Anatomic reconstruction of the coracoclavicular ligament in a recent acromioclavicular joint dislocation

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Background
Injuries to the acromioclavicular (AC) joint are common, representing about 9% of all shoulder injuries. They are graded according to the Rockwood classification system. The rationale of surgical treatment is to restore normal anatomy, enabling patient to regain normal shoulder function. A wide variety of surgical procedures have been reported, including transarticular pins or screws; AC wire or suture fixation; coracoclavicular (CC) screws; and CC fixation with synthetic grafts.

Patients and methods
This was a prospective series of 12 patients with acute grades III–V AC joint dislocations through anatomic reconstruction of the coracoclavicular ligament using autogenous semitendinosus tendon. There were 10 men and two women ranging in age from 20 to 45 years (mean 30.25 years). The right shoulder was involved in eight patients (67%) and the left shoulder was involved in four (33%). The primary diagnosis was AC joint dislocation Rockwood type III in seven patients, type IV in four, and type V in one.

Results
The mean follow-up period was 14.3 months (12–18 months). On the visual analogue scale, the pain improved from an average 6.2 points preoperatively to an average of 2.3 points postoperatively. The procedure allowed for both satisfactory functional outcome and a low complication rate, with excellent or good results in 92% of the patients, with full return to previous activities in 12 months.

Conclusion
CC reconstruction using a semitendinosus tendon graft provides satisfactory results. This method aims at a reconstruction in which the course of the slings of the tendon is very close to the course of the original CC ligaments.

Keywords:
acromioclavicular dislocation, acromioclavicular joint, coracoclavicular ligament

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Introduction

The acromioclavicular (AC) articulation is important in the suspension and function of the upper limb [1]. This small, superficially located joint lies at the focal point of large muscular forces, assists in supporting the weight of the arm and shoulder girdle, and is susceptible to frequent traumatic events [2,3].

The distal clavicle is held in place by the AC capsular ligaments and the stout coracoclavicular (CC) ligaments, the conoid and trapezoid. Additional support is provided by the large muscles of the shoulder, including the deltoid, trapezius, pectoralis major, and the serratus anterior [4]. Experiments have shown that the AC ligaments, specifically the superior and posterior AC ligaments, serve as the primary restraints to anterior–posterior translation and posterior axial rotation, whereas the CC ligaments serve as the primary restraints to superior–inferior translation and anterior axial rotation [5,6].

Injuries to the AC joint are common, representing about 9% of all shoulder injuries [7]; they typically occur through either a direct impact to the shoulder or by indirect force from a fall on an outstretched arm, thus affecting mainly active patients and those involved in contact sports [8–11].

They are commonly graded according to the classification system of Allman and Tossy, as modified by Rockwood [2,12,13]. Depending on the magnitude of injury to the AC joint capsule and ligaments as well as to the CC ligaments, these injuries can be classified by increasing severity as type I through type VI. Type I and type II injuries are sprains of the AC joint that are generally considered stable patterns and are treated conservatively; most return to preinjury status. However, high-grade injuries, typically types IV, V, and VI, are characterized by complete dislocation of the AC joint, with disruption of the AC and CC ligaments and injury to the deltotrapezial fascia with greater than 100% displacement in either a posterior or an inferior direction. These injuries are treated surgically. Type III separations similarly disrupt the AC and CC ligaments but do not violate the deltotrapezial fascia; the treatment of type III separations remains controversial.

Although debate continues on surgical versus nonsurgical treatment of type III injuries [14,15], the advantage

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of surgical treatment over nonoperative care has been shown clearly for type IV and more severe injuries [7,15].

The rationale of surgical treatment is to restore normal anatomy, enabling the patient to regain normal shoulder function. A wide variety of surgical procedures have been reported, including transarticular pins or screws [16], AC wire or suture fixation [17], CC screws [18,19], and CC fixation with synthetic grafts [20–23]. In a widely used procedure, the acromial attachment of the coracoacromial ligament is transferred to the most distal part of the clavicle [24].

Disruption of the CC ligaments is the critical part of the pathogenesis, and consequently, most techniques focus on the repair, reconstruction, or reapproximation of the conoid and trapezoid ligaments [24–26].

The aim of this study is to describe the technique used for the anatomic coracoclavicular reconstruction (ACCR) using an autogenous semitendinosus graft and report our experience in the treatment of acute AC dislocations types III–VI according to Rockwood [12].

