure 1.2). These steps are repeated once more in the same fashion. It is important to note that the suture threads should not cross directly through the tear site, prohibiting adequate approximation of the tendons. Instead, the threads cross over the tear site at the
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articulor or bursal side (Figure 1.3). The edges of the tear are gently approximated in a side-to-side manner by alternatively pulling on the threads through the lateral portal. Care is taken not to create an unwanted loop in the suture. The defect is closed, and the strain is evenly distributed over the tendon limbs and supported by the width of the uninterrupted FiberTape suture. The FiberTape is secured at the level of the footprint by a knotless suture anchor through the lateral portal. We prefer to

Figure 1. Schematic representation of the Shoestring Bridge technique
1. The FiberTape is passed through the anterior tear limb starting at the apex of the tear from the bursal side to the articular side and back through the posterior limb to the bursal side.
2. The posterior thread is then passed back through the anterior limb more laterally and, in the same manner, the anterior thread is passed through the posterior limb.
3. These steps are repeated once more in the same fashion.
4. The edges of the tear are gently approximated in a side-to-side manner by alternatively pulling on the threads and the defect is closed. The suture is then secured using a knotless suture anchor.

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use a titanium SwiveLock 4.75 mm x 24.5 mm suture anchor (Arthrex, Naples, Florida). The suture now has a configuration similar as one would use to lace up his or her shoe, hence, the Shoestring Bridge technique (Figure 1.4 and Figure 2).

Figure 2. Intraoperative image of the Shoestring Bridge technique after the defect has been closed and fixated with a single suture anchor.

**Rehabilitation.** After wound closure a standard dressing is applied and the arm is placed in a sling for 6 weeks. A postoperative radiograph of the operated shoulder is made to evaluate the position of the bone anchor. Active exercises of the elbow, wrist and hand are encouraged. Postoperative rehabilitation is supervised by a physical therapist and consists of passive abduction in the scapular plane in the first 4 to 6 weeks. After this active range-of-motion exercises are started. When the patient is free of pain, scapula and rotator cuff isotonic strengthening exercises are initiated.

**Patient evaluation.** Just prior to surgery and at the final follow-up, several outcome measures were collected. We measured active forward flexion to evaluate function. We looked at pain using the Visual Analogue Score for pain (VAS pain)\(^2\), and outcomes using the Simple Shoulder Test (SST)\(^2\) and the Disabilities of the Arm, Shoulder and Hand (DASH) score.\(^2\) Patients were asked about their satisfaction and
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if they would have the same procedure on the contralateral shoulder if deemed necessary. At the last follow-up visit, a standardised ultrasonogram of the operated shoulder was obtained by a single, experienced musculoskeletal ultrasonographer to evaluate the integrity of the repaired tendons. Because there is no ultrasound-based classification system for rotator cuff repairs available, the repairs were scored as intact with complete footprint coverage, intact with partial footprint coverage or retear.

**Statistical analysis.** The Wilcoxon rank test was performed using SPSS statistical software (version 19.0, SPSS Inc, Chicago, IL) for the pre- and postoperative active forward flexion, VAS pain, SST and DASH scores. A P-value of <0.05 was considered statistically significant.

**RESULTS**

**Clinical outcome scores.** Table 2 lists the preoperative and postoperative measurements and outcomes. All scores showed a significant improvement as compared to the preoperative scores. Active forward flexion improved from a preoperative mean of 70º (SD 29º) to a mean of 139º (SD 39º) postoperatively (P< 0.001) (Figure 3). The VAS score for pain showed an improvement from the preoperative mean of 8.0 points (SD 1.4) to 2.5 points (SD 1.8) (P<0.001) at follow up. The score of the SST showed an increase from a preoperative mean of 15% (SD 19%) to 72 % (SD 23%) (P<0.001) postoperatively. The DASH scores improved from a preoperative average of 62 points (SD 17) to 21 points (SD 14) (P<0.001).

<table>
<thead>
<tr>
<th></th>
<th>Preoperative mean (SD)</th>
<th>Postoperative mean (SD)</th>
<th>P-value</th>
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<tbody>
<tr>
<td>Active forward flexion</td>
<td>70º (29º)</td>
<td>139º (39º)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VAS Pain</td>
<td>8.0 (1.4)</td>
<td>2.5 (1.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SST</td>
<td>15% (19)</td>
<td>72% (23)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DASH</td>
<td>62 (17)</td>
<td>21 (14)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

VAS Pain: visual analogue score for pain. SST: simple shoulder test. DASH: Disabilities of the Arm, Shoulder and Hand score.
Integrity of the repair. Ultrasound evaluation showed that 25 out of 31 patients (81%) had an intact cuff with healed tendons (Figure 4). Seventeen of these 25 patients had an intact cuff with partial coverage of the anatomic footprint. These patients all had significant improvements in their outcome scores. 6 out of 31 patients (19%) had a complete re-tear of the repaired tendons. Only 3 of these 6 patients with a re-tear had no improvement in their outcome scores and were not satisfied with the result. The other 28 patients were satisfied and would undergo the same procedure again on the contralateral shoulder if necessary.

