RESEARCH ARTICLE

Clinical and Economic Advantages of Anchorless Arthroscopic Transosseous Suture Repair of the Rotator Cuff

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Abstract

In 2005, an anchorless technique was developed for arthroscopic transosseous rotator cuff repair to reproduce open surgery. Since May 2015, the retear rate has decreased with the use of absorbable sutures in mattress suturing. This study analyzed 389 patients who underwent surgery using absorbable mattress sutures. Three 2-mm Kirschner wires with perforated tips were inserted through the inferior margin of the greater tuberosity into the medial edge of the footprint. After pulling the rotator cuff stump laterally, three Kirschner wires were penetrated through the rotator cuff and skin. Two glycolic acid and three polyester sutures were passed through three bone tunnels using the perforated tips of the Kirschner wires. Surgery was completed by inserting two absorbable mattress sutures and three nonabsorbable bridging sutures. The retear rate after surgery with absorbable mattress sutures was 1.8%. The cost of surgical materials used in our procedure was $12. The application of an absorbable suture in mattress suturing was associated with a low retear rate. Further, this technique only requires sutures. Hence, it is considered economically advantageous.

Key words: Shoulder joint, Rotator cuff, Arthroscopy, Transosseous suture, Suture technique, Absorbable suture, Anchorless

1 Introduction

The arthroscopic anchor technique is the mainstay of rotator cuff repair. However, it has disadvantages such as use of expensive materials, occurrence of anchor pull-out, and challenges during resurgery in patients with retears. Since 2005, we have been performing arthroscopic transosseous suture (ATOS) repair of the rotator cuff without using implants. Only cost effective sutures are used in this procedure, and it has good clinical outcomes.

In 2013, we reported in detail the technique and clinical outcomes of 384 patients who underwent ATOS repair using three linear bone tunnels and five nonabsorbable polyester sutures.[1] Since May 2015, we have been using polyglycolic acid (PGA) sutures in mattress suturing to obtain satisfactory initial fixing power without applying excessive tension on the rotator cuff.[2] This study validated the clinical outcomes of ATOS using absorbable mattress sutures and its advantages in terms of cost.

2 Methods

2.1 Surgical technique

The patient was laterally placed under a 2-kg indirect arm traction. After subacromial decompression and adequate footprint decortication, the tip of the drill guide was placed on the medial edge of the footprint. Three 2-mm Kirschner wires with perforated tips were inserted from the inferior margin of the greater tuberosity into the medial edge of the footprint at a superiorly directed angle (60°–65°). While pulling the rotator cuff stump outward with a grasper, three Kirschner wires were penetrated through the rotator cuff and skin (Figure 1).

A nylon suture attached to the 65-cm PGA mattress suture and 65-cm polyester bridging suture was passed through the perforations of the anterior and posterior Kirschner wires. Then, nylon loops connected doubly in a series were passed through the central Kirschner wire (Figure 2). To clarify suture management, the suture ends were added according to alphabetical symbols: mattress suture, m; nylon loops connected doubly in series, n; anterior bridging suture, ab; and posterior bridging suture, pb. The sutures were then pulled out through the lower portal, passing through the rotator cuff and the bone tunnels in the greater tuberosity. The anterior and posterior PGA and polyester sutures, which have been pulled out through the lower portal, were tied into a big knot. Then, the distal part of the PGA suture was cut and pulled up.