Patients and methods

A prospective series of 12 patients with acute grades III–V AC joint dislocations of traumatic etiology were treated surgically by anatomic reconstruction of the CC ligament using an autogenous semitendinosus tendon graft at the Zagazig University Hospitals between January 2008 and December 2009. Patients with grades I–II AC joint dislocations, chronic etiology, or concomitant chronic disease were excluded from the study. The most common reasons for which our patients sought surgery were pain over the AC joint, feeling of AC joint instability, and deformity of the shoulder. There were 10 men and two women ranging in age from 20 to 45 years (mean 30.25 years). The mean follow-up period was 14.3 months, with a range of 12–18 months. The right shoulder was involved in eight patients (67%) and the left shoulder was involved in four (33%). The primary diagnosis was AC joint dislocation Rockwood [12] type III in seven patients, type IV in four, and type V in one. The original trauma was a road traffic accident in seven (58.4%) patients, a fall from a height in three (25%), and sports injury in two (16.6%). All patients were followed up clinically and radiographically.

Clinical evaluation

Patients were assessed for pain relief using a visual analogue scale graded from 0 (no pain) to 10 points (maximal pain).

Imatani's [27] scoring system was used to evaluate the functional outcomes of the shoulders. It included assessment of pain, function, and movement of the shoulder. Four grades were categorized and a satisfactory outcome included an excellent or a good result (Table 1). This scoring system was used because of its relative simplicity and practicality.

Table 1 The scoring system by Imatani for acromioclavicular separation

Distribution	Score
Pain (40 points)	
None	40
Slight, occasional	25
Moderate, tolerable	10
Limited activities, severe, constant, disabling	5
Function (30 points)	
Weakness (proportion of preinjury)	20
Use of shoulder	5
Change of occupation	5
Movement (30 points)	
Abduction	10
Flexion	10
Adduction	10
Result	
Excellent	91–100
Good	81–90
Fair	61–80
Poor	<60

Radiologic evaluation

Preoperative and postoperative radiographs of the AC joint in two planes were available in anteroposterior (AP) and axillary views for each patient [28]. On the AP view, the distance between the coracoid process and the clavicle was measured, as well as the distance between the distal end of the clavicle and the acromion. On the axillary view, the position of the clavicle relative to the end of the acromion in the horizontal plane was assessed.

Measurement was performed between the anterior border of the acromion and the anterior edge of the lateral clavicle. At follow-up, the AP and axillary views were performed for both sides. The axillary view was performed with the arm in 90° abduction and with the upper arm in the scapular plane.

Surgical technique

Anesthesia and positioning

All patients were administered general anesthesia. Patients were placed in a beach chair position of 60° of flexion.

Exposure

The incision begins at the posterior edge of the clavicle ~3.5 cm medial to the AC joint and extends inferiorly toward the coracoid. The incision was about 6 cm in length and was centered over or slightly medial to the coracoid. The incision could be extended posterior if further access was required. A scalpel was used to cut skin, and then needle tip electrocautery was used to achieve hemostasis and dissect down to the deltotrapezial fascia. The deltotrapezial fascia was then elevated off of the clavicle as full-thickness flaps. Medial and lateral skin flaps were elevated with a needle-tipped diathermy. The retaining retractor assisted to exposure transverse incision was made along the mid axis of the clavicle extending into the AC joint. Full-thickness flaps of the superior AC joint capsule were elevated superiorly and inferiorly with the diathermy. The anterior and posterior portion of the distal clavicle was completely exposed. We did not perform a distal clavicle resection in any of the patients in the study. The medial and lateral coracoid base was

exposed with a Cobb elevator. Care was taken to avoid excessive medial dissection to prevent musculocutaneous nerve injury. The articular disc of the AC joint was excised if damaged.

Clavicular tunnels preparation

The clavicle was prepared by drilling bone tunnels in the anatomic locations of the coracoclavicular ligaments. The conoid ligament tunnel was placed 50 mm medial to the AC joint and at the posterior aspect of the clavicle. This was positioned along the posterior superior cortex and it was directed at 30° anterior, aiming toward the coracoid. The tunnel was drilled in a gradual manner using a 3.5 drill bit, followed by a 4.5 drill bit, and finally we used a 5 mm chanz to create a 5 mm tunnel. Next, the trapezoid ligament tunnel was prepared in the same manner. It was placed 30 mm from the lateral edge of the clavicle at its center. This was again directed 30° anterior toward the coracoid. The goal was to make the tunnel as small as possible while still allowing for graft passage, and therefore, it should be somewhat difficult to pass the graft.

