Scientific Research Publishing

Journal of Biosciences and Medicines, 2025, 13(4), 300-319
https://www.scirp.org/journal/jbm
ISSN Online: 2327-509X
ISSN Print: 2327-5081

A Case Series of Arthroscopically Assisted Anatomical Coracoclavicular Ligaments and Acromioclavicular Joint Reconstruction in Chronic High-Grade Acromioclavicular Joint Separations

Lye Hock Tan[1], Salleh Sazali[1], Mohd Rofi Mohd Hafiz Syazwan[2], Zhuang Li Lim[1], Abdullah Mohd Firdaus[1], Khalid Khairullina[1]

[1]Sports Clinic, Department of Orthopaedics and Trauma Surgery, Tengku Ampuan Afzan Hospital, Kuantan, Malaysia
[2]Sports Clinic, Department of Orthopaedics and Trauma Surgery, Sultanah Nur Zahirah Hospital, Kuala Terengganu, Malaysia
Email: lyehocktan1980@gmail.com

How to cite this paper: Tan, L.H., Sazali, S., Syazwan, M.R.M.H., Lim, Z.L., Mohd Firdaus, A. and Khairullina, K. (2025) A Case Series of Arthroscopically Assisted Anatomical Coracoclavicular Ligaments and Acromioclavicular Joint Reconstruction in Chronic High-Grade Acromioclavicular Joint Separations. *Journal of Biosciences and Medicines*, **13**, 300-319.
https://doi.org/10.4236/jbm.2025.134025

Received: March 11, 2025
Accepted: April 19, 2025
Published: April 22, 2025

Abstract

Introduction: Acromioclavicular (AC) joint separation is regarded as a common shoulder girdle injury that disrupts the anatomical and functional linkage between the upper extremity and the trunk. Various surgical techniques have been developed to treat high-grade AC joint disruption, with convincing clinical outcomes. There are numerous complications that need to be aware of and reduced to ensure consistent positive treatment results. **Methods:** This was a retrospective report of 6 cases (5 male; 1 female; mean age 25.7 years) of arthroscopically assisted AC joint and coracoclavicular (CC) ligaments anatomical reconstruction for chronic high-grade (Rockwood type IIIB - V) AC joint injury. Patient-reported clinical outcomes and complications encountered were acknowledged and highlighted. The average time from injury to surgery was 194.3 days. **Results:** The American shoulder and elbow surgeons (ASES) score for the 6 patients increased with a median of 36 at pre-operative to 77.5 at 6 months post-operative and 92.5 at final follow-up. The Visual Analogue Scale, VAS for pain showed improvements from the median of 5.5 at pre-operative to 3.0 at 6 months post-operative and 1.0 at final follow-up. Three patients had tolerable shoulder discomfort post-operatively. Two clavicle tunnels widening (cTW) were detected. One patient presented with loss of reduction (LOR). No infection was encountered post-operatively. All the patients regained full shoulder range of motion post-operatively. No concomitant intraarticular pathology was detected during surgeries. **Conclusion:** Arthroscopically assisted AC joint and CC ligament anatomical reconstruction with

biological graft is a feasible and promising technique to treat chronic AC joint separations. This minimally invasive approach enables accurate implant and graft placement and reduces soft tissue disturbance to the minimum.

Keywords

Acromioclavicular Joint Separations, Coracoclavicular Ligaments, Arthroscopic Assisted, Chronic High-Grade Rockwood

1. Introduction

A little over a century has passed since the first introduction of treatment for acromioclavicular (AC) joint instability by Cadenet in 1917 [1]. In contrast to the pale options in conservative treatment for AC joint instability, surgical or operative treatments seem to be derived in various forms. More than 150 techniques have been described for the surgical treatments of AC joint injury [2]. Wide range of complication rates have been reported from 5% to 30% of cases [3]. ACJ injuries are fairly common with an incidence of 12% of all shoulder girdle injuries [4]. Higher prevalence was seen in male in their 20 to 30 decades participating in high-contact sports [5]. High-impact injury to the shoulder results in disruption of the stabilizing structures around the AC joint. Falling from height, road traffic accidents and high-energy contact sports are among the common causes of AC joint injuries. The common occurring mechanism of injury is a direct impact to the acromion with an adducted shoulder. The force will drive the acromion inferiorly from the clavicle, which then starts the cascade of disruption of the AC ligaments, followed by the coracoclavicular (CC) ligaments. Indirect mechanism of injury describes an abducted arm causing the humeral head to impact onto acromion, forcing it to displace superiorly from the clavicle.

2. Anatomy

2.1. Acromioclavicular Joint

The AC joint is a diarthrodial joint formed by the lateral end of clavicle and medial part of acromion. AC joint is one of the important parts of the larger superior shoulder suspensory complex (SSSC) [6] [7]. It is the sole link that connects the upper extremities to the axial skeleton. The clavicular and acromial articulating surface has a hyaline cartilage coverage with a fibrocartilaginous disk in between with a thickness of 1.5 to 4mm [8], that will undergo degeneration between the 2nd and 4th decades of life [9]. The AC joint has a relatively thin capsule where stability is contributed by both static and dynamic constraints. The AC ligaments are the focal thickening of the AC capsule. In contrast to the perceptions by the majority that AC ligaments consist of anterior, posterior, superior and inferior components [10] [11], Nakazawa *et al.* grouped superoposterior (SP) and anteroinferior (AI)

as 2 distinctive ligament complexes of the AC joint [12]. The AC ligaments mainly resist antero-posterior translation of the AC joint while also offer restraint against posterior axial rotation of the clavicle [13].