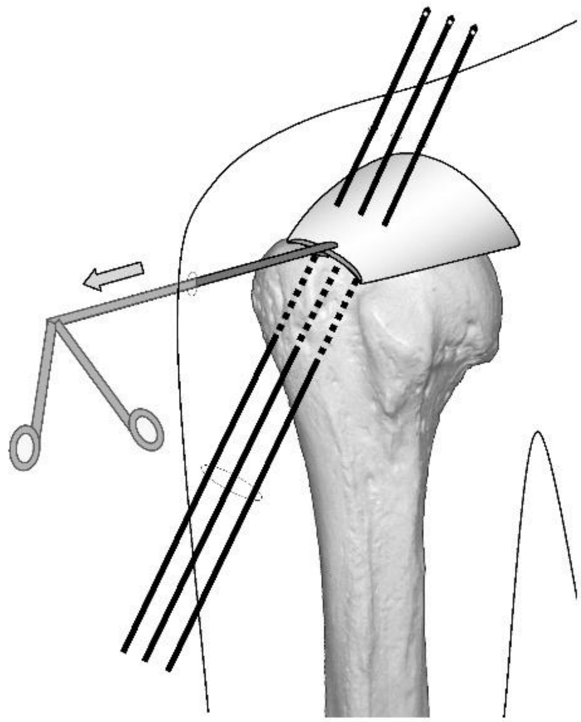

Figure 1

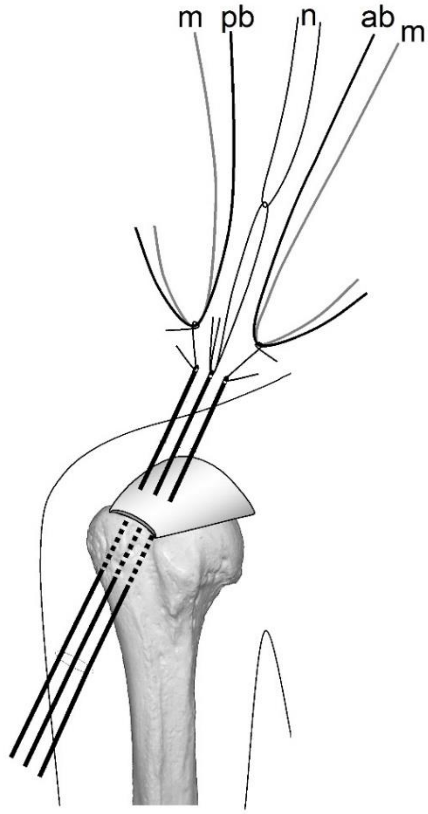

Figure 2

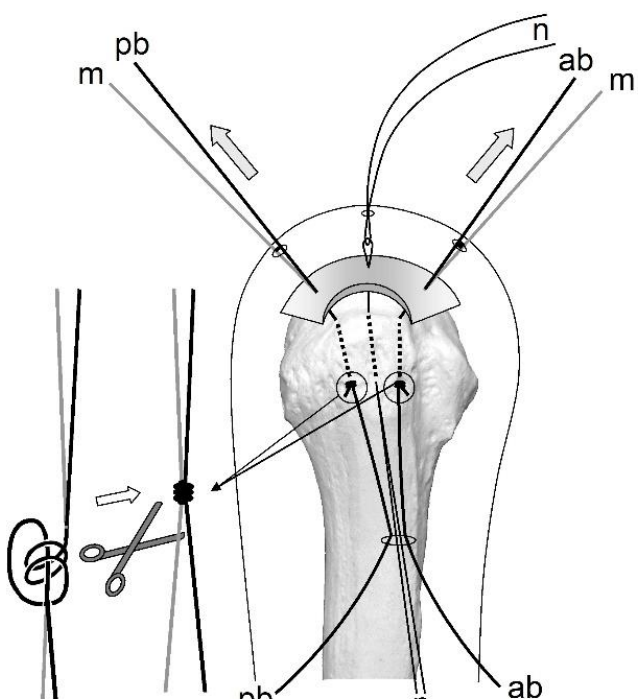

Figure 3

The knot was anchored at the inferior margin of the greater tuberosity (Figure 3). The central nylon loops and two PGA sutures inserted through the rotator cuff were then pulled out through the anterolateral portal. Next, the two PGA sutures extracted through the anterolateral portal were drawn through the lower portal, passing through the central bone tunnel using the nylon loops (Figure 4A). These PGA sutures were used in mattress suturing. After returning the nylon loops to the starting position, a 65-cm polyester suture for central bridging suturing (cb) was inserted into the nylon loop (Figure 4B) and was drawn through the central bone tunnel and lower portal (Figure 4C).

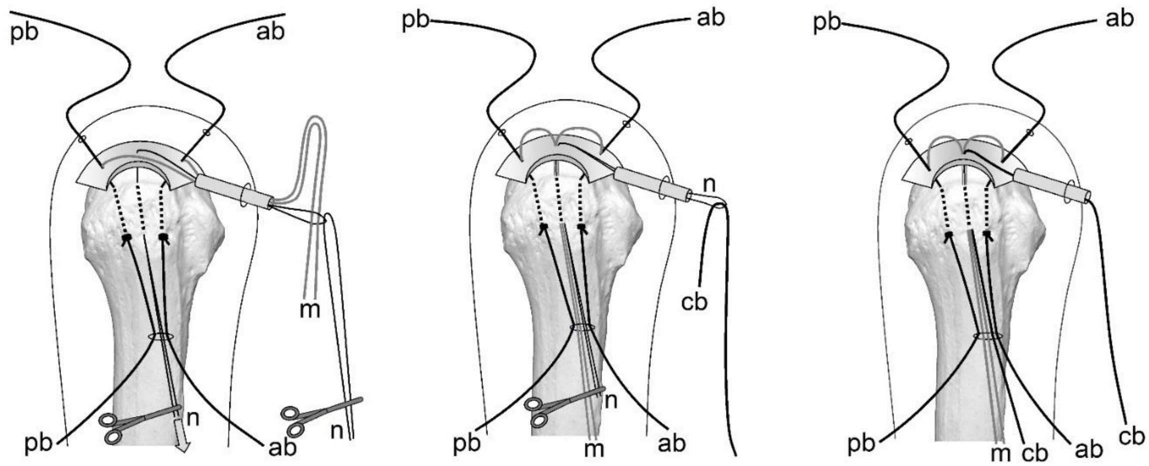

Figure 4A **Figure 4B** **Figure 4C**

Then, two PGA sutures were tied with polyester sutures using a square knot, and this polyester ligature was twisted around the mattress sutures and was ligated via square knotting. This process was repeated once, and the resulting knot was inserted into the inferior margin of the greater tuberosity using a knot pusher (Figure 5). The upper limb of the central bridging suture attached to the rotator cuff was then pulled out through the lower portal along the lateral wall of the greater tuberosity. This limb was tied to the other limb traversing the central bone tunnel with the same method used in mattress suturing (Figure 6). The anterior and posterior limbs bound to the bridging suture cannot be pulled out directly through the lower portal.