Graft preparation and passage

A semitendinosus autograft was harvested through an oblique skin incision centered over the tibial insertion of the pes anserine tendons. High-strength nonabsorbable suture was used to taper the end of the graft. The stitch should also 'bullet' the end of the graft by making the distal diameter as small as possible. This will facilitate graft passage through a small tunnel and prevent fraying of the graft edges. The graft was passed beneath the coracoid, using a curved clamp or curved suture passing device. A number 3, high-strength, nonabsorbable suture was passed with the graft to provide additional non-biologic fixation. We used a pediatric feeding catheter to facilitate the passage of the nonabsorbable suture and the graft around the base of the coracoid process. The graft was passed from medial to lateral under direct visualization.

After passing beneath the coracoid, the limbs of the graft were crossed before being shuttled through the bone tunnels. The graft was passed through the posteromedial tunnel first. The graft was then loaded cyclically by pulling up on both ends in order to remove any slack, and see-sawed back and forth to ensure easy passage.

Graft fixation

The AC joint was reduced by pushing up on the elbow to elevate the scapulohumeral complex. Before fixation, the quality of reduction was examined visually to ensure acceptable reduction. Although an assistant maintained the reduction, a K-wire or more was introduced through the AC joint to further maintain the reduction, and allowed the graft to be secured tightly. The grafts were secured by tying it and suturing the tendons on themselves above the clavicle. We used nonabsorbable sutures to secure the tendons to the surrounding soft tissues. The number 3 high-strength nonabsorbable suture that accompanied the graft was tied on the superior aspect of the clavicle for additional security. The remnants of the CC ligaments were not directly repaired as they were approximated with tightening of the graft and left to heal naturally. The K-wire was removed 4 weeks later, when the soft tissue healed around the graft. We used this maneuver in all patients in the study.

Closure

A suction drain number 12 was used in all patients in the study. The deltotrapezial fascia was closed with interrupted nonabsorbable sutures. This was a critical step and great care should be exercised. Both attachments of the anterior deltoid fascia and the trapezius fascia were brought together with interrupted stitches. The knots were placed on the posterior side of the flap to minimize skin irritation. The deep dermal layer was closed with buried 3.0 vicryl sutures, and a running subcuticular closure was used on skin.

Postoperative follow-up

The suction drain was removed after 2 days. Sutures were removed at 2 weeks. Patients were seen at 1, 2, 3, and 6 months and then annually. Postoperative radiographs included bilateral AP and axillary views to measure the coracoid–clavicular distance.

Rehabilitation

A pouch arm sling with a shoulder immobilizer was worn for 6 weeks. Pendulum exercises were begun at 4 weeks, with limitation of passive external rotation to 30° and passive forward flexion to 90°. Active range of motion was started at 8 weeks. Strengthening was started at 12–16 weeks. Sports-specific activities and return to full athletics were allowed at 16–24 weeks. Return to heavy labor was allowed at 6 months.

Results

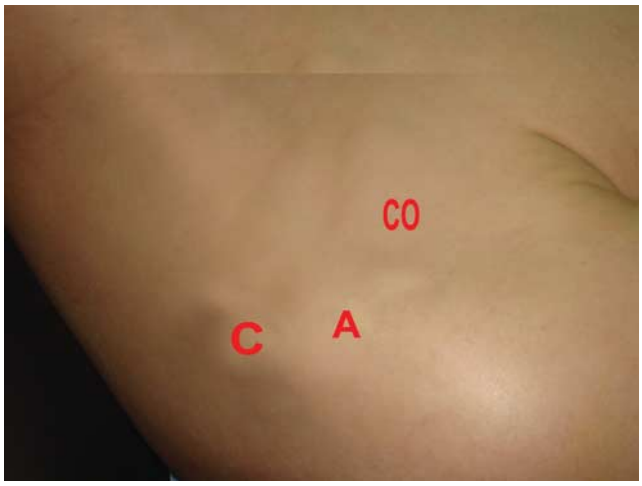
Clinical results

Twelve patients with acute grades III–V AC joint dislocations of traumatic etiology were treated surgically by anatomic reconstruction of the CC ligament using an autogenous semitendinosus tendon graft at the Zagazig University Hospitals. They were followed up for 12–18 months; the mean follow-up period was 14.3 months. On the visual analogue scale, the pain improved from an average 6.2 points (range 3–9 points) preoperatively to an average of 2.3 points (range 0–6 points) postoperatively. No patients had pain at rest.