2.2. Coracoclavicular Ligaments

CC ligaments play an important role in superoinferior stability and resisting larger displacement force, to a lesser extent providing rotational stability and stability with protraction and retraction of the scapula [13] [14]. The conoid and trapezoid ligaments, which are positioned at anteromedial and posterolateral respectively, connect the clavicle and the coracoid. The more medially located conoid ligament inserted about 4.6 cm whereas the trapezoid ligament has its center located at 2.5 cm from the lateral edge of the clavicle [15]-[17]. The average distance between the clavicle and the coracoid process ranges from 1.1 to 1.3 cm [18].

The additional stability of the AC joint is contributed by the dynamic stabilizers which comprise of dynamic stabilizers which are the trapezius and deltoid musculofascial attachments [19] [20]. Instability of the AC joint is caused by injuries that disrupt the integrity of the static and/or dynamic stabilizers of the AC joint.

3. Classification of Injuries

Tossy *et al.* developed a classification system for AC joint injuries in 1963 [21], which was then expanded by Rockwood to become the 6-part classification which is widely utilized to date [22].

Rockwood Types I and II injury are stable or low-grade injury which non-operative treatments are the first to be considered [10]. Conservative management has shown favorable outcome, higher return to activities and less complications [23] [24] (**Table 1**).

The other side of the injury spectrum, which consists of high-grade Types IV, V and VI, require surgical treatments to restore the integrity and functionality of the AC joint [14] [24]. Type IV injuries involve the complete tear of the AC, CC ligaments and trapezial fascia injury with the posterior displacement of the distal clavicle. Type V AC joint separation is characterized by a bigger gap of CC space and the irreducible penetration of distal clavicle through a torn deltotrapezial fascia. In Type VI injuries, the mechanism of hyperabduction and external rotation causes the distal clavicle to be inferiorly dislocated into subacromial or subcoracoid with the detachment of trapezius and deltoid at the insertion sites.

Much debatable is the Type III injury where non-operative and operative treatments have their respective proponents. The optimal managements for Type III injury still remain controversial [25]. A consensus had been established that Type III injuries to be further divided into stable (IIIA) and unstable (IIIB) based on functionality assessment [24]. Initial conservative treatments are allowed for Type III injuries with reassessments after 3 - 6 weeks. The presence of persisting pain, shoulder dyskinesia and overriding distal clavicle on acromion on cross body adduction radiographic view during reassessment points towards an unstable

Table 1. AC joint injuries with associated clinical and radiological findings.

Type	AC Ligaments	CC Ligaments	Radiographic Displacement	Physical Examination
I	Sprained/ Partially Torn	Intact	None	Tenderness at ACJ, provocative tests positive
II	Ruptured	Sprained/ Partially Torn	Minimal	ACJ subluxation/displacement with provocative stress
III	Ruptured	Ruptured	Increased CC Distance 100%	Superior displacement of the distal clavicle Acromion and shoulder girdle inferior to distal clavicle
IV	Ruptured	Ruptured	Clavicular Posterior Displacement Through Trapezius	Palpable distal clavicle posteriorly through trapezial fascia Associated anterior (sternoclavicular) SC joint injury/dislocation
V	Ruptured	Ruptured	Increased CC Distance 100% - 300%	Gross superior displacement of distal clavicle and inferior translation of acromion/scapular complex Trapezial and deltoid fascia protrusion and skin tenting
VI	Ruptured	Ruptured	Clavicular Inferior Displacement (Subacromial/ Subcoracoid)	Palpable defect and displaced distal clavicle Rule out associated neurovascular injury

Type IIIB injuries which surgical intervention is recommended. Inability to pursue with daily activities, work or sport due to irretractable pain, is the valid reason to warrant for a subsequent surgical treatment.

Time of injury is among the determining factors for interventions and outcomes of treatments. AC joint ligaments lose the potential to heal after 3 weeks post injury [26]. A consensus among the ESA-ESSKA members recommended that 3 weeks from injury is the time point to distinguish between acute and chronic injury.

4. Surgical Treatments

The surgical interventions for unstable AC joint injuries had seen much diversification, from the earlier open techniques to the current arthroscopic assisted method, rigid versus non-rigid fixation, anatomical versus non-anatomical reconstruction, and graft versus non-graft reconstruction. Most of the techniques that evolved to date were improvements or combinations of historically described techniques. In 1941, Bosworth described an anatomic fixation of the clavicle to the coracoid using a non-cannulated lag-screw fixation technique [27]. Rigid fixation using coracoclavicular screw fixation or hook plate fixation require hardware removal in 8 to 12 weeks post-operatively to prevent screw migration and hardware failure. The motions between coracoid and clavicle can lead to implant fatigue and failure over time [28]. Tsou reported a high percentage of failure (32%) in 17 of 53 patients who underwent percutaneous cannulated screw fixation [29]. Although hook plate fixation of the AC joint provides a stable fixation and higher American shoulder and elbow surgeons (ASES) score and lower VAS scores, it causes subacromial erosion and requires removal later [30]. They saw all patients' post hook plate removal

showed an increase in the CC distance. Yoon *et al.* reported as high as 9 of 24 patients treated with hook plate had subacromial erosion [31]. Hardware removal and implant failure were among the reasons for the decrease popularity of rigid fixation.

Weaver-Dunn procedure received much attention during its introduction in 1972 as one of the important treatments for AC joint separation using coracoacromial ligament transfer [32]. However, this non-anatomical reconstruction technique has lost its enthrallment as anatomical restoration of the AC joint separation became the mainstream treatments.