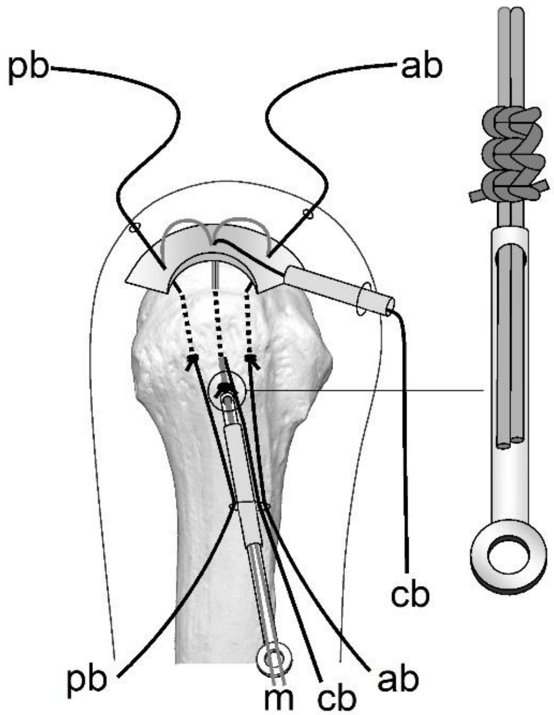

Figure 5

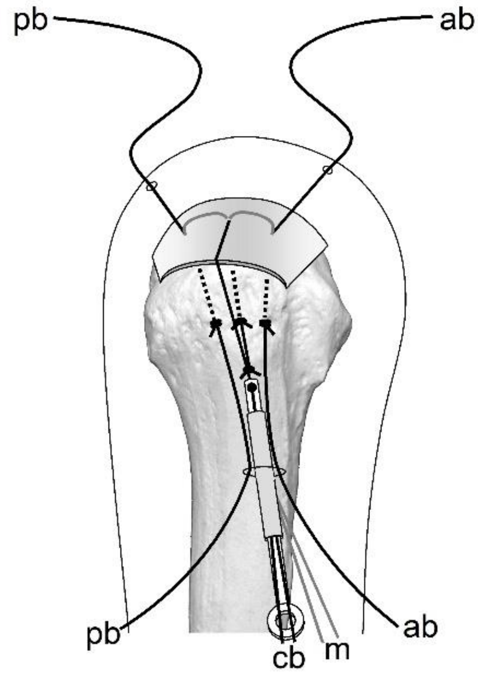

Figure 6

Thus, they were first pulled out via the anterolateral portal (Figure 7A) and then via the lower portal (Figure 7B). The limb extracted through the lower portal and the other limb passing through the anterior bone tunnel were tied similarly (Figure 7C). In posterior bridging suturing, the same process was repeated.

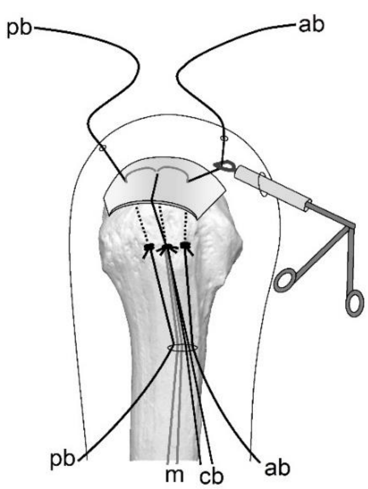

Figure 7A

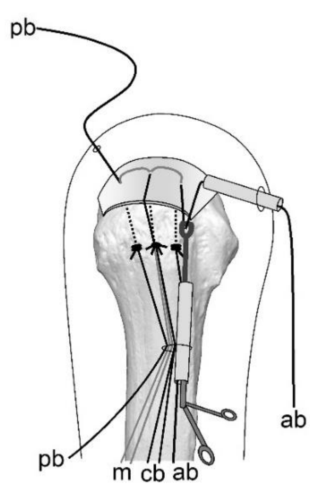

Figure 7B

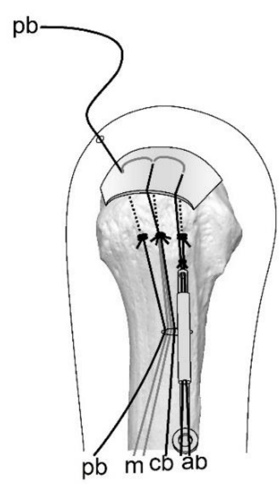

Figure 7C

The mattress and bridging sutures were further tightened and secured with three half-hitch knots. Figure 8 shows a photo and illustration at the end of ATOS repair. The torn rotator cuff was pulled to the footprint using two PGA mattress sutures (purple sutures in Figure 8) and was compressed tightly to the footprint with three polyester bridging sutures (green-colored in Figure 8). Extra mattress and bridging sutures can easily be added by placing the tip of the drill guide on the rotator cuff after suturing. When the AP diameter of the rotator cuff tear exceeds 3 cm, we added two extra bridging sutures. None of the patients underwent tenotomy and tenodesis of the long head of the biceps brachialis.