In terms of the range of motion, 10 patients regained full range of motion as compared with the opposite shoulder, whereas two patients had limitation of abduction of 15 and 20° as compared with the opposite shoulder.

During the postoperative evaluation, the clinical functional result was determined using the score of Imatani scoring system [27], which was specifically designed to evaluate acromioclavicular joint injuries. This scale assigns 40 points for pain, 30 for function and strength, and 30 for motion. For greater accuracy, we clearly asked

Figure 1



Landmarks of skin incision (A) acronion; (C) clavicle (distal end); (CO) coracoid process.

the patients about the exact location of pain and recorded only the pain related to the acromioclavicular joint. A score of 90– 100 was deemed excellent; 80–89 good; 70–79 fair; and less than 70 poor. Eight patients in the study showed excellent results, three patients showed good result, and one showed fair results.

We encountered two complications in this study (16.6%); one patient showed residual prominence of the distal end of the clavicle without any clinical discomfort and the other patient showed severe infection 1 week after surgery that resolved completely following treatment with the appropriate antibiotics for 4 weeks. This patient developed bony ossification and fusion of the AC joint with residual shoulder pain that required oral analgesics. The results were satisfactory in 11 patients (92%) and unsatisfactory only in one(8%).

Radiologic results

On the AP view, the mean CC distance decreased from an average of 16 mm preoperatively (range 10–26 mm) to an average of 12 mm postoperatively (range 9–22 mm). Posterior displacement of the distal clavicle on the axillary view decreased from an average of 15 mm preoperatively (range 8–24 mm) to an average of 8 mm postoperatively (range 5–18 mm). The decrease in the CC distance and the posterior displacement was statistically significant ($P<0.01$) (Figs 1–4).

Discussion

The surgical techniques available for reconstruction of the injured AC joint are varied and evolving. There are over 100 different surgical procedures for reconstruction of the AC joint, implying that there is no ideal method of reconstruction.

A review of the literature yielded five main surgical techniques: fixation across the AC joint, dynamic muscle transfer, fixation between the clavicle and the coracoid, reconstruction of ligaments, and excision of the distal clavicle. Because of its high rate of clinical success, lesser amount of soft tissue dissection, and relatively low incidence of complications, CC reconstruction has become a more common surgical procedure for the treatment of severe AC joint injuries [29].