Anatomical reconstruction of the AC joint had shown better postoperative outcomes compared to non-anatomical reconstruction [33] [34]. A cadaveric study by Mazzocca comparing between arthroscopic reconstruction, anatomical CC ligament reconstruction and modified Weaver-Dunn procedure, concluded that the anatomical CC reconstruction has less anterior and posterior translation and more closely approximates the intact state of the AC and CC ligaments, restoring their functions [35]. A series of anatomical reconstructions showed a good preliminary result with improvements in American shoulder and elbow surgeons (ASES) score and Constant-Murley score [36].

4.1. Arthroscopic Assisted

Arthroscopic stabilization of AC joint instability has gained much attention in recent years. Apart from its minimal invasive benefit, arthroscopic assisted CC ligament reconstruction is also advantageous in the detection and treatment of associated glenohumeral pathologies in patients with AC joint dislocation. Pauly *et al.* reported traumatic intraarticular lesions in 14% of patients presented with high-grade AC joint dislocations [37]. This was echoed by Tischer *et al.* who reported 18.2% of patients with acute high-grade AC joint dislocations, displayed concomitant intraarticular injuries with superior labral anterior posterior (SLAP) lesion being the commonest [38]. Boileau *et al.* found that 48% and 30% of patients with chronic and acute AC joint dislocation respectively, had intra-articular lesions that can easily be missed during isolated open AC joint repair [39]. A study by Markel *et al.* found that about 40% of patients with AC joint injuries had associated concomitant injury during diagnostic arthroscopy, with the percentage rises to 57.3% in patients over 35 years of age. The most commonly detected pathologies were rotator cuff injuries, SLAP lesions and chondral defects [40].

A retrospective study by Jensen *et al.* showed 53% of the total of 376 patients who underwent arthroscopic assisted stabilization of AC joint injuries, had on or more concomitant glenohumeral pathologies. Repairs were performed in 45 patients (12%) and the remaining 156 patients had a debridement. Jensen *et al.* also concluded that a concomitant glenohumeral pathology was significant in patients with higher grades of AC joint injuries, chronic injury and increasing age. Biceps tendon complex and rotator cuff lesions are the leading concomitant pathologies found, followed by chondral lesions [41].

Natera-Cisneros *et al.* found that patients who underwent arthroscopic CC ligament reconstruction had higher global satisfactory rate and lower post-operative VAS score compared to hook plate fixation [42]. Another study comparing arthroscopic procedure and hook plate also saw improved post-operative Constant-Murley scores [43].

However, there were studies that showed no statistical significance in outcome scores between open and arthroscopic methods. Vrgoč *et al.* found that using open method Kirschner wire with FiberTape and arthroscopic TightRope System had equally good clinical outcomes with no significant difference between both [44]. Li *et al.* noticed no statistically significant difference in ASES score and University of California Los Angeles (UCLA) Shoulder Score when comparing arthroscopic CC ligaments reconstruction with the modified Weaver-Dunn procedure [45].

Faggiani *et al.* in their cohort study consisted of 16 patients, found that patients treated with mini-open technique returned to their sport significantly earlier, whereas arthroscopic assisted technique achieved significantly better in objective Constant-Murley Score parameters [46]. One retrospective study by Behrens *et al.* concluded that both mini-open technique and arthroscopic technique used for AC joint stabilization had equally excellent clinical and sonographic outcomes [47].

Dyrna *et al.* and Saier *et al.* proposed that AC joint capsule should be reconstructed to prevent horizontal and rotational instability of the AC joint [2] [48]. Reconstruction of the AC ligament at the optimal location will provide additional stability in resisting horizontal and rotational forces acting on the AC joint, thus reducing the risk of AC joint reconstruction failure.

Several mechanisms for failure of AC joint reconstruction have been reported which included hardware migration, persistent pain, distal clavicle osteolysis, clavicle fracture, coracoid fracture, graft failure and recurrent separations [49]. Generally, the establishment and advance in arthroscopy surgery as a minimal invasive procedure over the years has advantages over open surgical methods. Arthroscopic or arthroscopically assisted techniques of AC joint reconstruction provide better visualization of the base of the coracoid, lesser dissection and smaller incisions [50], besides enables the surgeons to identify and treat associated pathologies within the glenohumeral joint or subacromial space simultaneously [51].

4.2. Complications

There were significant discrepancies among literature reporting the outcome results and complications. Contrary to the excellent functional outcomes following AC joint reconstruction, the other end of the result spectrum showed some significant complication rates of arthroscopic or arthroscopically assisted techniques which included hardware erosion into the clavicle [52], hardware failures [53], persistent pain, infection, clavicle or coracoid fractures, CC ligament calcification and shoulder stiffness [54] [55]. In a systemic review by Woodmass *et al.*, the 5 most

commonly documented complications were CC calcification (31.6%), loss of reduction (26.8%), shoulder pain (26.7%), fracture (5.3%) and infection (3.8%) [56]. Postoperative shoulder pain was mainly caused by capsulitis, hardware irritation and AC joint pain. The most significant finding of the review was the high rate of failure following arthroscopic allograft or autograft ligament reconstruction, especially in patients with chronic AC joint separations and when tunnels were involved in the coracoid or the clavicle. Fractures of the coracoid and the clavicle had been reported when multiple drill holes for fixation were performed [3]. Milewski *et al.*, in a series, found that high complications especially fractures of the coracoid and the clavicle in cases where the tunnel technique was used [57]. Loss of reduction (LOR) was another postoperative complication noted in chronic high grade AC joint separations. Chen *et al.* found that 14% reduction failure in their open approach endobutton fixation was due to the early commencement (<6 weeks) of weight bearing of the operated upper limb [58].

5. Objective

The objective of this series was to identify the advantages of arthroscopic assisted anatomical reconstruction of chronic AC joint separation in the aspects of patient reported outcomes and the possible complications that would arise from the approach practiced.