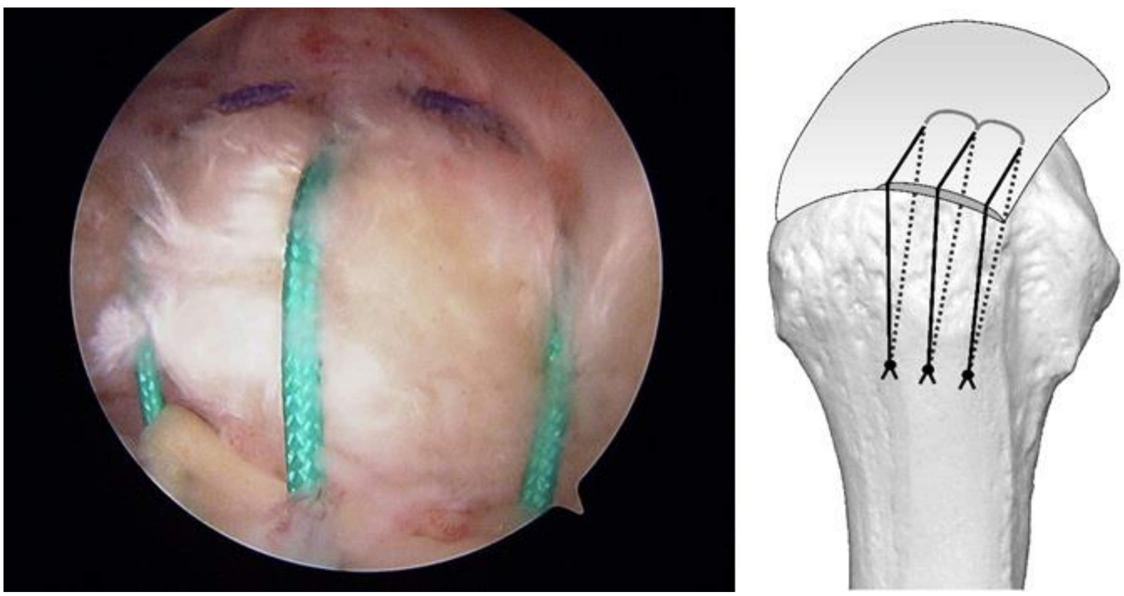

Figure 8

A soft brace holding the arm at 45º flexion and 45º internal rotations was used for 4 weeks. A physiotherapist started passive elevation 2 weeks after surgery. Active elevation was allowed at 4 weeks, and the patients were permitted to drive 6 weeks after surgery. In patients with tears > 3 cm, we extended the duration of each postoperative fixation and start times of passive elevation, active elevation, and driving to 2 weeks.

2.2 Patients and methods

Between April 2015 and March 2019, we performed ATOS repair on 471 consecutive patients (471 shoulders) with complete rotator cuff tears. Global tears with a medial-to-lateral diameter of > 5 cm were excluded from this study because they underwent open infraspinatus translocation and ATOS repair. Upper subscapularis tear was accompanied in 36 (9.3%) patients. These subscapularis tears also managed via ATOS repair before supraspinatus ATOS repair. The inclusion criteria were as follows: (1) patients who underwent UCLA assessment 2 years after surgery, (2) those who underwent magnetic resonance imaging (MRI) 1–1.5 years after surgery, and (3) those with complete surgical records including accurate intraoperative data about rotator cuff tear size. Meanwhile, the exclusion criteria were as follows: (1) patients with previous fracture, (2) those who underwent revision rotator cuff repair, and (3) those with preoperative cervical radiculopathy or axillary nerve palsy. Ultimately, 389 patients (389 shoulders; 266 right and 123 left) (199 women and 190 men) were included in the study. The follow-up rate was 82.6%. The average age of the patients at the time of surgery was 65.7 (range: 38–84) years. The medial-to-lateral diameters of the tear were < 1 cm in 74, 1–3 cm in 249, and 3–4.8 cm in 66 shoulders. The minimum follow-up duration was 2.1 (mean: 2.8; range: 2.1–4.3) years. The MRI image of the rotator cuff suture site obtained 1 year after surgery was used to assess for retears, which were classified according to the system established by Sugaya et al.[3] Sugaya type IV was defined as the presence of a minor discontinuity, as observed on oblique coronal and sagittal views on T2-weighted images, indicating a small tear. Type V was defined as the presence of a major discontinuity suggesting a medium or large tear. Before and 2 years after surgery, we evaluated the shoulders using the UCLA Shoulder Rating Scale scores,[4] consisting of the following five subscales: pain (10 points), function (10), active forward flexion (5), strength of forward flexion (5), and satisfaction of patient (5), with 30 and 35 as the best possible score before and after surgery, respectively. We used Mann–Whitney and t-tests for statistical analysis (EZR on R commander Version 1.37). Significance was set at $p < 0.05$. To assess for axillary nerve damage, all patients underwent electromyography (EMG) of the deltoid muscle before and 1 month after surgery.