Figure 3. Clinical image of 69 year old patient achieving 170 degrees of forward flexion 2.5 years after successful repair of a massive rotator cuff tear using the Shoestring Bridge technique.
Complications. No intraoperative or postoperative complications were noticed. No backing out of the suture anchors was observed, although this is a risk in chronic, massive tears with osteopenic bone in the area of the major tubercle. One patient with a symptomatic rerupture had reversed shoulder arthroplasty.

DISCUSSION

The results of this study showed that massive, contracted U-shaped rotator cuff tears can be treated successfully using the Shoestring Bridge technique with healing of the repaired tendons in approximately 80% of patients after 2 years. Our results show significant improvement of the outcome scores, which are also seen in studies of other procedures for massive and contracted rotator cuff tears, such as interval slides, partial repairs and biologic augmentations.\textsuperscript{11-18} However, because there is no standard classification system available for rotator cuff tears, comparison between studies is difficult. Furthermore, the outcome scores in these studies all improved significantly, but were not quite comparable because of different outcome scores.
used. A strong asset of our study is that we evaluated the integrity of the repair at final follow-up. Our results show a retear rate of 19% after a mean follow up of 26.5 months for these massive tears. Former studies on specific repair techniques, e.g. interval slides, partial repairs, did not evaluate the repair integrity, and so, information on the retear rate for these techniques is unavailable.

The Shoestring Bridge technique uses a principally different approach for the repair of massive, contracted cuff tears. It has two important distinctions. First, it is a side-to-side repair with adaptation of the cuff to the footprint without complete anatomic reconstruction of the footprint. This was seen on ultrasonographic evaluation as 17 of the 25 our patients with an intact cuff repair had partial coverage of the anatomical footprint. We hypothesised that the Shoestring Bridge technique mainly ensures functionality of the rotator cuff by restoring the rotator cable principle. The rotator cable is an arch of thick fibres running through the cuff from the anterior margin of the supraspinatus insertion to the posterior margin of the infraspinatus insertion. It has the configuration of a suspension bridge and transfers stress from the rotator cuff through the cable to the humerus. Tears that are brought back and contained within the rotator crescent do not disturb force coupling about the joint and do not lead to loss of function. Furthermore, there is no need for extensive release of the supraspinatus tendon as is done when performing interval slides, which risks release of the coracohumeral ligament (anterior interval slide) or injury to the suprascapular nerve (posterior interval slide). Second, the Shoestring Bridge uses a single uninterrupted suture in a configuration of a shoestring. Mazzocca et al. performed a biomechanical evaluation of the margin convergence repair in large retracted tears in a cadaveric shoulder model. They found a significantly decreased strain over the rotator cuff and that the first medial side-to-side suture has the greatest increase in intrinsic cuff tension. Each subsequent suture has a comparable but less dramatic effect. Considering these findings, one could explain that an uninterrupted FiberTape suture ensures a better distribution of the strain over the entire repair than interrupted sutures do and prevents excessive tensioning as would been seen with complete mobilisation of the tendons onto the anatomic footprint when performing end-to-bone fixation. In addition to this, we believe that the FiberTape suture has high tissue cut-through resistance as a result of its width and structure. Theoretically, these features make the repair more resilient.
in spite of decreased tissue quality. However, we are not aware of any biomechanical studies reporting on cut-through resistance of FiberTape sutures to support this.

An interesting point of discussion in our technique is the fixation to the greater tubercle with a single bone anchor in these massive tears. When the single suture thread would tear at 1 point the whole construct could collapse and the repair would fail. This can be prevented by reinforcement of the suture construct using multiple suture anchors and creating linked suture-bridge construct. Critical appraisal of the currently available scientific data shows that this second-generation double row fixation of cuff tears might have superior results, both clinically and biomechanically. A possible advantage of our technique however is that the material costs are relatively low. Because, in contrast to other repair procedures, we only use 1 suture and 1 bone anchor.

Our study has some methodological limitations. The number of patients enrolled in this study is relatively small. In addition, there was no control group, operative or nonoperative. It is known that the clinical behaviour of symptomatic massive rotator cuff tears can be mild, despite progressive joint degeneration. On the other hand, all patients have had a substantial period of active nonoperative treatment without relief of symptoms. Another limitation of our study is that patient strength evaluation was not incorporated in our outcome scores. Factors that could have influenced the improved outcome scores are the subacromial debridement and biceps tenotomy. Though only selectively performed in our study, both of these factors are known to relief symptoms in rotator cuff disease. These procedures, however, do not slow down progressive joint degeneration when performed solitarily. Furthermore, no biomechanical testing of the Shoestring Bridge repair technique has been performed, so the exact mechanical behaviour is unknown.

**CONCLUSION**

Arthroscopic side-to-side repair using the Shoestring Bridge technique is effective in the treatment of massive, U-shaped, contracted supraspinatus and infraspinatus tears. It provides the shoulder surgeon with treatment modality with significant improvement in pain and function, high patient satisfaction and a low retear rate.
References


Shoestring Bridge Technique