6. Method

We retrospectively reported 6 (5 male, 1 female) chronic high grade AC joint injury cases who underwent arthroscopically assisted AC joint reconstruction surgery between year 2018 to 2023. Patients who had completed follow-ups and were discharged from the clinic were included. The small number of cases was due to inadequate data as some patients did not attend follow-ups. The mean age was 25.7 years-old (range, 21 - 30 years-old) at the time of injury. The mechanism of injury was due to various degrees of severity of motor vehicle accidents. The mean duration of follow-up was 39.6 months (range, 24 - 56 months). The demographic data of the patients was shown in (**Table 2**). The average time from injury to surgery was 194.3 days (range, 21 - 461 days).

Table 2. Demographic summary of chronic coracoclavicular ligament and acromioclavicular joint reconstructions.

Patient	Sex	Age (year)	Side	Rockwood Type	Time to Surgery (day)	Folow-up Duration (month)	Complications
C1	M	29	RIGHT	IV	86	56	Discomfort over shoulder, tunnels widening
C2	M	25	RIGHT	IIIB	282	42	Discomfort over shoulder
C3	F	25	RIGHT	V	39	44.5	Dull pain over shoulder
C4	M	24	RIGHT	V	277	43	Nil
C5	M	30	RIGHT	IV	461	28	Nil
C6	M	21	LEFT	V	21	24	Loss of reduction, tunnels widening

All the 6 cases had arthroscopically assisted anatomical CC ligament reconstruction done with a knotless suture-button system (Arthrex, Naples, FL) and autologous hamstring (semitendinosus) graft. The AC joint was also reconstructed with FiberTape, and the AC joint capsule and deltotrapezial fascia were repaired. The surgeries were performed with the patients on beach-chair position under general anesthesia. A C-arm coming in from the contralateral side was used to confirm the AC joint anatomical reduction and fluoroscopy assessment. The operated arm was left free to rest on patient's body without using any arm holder. The injured upper limb, shoulder and ipsilateral lower limb were cleaned and draped in a sterile manner.

A standard diagnostic shoulder arthroscopy was performed with a 30˚ arthroscope via a standard posterior viewing portal. An anterior portal just lateral to the coracoid was created, through the rotator interval, for subcoracoid debridement to expose the inferior surface of base of the coracoid. An anterolateral portal was created for the viewing of the coracoid undersurface. Simultaneously, the semitendinosus tendon was harvested from the ipsilateral lower limb through an anteromedial approach on the tibia. A horizontal incision along the axis of the clavicle was made 5 cm medial from the AC joint and extended 2 cm lateral to the AC joint. The superior, anterior and posterior borders of the clavicle which correspond to the attachment of the CC ligaments on the clavicle was adequately exposed for later drilling of tunnels. The AC joint was adequately debrided and assessed. Any invaginated tissue was released and debrided to facilitate the reduction of the joint.

A 1.6 mm Kirschner wire was temporarily inserted percutaneously across the AC joint to maintain the reduction with the C-arm guidance. An AC aiming guide (Arthrex, Naples, FL) was inserted through anterior portal with the aiming arm at the undersurface of the coracoid. The drilling sleeve was put at the superior of the clavicle, 3.5 cm medial to the AC joint, centered anterior to posterior. Drilling was performed with a 3.0 mm cannulated drill (Arthrex) at the superocentral part of the clavicle to avoid being too anterior or posterior to the rim that would increase the risk of clavicle fracture. Direct arthroscopic visualization of the undersurface of the coracoid was performed during drilling of the clavicle till the cannulated drill exited the designated center part of the coracoid undersurface (**Figure 1**). By adjusting the aiming device under the coracoid and the sleeve above the clavicle, two tunnels for the semitendinosus graft passage were drilled 1.0 cm medial and 1.0 cm lateral to the first tunnel with 5.0 mm cannulated drill bit. The drilling was ensured at central position anterior to posterior on the superior clavicle. The drill bit's exit on medial and lateral of the coracoid were directly visualized with arthroscope. Double loaded knotless CC fixation device (Knotless AC TightRope device, Arthrex) with cortical fixation button (Dog Bone, Arthrex) was then shuttled from coracoid to clavicle. The cortical fixation button was manipulated to sit snugly on the undersurface of the coracoid under direct arthroscopic visualization. Another cortical fixation button was attached to the tight rope on the superior part of the clavicle. The FiberTape was then pulled and

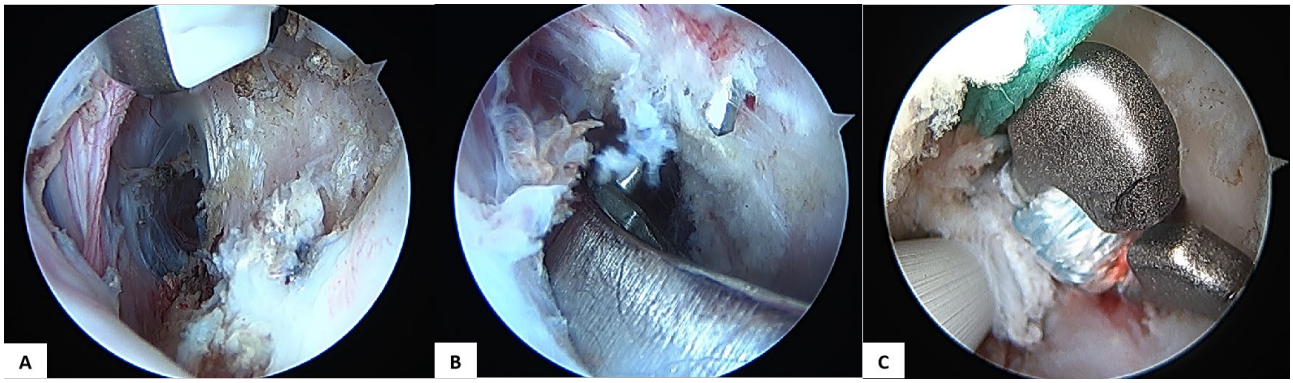

Figure 1. Arthroscopic view of coracoid undersurface. (A) Debridement of coracoid base; (B) Drilling at the center of coracoid base with aiming guide; (C) Dog bone button on undersurface of coracoid. Ethibond suture (green) was to shuttle the semitendinosus graft.