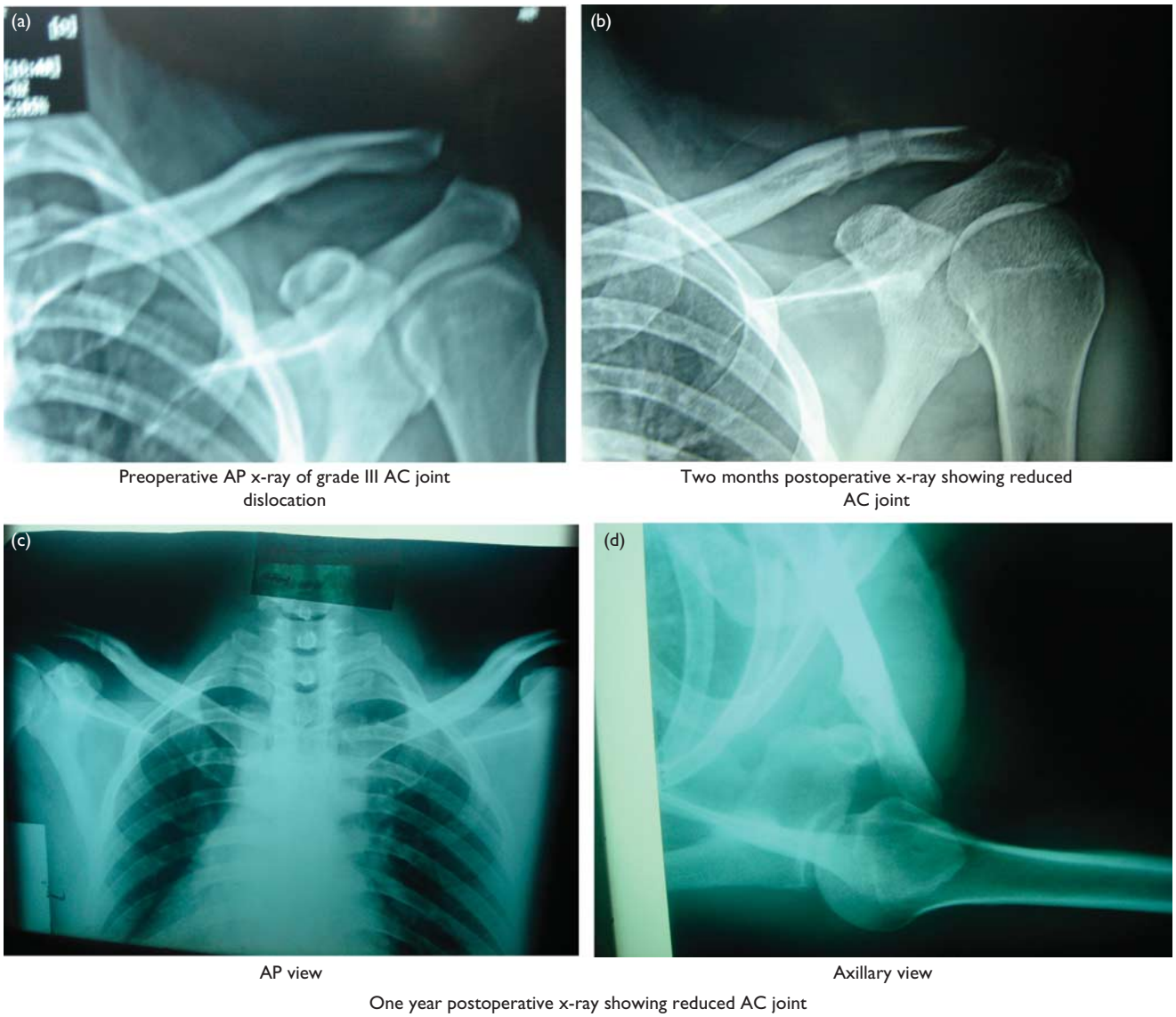
The functional anatomy of the coracoclavicular ligaments has been well described. Owing largely to cadaveric studies, the attachments of the CC ligaments have been localized precisely to the base of the coracoid and the inferior surface of the clavicle, with the conoid originating more medially from the coracoid base and the trapezoid lying more laterally [30]. Fukuda [5] found the conoid ligament to be the primary restraint to anterior and superior displacement of the distal clavicle. Lee [31] showed that the trapezoid is a major restraint to posterior displacement of the clavicle. Both authors concluded that under significant stresses, the CC ligaments together are the primary stabilizers of the AC articulation. By addressing the primary pathology of complete AC joint dislocations, CC ligament reconstruction can successfully restore normal AC joint function. The majority of methods utilized to reconstruct these ligaments involve an open surgical dissection. Open reconstruction of the CC ligaments is a widely accepted technique for operative treatment of significant AC joint separations. Open reconstruction achieves the goals of restoration of AC joint anatomy and function and has yielded excellent results with long-term follow-up [32].

With the semitendinosus tendon graft, we aimed at anatomic reconstruction of the AC joint and its ligamentous properties. We reported successful AC reconstruction after recent AC dislocations and utilized a procedure, based on the use of autogenous semitendinosus graft, which allows for both satisfactory functional outcome and a low complication rate, with excellent or good results in 92% of the patients with full return to previous activities in 12 months.

In this study, patients with grade III AC were included, even if their surgical treatment had been questioned by other authors [33]. In fact, the severity of these injuries is often underestimated in primary diagnosis and, during surgery, most of them are found to be grades IV and V [34]. In the literature, early repair of AC dislocations has been reported to result in good clinical outcome. However, treatment of chronic AC dislocation is usually less effective and characterized by a higher complication rate and lower patient satisfaction [22]. Bannister *et al.* [35] reported that when reconstruction is performed more than 3 months after trauma, results are significantly worse, probably because of the presence of abundant scar tissue and muscle retraction.

The greatest challenge to reconstructive procedures for AC separation has been loss of reduction. In the case of Weaver–Dunn, this occurs in up to 24% of patients and is associated with inferior clinical results [24,32,36]. This may be occurring because the AC ligament has only 20% of the ultimate strength of the CC ligaments. Jari *et al.* [37] evaluated the biomechanical properties of a coracoacromial

Figure 2



(a) Preoperative anteroposterior (AP) radiograph of grade III acromioclavicular (AC) joint dislocation. (b) Two-month postoperative radiograph showing reduced AC joint. (c) One-year postoperative radiograph showing reduced AC joint. (d) AP and axillary view.

transfer and found that the stiffness of this repair is significantly less than that of the native CC ligaments.