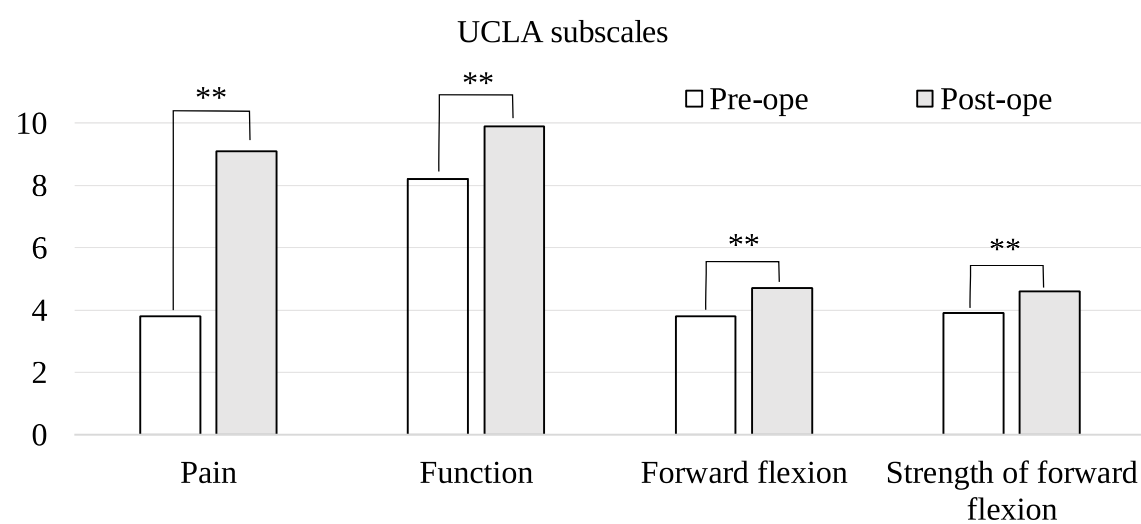

Figure 9

3 Results

The preoperative and postoperative UCLA

subscales changed as follows: mean pain score 3.8 to 9.1, function 8.2 to 9.9, active forward flexion 3.8 to 4.7, strength of forward flexion 3.9 to 4.6, respectively. All subscales improved significantly after surgery (Figure 9). Postoperative pain scores were significantly higher in the small tear group than in the medium and the large tear groups (Figure 10).

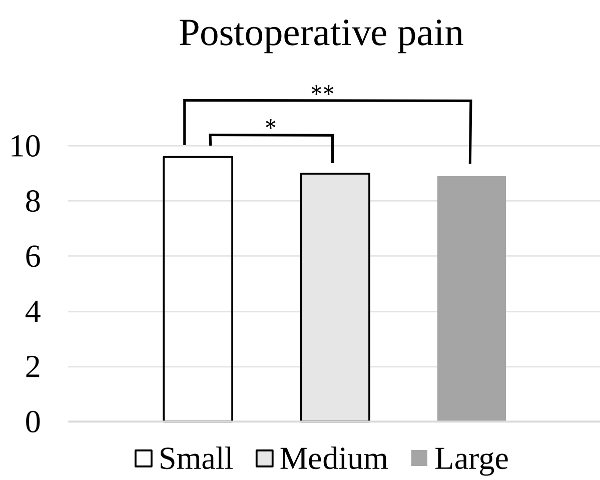

Figure 10

Postoperative score of active forward flexion was significantly higher in the small and medium tear groups than in the large tear group (Figure 11). Postoperative score for strength of forward flexion was significantly different among all rupture sizes (Figure 12). The mean score of satisfaction of patient was 4.6. Satisfaction was not significantly different depending on the tear size. The preoperative mean UCLA total score was 19.7 (range: 6–30), and the postoperative score was 32.9 (range: 13–35). The postoperative outcomes were excellent (34–35) in 62.2%, good (29–33) in 29.1%, and poor (< 29) in 8.7% of patients.