clipped temporarily to secure the AC joint reduction which was checked with C-arm fluoroscopy. Semitendinosus tendon graft was then shuttled through the 2 side tunnels to loop around coracoid undersurface. Further compression and reduction were done before knot was tied on the tight rope device. The graft was tied with a simple overhand throw on the superior part of the clavicle and further secured with a nonabsorbable suture. The temporary Kirschner wire was removed. The AC joint reduction was checked with the C-arm to ensure no reduction loss. Attention was then shifted to the AC joint where horizontal tunnels were drilled with 2.4 mm cannulated drill bit at the distal clavicle and the acromion, 1.0 cm and 1.5 cm from the AC joint respectively, in an anterior-posterior fashion. The remaining AC capsule was repaired with absorbable suture. FiberTape (Arthrex) was shuttled through the tunnels to make a figure of eight configuration to further compress and secure the AC joint reduction. C-arm fluoroscopy was performed to check final reduction of the AC joint. The deltotrapezial fascia was repaired securely with an absorbable suture before soft tissue closure in layers.

All the patients were put on abduction sling for 6 weeks. Cryocuff therapy was repeated every 2 hours on the operated shoulder. Post-operative isometric strength exercise was commenced as tolerated. Joint mobilization of the elbow, wrist and hand were encouraged. Pendulum exercise and gradual passive forward flexion of the shoulder from 0˚ to 90˚ and passive external rotation from 0˚ to 45˚ in adduction were started 2 weeks post-operatively. The abduction sling was removed after 6 weeks of surgery and progressive physiotherapy and rehabilitation with active range of motion and strength was started. Patients were being followed up post-operatively at 2 weeks, 6 weeks, 3 months and subsequently every 6 months.

7. Results

The American shoulder and elbow surgeons (ASES) score for the 6 patients increased with the median of 36 (range 15 to 82) at pre-operative to 77.5 (range 35 to 88) at 6 months post-operative and 92.5 (range 82 to 100) at final follow-up (**Figure 2**). All the patients returned to work 3 months post-operatively. All of them

were able to carry out daily activities without many difficulties as evidenced by the good ASES score at final follow-up. The Visual Analogue Scale for pain showed improvements from the median of 5.5 (range 2 to 8) at pre-operative to 3 (range 1 to 5) at 6 months post-operative and 1 (range 0 to 3) at final follow-up (Figure 3). The pain at their last follow-up was well tolerated and did not disturb their daily living and jobs.

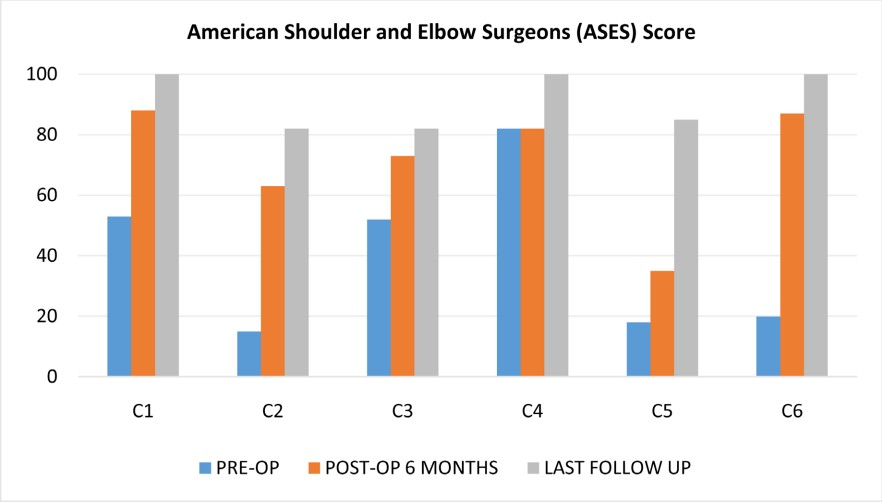

Figure 2. ASES score pre- and post-operative.

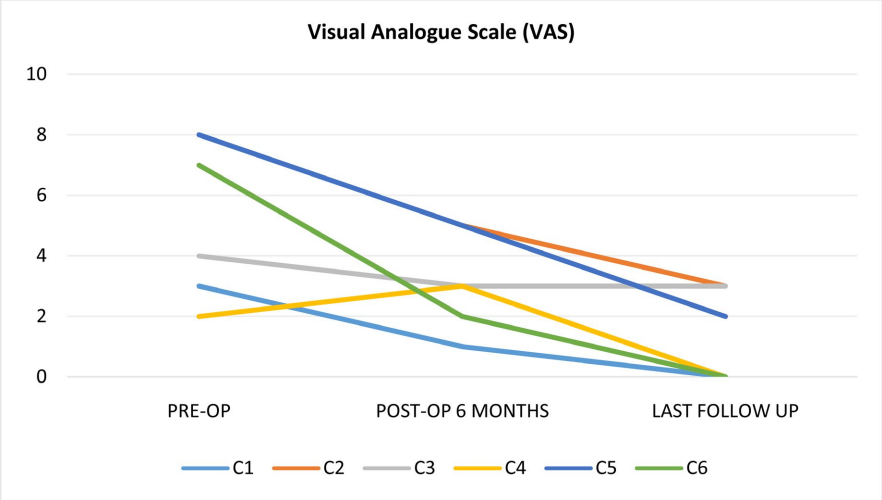

Figure 3. VAS pre- and post-operative.