This has led to the development of the ACCR, which aims to recreate the anatomy of the CC ligaments and utilize stronger graft materials. Multiple biomechanical studies have shown that anatomic reconstructions with a free tendon graft have greater stability and load to failure than the traditional Weaver–Dunn procedure, and also more closely reproduce the function of the native CC ligaments [38–41]. More importantly, this improvement in biomechanical properties may result in better clinical outcomes.

Tauber *et al.* [42] prospectively compared the traditional Weaver–Dunn reconstruction and a CC reconstruction with a semitendinosus allograft in 24 patients with grades III and V separations. The CC ligament reconstruction resulted in significantly better clinical and radiographic outcomes.

We believe that during the healing period, the tendon graft has to be protected by temporary augmentation. We used K-wires across the AC joint in all our cases. We did not encounter implant complications, such as breakage or migration, but we were very careful to closely monitor our patients by regular radiologic examinations and removed the wires exactly 4 weeks after surgery in all cases. In one patient, loss of reduction occurred but without an adverse effect on the clinical outcome.

A potential pitfall of this technique is 'blowout' of the posterior or the anterior cortex when preparing the posteromedial and anterolateral tunnels. To prevent this, the drill bit should be placed far enough away from the posterior cortex when drilling the conoid tunnel and far from the anterior cortex when drilling the trapezoid tunnel. In addition, to prevent fractures, there should be a 20–25 mm distance between the two tunnels and the trapezoid tunnel should not be placed any closer than 15 mm from the end of the

Figure 3

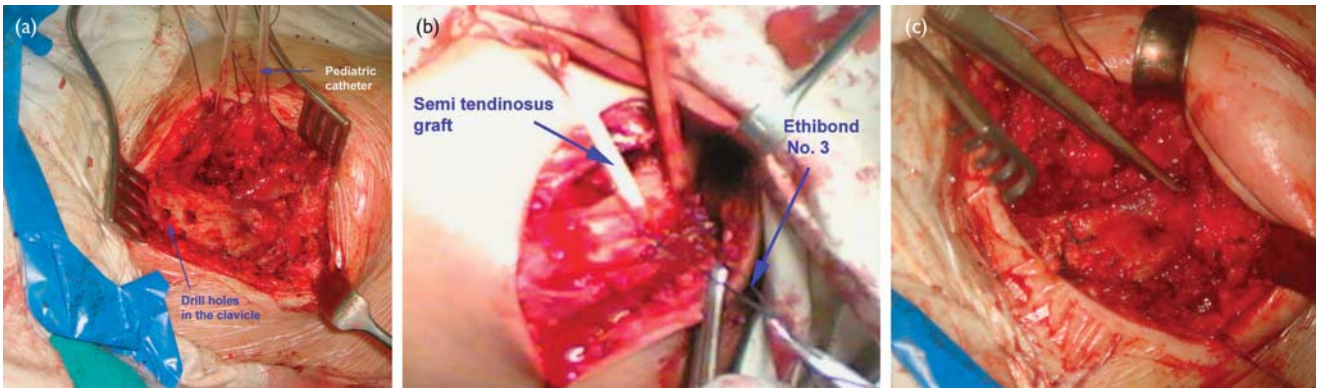
Preoperative AP x-ray of grade IV AC joint dislocation

Preoperative photo with significant prominence of the distal clavicle

Postoperative AP x-ray showing reduced AC joint

(a) Preoperative anteroposterior (AP) radiograph of grade IV acromioclavicular (AC) joint dislocation. (b) Preoperative photo with significant prominence of the distal clavicle. (c) Postoperative AP radiograph showing reduced AC joint.

Figure 4



Intraoperative photos.

clavicle. In our study, we did not encounter clavicular fractures; this may be attributed to the gradual drilling technique that we utilized with small to large diameter drill bits.

The final good results were attributed to the healing of the tendon graft. Although additional fixation by nonabsorbable sutures is used, the strength of

the nonabsorbable suture is known to decrease over time.

This study suggests that reconstruction of recent grades III–V AC dislocation is an effective procedure that allows for anatomic reconstruction of the CC ligament with a consequently excellent outcome.

Conclusion

Our case series represents a single reconstructive technique and does not allow for direct comparisons. We can state that coracoclavicular reconstruction using a semitendinosus tendon graft provides satisfactory results. This method aims at a reconstruction in which the course of the slings of the tendon is very close to the course of the original CC ligaments. This technique could be an alternative to the Weaver–Dunn procedure. Further investigation, including a larger number of patients, is required. The one disadvantage that has to be considered is that a tendon must be harvested from another region. Further long-term follow-up studies are required to ultimately assess the long-term efficacy of this procedure.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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