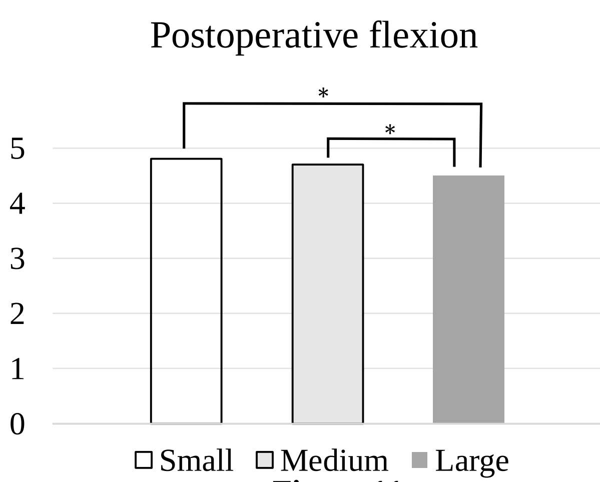

Figure 11

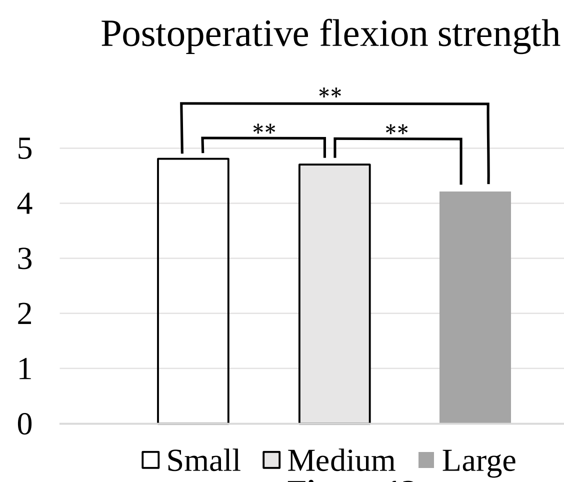

Figure 12

The mean preoperative and postoperative UCLA total scores were 20.6 and 34.1, respectively, in patients with small tears. Meanwhile, those of patients with medium (1–3 cm) and large tears (>3 cm) were 19.9 and 32.9, and 18.3 and 32.1, respectively. Total postoperative scores were significantly higher in the small tear group than in the medium and the large tear groups. Based on MRI images, seven (1.8%) patients (7 shoulders) were Sugaya type IV and V, which were considered retears. Based on the size of the original tear, the incidence rates of retear were 0% (0/74), 0.8% (2/249), and 7.6% (5/66) in patients with small (< 1 cm), medium (1–3 cm), and large (3–4.8 cm) tears. The retear rate was significantly lower in the small and medium tear groups than in the large tear group. All seven patients with retear experienced mild pain. However, they did not undergo revision surgery. Moreover, none of the patients had damaged axillary nerve on postoperative EMG and breakage of the bone tunnel caused by the suture. The mean surgical time was 116 (range: 49–208) min. In ATOS repair, because we do not use the disposable instruments, surgical material costs only PGA and polyester sutures, it is 12 dollars.

4 Discussion

4.1 Retear rate

As first described by Codman in 1911,[5] open rotator cuff repair using transosseous sutures has been considered the gold standard of rotator cuff repair. In 2005, an anchorless technique was developed for arthroscopic transosseous suture rotator cuff repair to reproduce open surgery. It is economical because the extra cost is only for the suture materials. In addition, problems correlated with anchors such as expensive cost, anchor pull-out, and challenges in resurgery are eliminated. In 2013, we conducted a study on the postoperative outcomes of ATOS repair using nonabsorbable polyester sutures.[1] Since April 2015, we have been using PGA sutures in mattress suturing to achieve initial cuff-securing force and to prevent exerting excessive tension on the rotator cuff. In addition to our method, other approaches for arthroscopic transosseous repair of the rotator cuff without implants include the use of a giant needle,[6,7] ArthroTunneler device (Tornier, Edina, MN, the USA),[8-13] hollow needle,[14-16] special equipment,[17-20] and anterior cruciate ligament guide.[21] Moreover, few reports have revealed the clinical outcomes of this technique in more than 50 patients.[1,2,13,14,16] That is, the retear rates were 12% in the study of Matis's report,[14] which used a hollow needle, and 3.7% in the report of Flanagin,[13] which used the ArthroTunneler™.