Post-operatively, 3 patients experienced tolerable discomfort over operated side. One of the patients with shoulder discomfort showed clavicular tunnels widening (cTW). One of the 6 patients showed a loss of reduction (LOR) and cTW radiographically but without pain or discomfort (Figures 4-6). A 6 mm superior displacement of the clavicle was deemed LOR [59]. The LOR was recognized at 4 months after surgery, with a CC distance of 24 mm. The LOR was seen as a result of failed AC joint reconstruction which was evidenced by the FiberTape cut out

from the acromion. Two patients had no complication or complaint post operatively. No infection occurred on the patients post-operatively.

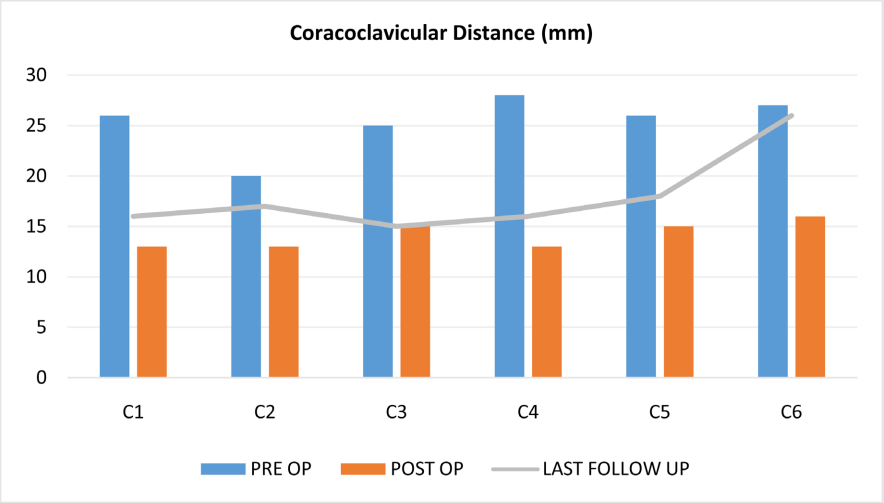

Figure 4. Coracoclavicular distance at pre-op, immediate post-op and final follow-up.

Figure 5. Plain radiographs of clavicular tunnels widening (cTW) with osteophytes adjacent to tunnels. (A) Pre-op; (B) Immediate post-op; (C) Final follow-up.

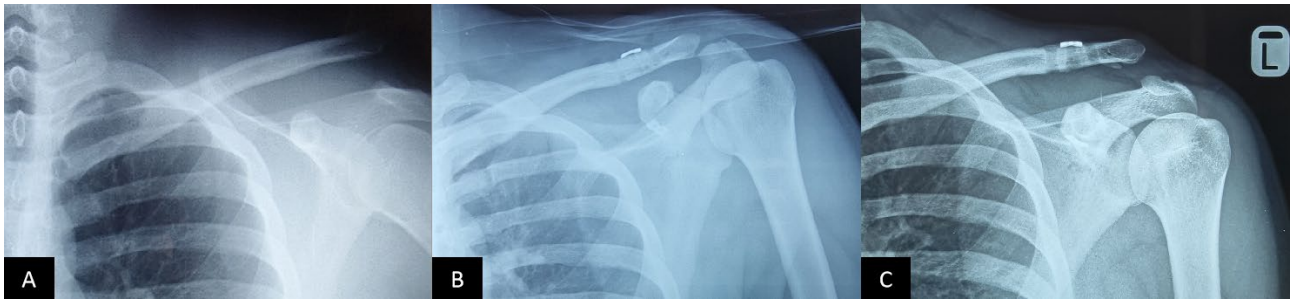

Figure 6. Plain radiographs of loss of reduction (LOR) and clavicular tunnels widening (cTW). (A) Pre-op; (B) Immediate post-op; (C) Final follow-up.

Three of the 6 patients presented with limited abduction and forward flexion which were below 90˚. The other 3 patients able to achieve full or near to full range in abduction and forward flexion. These 2 motions are essential in overhead activities which are greatly impaired in AC joint injuries. There was 1 patient who showed a reduced range of motion (ROM) in abduction, forward flexion, external

rotation and adducted internal rotation post-operatively at 3 months. The poor compliance with the physiotherapy programme was identified as the cause of the poor range of motion. The other 5 patients displayed progressive improvements in the ROM. Eventually, all the patients restored full functional range of motion at final follow-up without difficulty in carrying out their daily activities and jobs (Table 3). All the 6 patients returned to work at 3 months post-operatively.

Table 3. Functional shoulder ROM.

	Abduction			Forward Flexion			External Rotation			ADIR		
	Pre-op	Post-op 3 months	Last Follow-up	Pre-op	Post-op 3 months	Last Follow-up	Pre-op	Post-op 3 months	Last Follow-up	Pre-op	Post-op 3 months	Last Follow-up
C1	0 - 150	0 - 180	0 - 180	0 - 150	0 - 180	0 - 180	0 - 80	0 - 80	0 - 80	T12	T12	T12
C2	0 - 180	0 - 180	0 - 180	0 - 180	0 - 180	0 - 180	0 - 30	0 - 45	0 - 60	S1	S1	L1
C3	0 - 90	0 - 120	0 - 180	0 - 90	0 - 120	0 - 180	0 - 30	0 - 30	0 - 45	Buttock	L3	T10
C4	0 - 90	0 - 110	0 - 180	0 - 90	0 - 110	0 - 180	0 - 30	0 - 45	0 - 80	Buttock	L1	T8
C5	0 - 180	0 - 90	0 - 180	0 - 160	0 - 90	0 - 180	0 - 45	0 - 15	0 - 45	T12	L2	T12
C6	0 - 75	0 - 100	0 - 180	0 - 75	0 - 100	0 - 180	0 - 15	0 - 30	0 - 60	Buttock	L2	T10

ROM: range of motion; ADIR: adducted internal rotation; T: thoracic; S: sacral; L: lumbar.

8. Discussion

Injuries to the AC joint impaired the function and productivity of the patients. High grade AC joint separation involved the injury to the AC joint capsule, the CC ligaments and to some extent the rupture of deltotrapezial fascia. These circumstances required surgical intervention to restore the integrity of AC joint that formed the superior shoulder suspensory complex (SSSC) which is the essential link between the upper extremity and the trunk [60]. Various surgical techniques had been preferred with diverse outcomes. Biological augmentation with autologous or allogenous tendon grafts had been recommended for chronic injury reconstruction [61]. Complications of AC joint and CC ligaments reconstruction had been identified with CC ligament calcification, LOR and shoulder pain ranked as the commonest [56]. Coracoid and clavicular fractures occurred in reconstruction that involved tunnel drilling [57]. In our case series, discomfort at the operated site was the main issue the patients had. It was due to the soft tissue irritation by the prominent suture knots over the clavicle and around the AC joint. However, the discomfort was tolerable and none of the patients required second surgery.

The LOR noted on the patient was due to the FiberTape cut out from the acromion. Telltale sign was noted on radiograph during follow-up 2 months post-operatively, with a CC distance of 20mm. However, the patient did not have any discomfort or pain. Protected rehabilitation was carried out. Eventually, full range of motion of the shoulder was achieved. At the final follow-up, the CC distance was 26mm with cTW. No revision surgery was performed as the patient did not show

impairment from the reduction loss. The shallow tunnel drilled on the acromion was identified as the cause for the thin tunnel wall to break during AC joint motion. Subsequently, it led to the failure of the AC joint capsule repair and CC ligament reconstruction.

Another patient with cTW and shoulder discomfort did not show LOR radiographically. It was known that cTW was associated with recurrent vertical and horizontal instability [62]. However, the AC joint remained intact and stable clinically even cTW was evident radiographically. Osteophytes were observed on the undersurface of the clavicle adjacent to the tunnels.

Tunnels made on the coracoid and clavicle were the known risk of fractures to occur during or after CC ligament reconstruction [57] [63]. The risk of fracture was correlated to the number of tunnel and the diameter created. The strength reductions correlated highly with the ratio of the tunnel width relative to overall clavicle width [64]. A 6 mm diameter tunnel posed a higher risk for fracture than a tunnel with 2.4 mm diameter. Multiple fixation points and drill holes may increase the risk of coracoid and clavicle fractures (4% - 11%) [3]. Milewski *et al.* found a pooled complications of 80% in their coracoid tunnel group with 2 coracoid fractures which had tunnels of 5 mm and 6 mm diameter. In their coracoid loop group, complications of 35% were reported but without coracoid fracture [57]. LOR was relatively high in the coracoid tunnel group (50%) compared to the coracoid loop group (12%).

Chernchujit *et al.* found that anatomical AC joint reconstruction had a better outcome than AC joint fixation in respect of specific AC score (SACS) and posterior translation [65]. Complications rate of 17% was found in their study. In our series, the CC ligaments were anatomically reconstructed with semitendinosus graft in addition to FiberTape AC joint stabilization for that the torn CC ligaments in chronic high-grade injuries had lost the ability to heal over time. Reconstructing the CC ligaments with biologic graft option enables the AC joint reduction to be maintained by the restoration of the CC ligaments function as close as possible. This non-rigid reconstruction allowed some mobility of the clavicle at the AC joint which mimicked its native characteristics.

A 3.0 mm diameter tunnel was made as the central tunnel for the FiberTape and Dog Bone device fixation. The central tunnel was 3.5 cm medial to the AC joint. It was located halfway in between the native conoid and trapezoid ligaments insertion at the clavicular tubercles. The centers of conoid and trapezoid ligaments insertion on clavicles were at around 4.5 cm and 2.5 cm respectively, from the lateral edge of the clavicle [66]. Thus, the 5.0 mm diameter tunnels for the semitendinosus autograft passage were created according to the center of the footprints. The distance between tunnels and the proximity to the clavicle anterior posterior rim were adequately spaced to ensure no weak links and reduce the risk of fracture. Geaney *et al.* showed that tunnel placement in the clavicle corresponding to the attachment of the CC ligaments has the highest bone marrow density and correlates to higher loads to failure experimentally [67]. Single tunnel on the coracoid for the FiberTape

and graft loop around coracoid technique was performed to prevent the coracoid fracture risk. Figure of 8 FiberTape reconstruction was performed to reinforce the AC joint in addition to the capsule repair. It was shown that combined stabilization of the AC joint capsule and CC ligaments could restore the stability against rotational and translational loads [68].

The clavicular vertical tunnel graft fixation technique was preferred over the graft loop around clavicle or the horizontal tunnel graft fixation methods as vertical tunnel provides better graft fixation and smaller tunnel diameter to bone width ratio thus reduced the clavicle fracture risk. One study had found there were comparable average clavicle length between Chinese population and the Western population [69]. However, extra care must be taken when tunnels are made on the clavicle, especially in shorter clavicle where the midshaft has the lowest thickness compared to the sternal and the acromial part [17] [69].