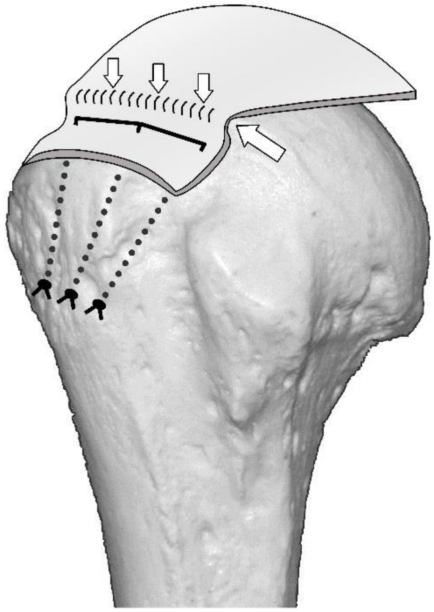

Figure 13

In the research of Hubert et al., the retear rate is similar to that of open transosseous repair.[16] Duquin et al. reviewed 1252 cases in 2010. Results showed that the recurrence rates after open transosseous repair were 17%, 20%, 18%, and 44% in patients with small, medium, large, and global tears, respectively. In addition, the retear rate of the double row anchor method ranged from 7% for tears < 1 cm to 41% for those > 5 cm.[22] With the ATOS repair using PGA sutures in mattress suturing, there were no retears for tears < 1 cm. The retear rates were 0.8% and 7.6% for tears measuring 1–3 and 3–4.8 cm, respectively, and the overall rate was 1.8%. In our procedure, mattress sutures were used to draw the cuff stump peripherally and to apply adequate initial fixing power to the footprint. Mattress sutures are used to firmly secure the rotator cuff at the inner edge of the footprint. Thus, the cuff is subjected to a strong compressive stress at the outer edge of the humeral head (Figure 13). The bonding process between the rotator cuff and the footprint progresses and the rotator cuff achieves adequate stability in 3 weeks. If the compression and restraint of the rotator cuff caused by non-absorbable mattress sutures persists for more than 3 weeks, the physiological attachment structure of the rotator cuff cannot be reconstructed. However, there is no histological evidence for this hypothesis, and this is considered a limitation of this study. We believe that the long-lasting strong anchoring force of the nonabsorbable mattress sutures can inhibit cuff healing. In relation to this reason, absorbable sutures, specifically PGA, were used in mattress suturing. This type of suture is absorbable, and it has an outstanding tensile strength. Moreover, it is absorbed in the body via a simple hydrolytic mechanism. PGA mattress sutures can retain their original tensile strength until the rotator cuff achieves adequate stability. By using our technique, the torn rotator cuff can be drawn and pressed down to the footprint with two absorbable PGA mattress sutures and three nonabsorbable polyester bridging sutures. Mattress sutures were required to pull the torn rotator cuff to the footprint and prevent excessive tension during the initial healing period until stability between the torn rotator cuff and footprint is achieved. Then, the nonabsorbable mattress sutures suppress cuff movement excessively and inhibit healing. The tensile strengths of PGA sutures were 65% and 35% after 2 and 3 weeks, respectively. Therefore, preventing unnecessary suppression of rotator cuff movement caused by nonabsorbable mattress sutures reduced the retear rate.

4.2 Challenges associated with the procedure

Although suturing was complicated, as shown in our figures, the knot tying required in this procedure was performed by hands, and it was easier than tying sliding knots. Our procedure was not more difficult than the anchor method, and it could be performed by any surgeon who is skilled in arthroscopic technique. For any surgery, experience is required to master the technique. Even surgeons who are not experienced in using an arthroscope in the lateral position reached the learning curve plateau in 30 cases. The Kirschner wires, which are inserted to target the medial edge of the footprint from the inferior margin of the greater tuberosity, appear on the skin behind the AC joint. Although the Kirschner wires penetrate the acromion, this does not cause any problems.

4.3 Cuff-to-footprint bonding and bone tunnel problem

In our technique, the strength of the rotator cuff fixation was not based on the surface bone quality of the footprint. Instead, it depended on the durable cortical bone of the inferior margin of the greater tuberosity. The strong fixing force of mattress sutures restrict cuff movement, and bridging sutures generate a greater bonding force between the rotator cuff and footprint. Furthermore, compared with larger anchor holes, three bone tunnels with a diameter of 2 mm can maximize the cuff-to-footprint contact area and can create a wide cuff-to-bone healing area. Rotator cuff tears commonly occur among elderly individuals with osteoporosis. Therefore, problems with bone tunnels are a theoretical concern with the transosseous techniques. Liu et al. showed that the incidence rate of intraoperative bone laceration in surgery using the ArthroTunneler method was 44%.[11] However, there were no problems correlated with the bone tunnels in our procedure used long straight bone tunnels from the inferior margin of the greater tuberosity to the medial edge of the footprint. Further, knot tying was performed at the lower margin of the greater tuberosity, where the bone cortex is solid. In addition, we did not use the sliding knot technique. Therefore, none of the patients experienced suture rupture in the bone tunnel due to friction. Moreover, there was no breakage of the bone tunnel. However, the incidence rate of anchor pull-out is 2.4%.[23] Our procedure is more suitable for osteoporotic patients, and the use of the distal durable cortical bone of the greater tuberosity is an advantage.

4.4 Resurgery in retear cases

Reoperation is challenging due to the presence of anchors in the greater tuberosity. This problem is evident when numerous metal anchors have been used. Because our anchorless technique uses only sutures and three bone tunnels with a diameter of 2 mm, it can facilitate revision surgery.

4.5 Axillary nerve protection

The axillary nerve must be protected during this procedure as Kirschner wires are inserted from the inferior margin of the greater tuberosity. When these wires are inserted distally to the axillary nerve, entrapment caused by bridging suturing is inevitable. To prevent axillary nerve injury, we identified the neurovascular bundle via preoperative MRI and set the insertion angle of the aiming guide. Thus, the Kirschner wire can be inserted 1 cm above the neurovascular bundle (Figure 14). The intersection of the line connecting the medial edge of the footprint [B], Kirschner wire insertion point [A], and line [AC] perpendicular to the humeral long axis is the proper insertion angle (Figure 14, angle BAC). The angle is commonly 60º–65º.[2] Thus, an insertion angle of 60° is suitable for any case. Postoperative MRI showed that the neurovascular bundle and Kirschner wire insertion point are distant from each other (Figure 15). Based on postoperative EMG of the deltoid muscle, none of the patients presented with axillary nerve damage. Blas-Dobón conducted a cadaver study using an aiming guide, which is similar to that used in this study. Results showed that a Kirschner wire insertion angle of ≤ 60° can effectively protect the axillary nerve.[24] Gupta showed that drilling at an insertion angle of 60° to the humerus has a 5-mm safety margin for the axillary nerve based on MRI results, and this is similar to the current study.[25] The conclusions of these studies support those of ours.[2]

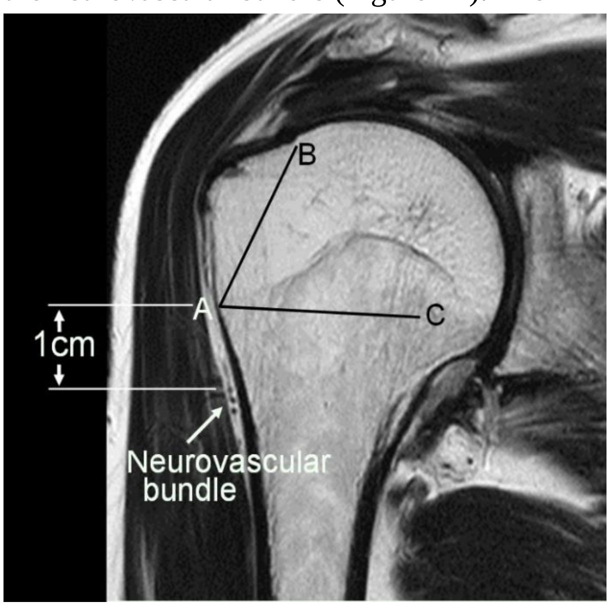

Figure 14

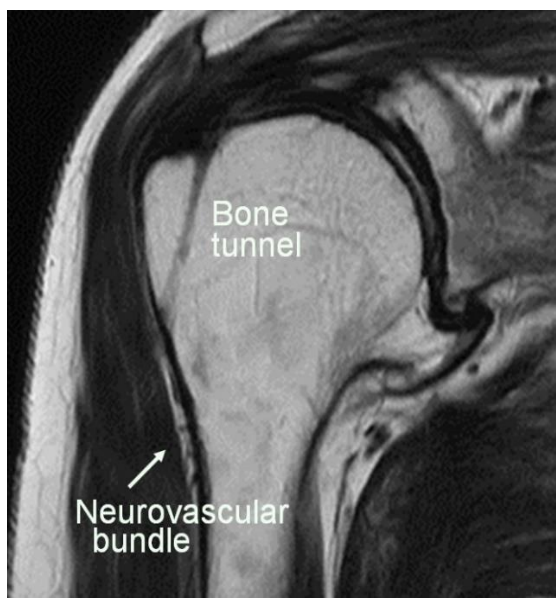

Figure 15

4.6 Economic advantage of ATOS repair

The average duration of ATOS repair was 116 min, which is longer than that of the anchor method. Another disadvantage is that it requires two surgeons. We compared the surgical cost between ATOS repair and the anchor method.[26] The difference in terms of cost according to surgical method is attributed to the use of surgical materials and professional fees. Our technique requires two surgeons, one anesthesiologist, and two nurses. In our hospital, doctors and nurses are paid $119/hour and $30/hour, respectively. Therefore, the total personnel expenses are $417/hour ($119 x 3 + $30 x 2). The cost of PGA and polyester sutures used in our procedure is $12. The overall average duration of ATOS repair is 116 min in 389 cases. Therefore, the cost of ATOS repair is $818 ($417 x 116/60 + $12). In Japan, 25,519 surgeries using the anchor method were performed, and 80,943 anchors were used in 2019. Therefore, the average number of anchors used was 3.2 pieces. In Japan, the standard price of anchors is $319. Therefore, the cost of materials used in surgeries using the anchor method is $1021 ($319 × 3.2). This price, which excludes professional fees for surgeries using the anchor method, is higher than the average surgical cost of ATOS repair. If the anchor method is replaced with ATOS repair, Japan can save $25.7 million for the annual cost of surgical materials ($319 × 80,943). Thus, ATOS repair can be a promising method.

The surgical material cost of the ArthroTunneler method is $600, and that of the Hubert's hollow needle method is $121. The cost and retear rate of various methods are shown in Table 1. The procedure in the current study has the lowest retear rate and material costs. Hence, it is extremely advantageous

5 Acknowledgment

We thank Takasumi Kawai, RPT for his cooperation in collecting clinical data.

Table 1

Author	Matis	Flanagin	Hubert	Duquin		Kuroda
Method	Hollow needle	Arthro tunneler	Hollow needle	Anchor	Open	ATOS
Retear rate	12%	3.7%	= Open	7–41%	17–44%	1.8%
Cost		$600	$121	$1,021 Kuroda's calculation		$12

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