Studies had shown that high grade AC joint injuries are associated with higher incidence of intraarticular lesions. Rotator cuff injuries, SLAP lesion and chondral lesion were the frequently encountered pathologies in patients with AC joint dislocations [37] [38] [40]. These intraarticular pathologies are consensually agreed upon that surgical intervention is required to prevent subsequent morbidity such as persistent pain and poor clinical functions. It is made possible to be detected through arthroscopic examination of the shoulder without excessive soft tissue dissection. Arthroscopic assisted AC joint reconstruction has the advantages of minimally invasive procedure, which allows the direct visualization of the coracoid and the glenohumeral joint [70]. In our series, we found no intraarticular lesions in all the 6 patients. The direct arthroscopic visualization of the coracoid undersurface enabled the accurate position of coracoid drill hole hence reduced the risk of coracoid process fracture or implant migration that could lead to fixation and reduction failures.

9. Limitation

This paper reported the series of chronic AC joint separation cases that were treated at our center. The report of this series was to share the experience of arthroscopic assisted anatomic reconstruction for chronic AC joint disruption at our center. First and foremost, the number of high-grade AC joint injuries presented to our center was not vast. Majority of AC joint injuries were treated acutely within 3 weeks, hence the small number in this series. Furthermore, some of the post-operative patients were lost in follow up and inadequate data was available to be included in this series. There was no objective measurement of the strength of the operated limbs to be compared and reported.

10. Conclusions

The surgical treatments of AC joint separations will still be debatable in the recent future as there is still no best method to treat it. There were mixed clinical outcomes in regard to the various types of surgical methods. The complications that arise

from AC joint surgeries are multifactorial and generally technical based. Larger-size studies on surgical techniques and outcomes are of high value for the betterment of AC joint injury treatments. From this small series of patients, we learned that a better surgical approach to treating AC joint injuries could be tailored with the combination of existing proven techniques. Although complications in anatomical reconstruction of chronic AC joint separation are significant, it is imperative to uphold established technical principles with stepwise approach to ensure good outcomes and minimize complications.

Heterogenous studies comparing different approaches to chronic AC joint disruption should be encouraged to refine the reliable treatments with reproducible good clinical outcomes. Homogenous longitudinal studies should be conducted to recognize a better surgical intervention. Arthroscopic-based AC joint reconstruction has shown its advantages of being minimally invasive, enabling simultaneous solution to intraarticular pathologies and direct visualization of the accurate placement of implant in CC ligaments reconstruction. Advancement of the future path in AC joint and CC ligaments reconstruction should be centered on arthroscopic or arthroscopically assisted approach.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Cadenat, F. M. (1917) The Treatment of Dislocations and Fractures of the Outer End of the Clavicle. *International Clinical Psychopharmacology*, **1**, 145-169.

[2] Dyrna, F., Berthold, D.P., Feucht, M.J., Muench, L.N., Martetschläger, F., Imhoff, A.B., *et al.* (2019) The Importance of Biomechanical Properties in Revision Acromioclavicular Joint Stabilization: A Scoping Review. *Knee Surgery, Sports Traumatology, Arthroscopy*, **27**, 3844-3855. https://doi.org/10.1007/s00167-019-05742-6

[3] Martetschläger, F., Horan, M.P., Warth, R.J. and Millett, P.J. (2013) Complications after Anatomic Fixation and Reconstruction of the Coracoclavicular Ligaments. *The American Journal of Sports Medicine*, **41**, 2896-2903. https://doi.org/10.1177/0363546513502459

[4] Lemos, M.J. (1998) The Evaluation and Treatment of the Injured Acromioclavicular Joint in Athletes. *The American Journal of Sports Medicine*, **26**, 137-144. https://doi.org/10.1177/03635465980260010801

[5] Fraser-Moodie, J.A., Shortt, N.L. and Robinson, C.M. (2008) Injuries to the Acromioclavicular Joint. *The Journal of Bone and Joint Surgery. British Volume*, **90**, 697-707. https://doi.org/10.1302/0301-620x.90b6.20704

[6] Goss, T.P. (1993) Double Disruptions of the Superior Shoulder Suspensory Complex. *Journal of Orthopaedic Trauma*, **7**, 99-106. https://doi.org/10.1097/00005131-199304000-00001

[7] Goss, T.P. and Owens, B.D. (2009) Fractures of the Scapula. In: *Rockwood and Matsen's the Shoulder*, Elsevier, 333-380.

[8] Heers, G., Götz, J., Schubert, T., Schachner, H., Neumaier, U., Grifka, J., *et al.* (2007) MR Imaging of the Intraarticular Disk of the Acromioclavicular Joint: A Comparison with Anatomical, Histological and *In- Vivo* Findings. *Skeletal Radiology*, **36**, 23-28.

https://doi.org/10.1007/s00256-006-0181-6

[9] Depalma, A.F. (1959) 20 The Role of the Disks of the Sternoclavicular and the Acromioclavicular Joints. *Clinical Orthopaedics and Related Research®*, **13**, 222-233.

[10] Rockwood, C.A. (1990) Disorders of the Acromioclavicular Joint. *The Shoulder*, **1990**, 413-476.

[11] Stine, I.A. and Vangsness, C.T. (2009) Analysis of the Capsule and Ligament Insertions about the Acromioclavicular Joint: A Cadaveric Study. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, **25**, 968-974. https://doi.org/10.1016/j.arthro.2009.04.072

[12] Nakazawa, M., Nimura, A., Mochizuki, T., Koizumi, M., Sato, T. and Akita, K. (2016) The Orientation and Variation of the Acromioclavicular Ligament. *The American Journal of Sports Medicine*, **44**, 2690-2695. https://doi.org/10.1177/0363546516651440

[13] Fukuda, K., Craig, E.V., An, K.N., Cofield, R.H. and Chao, E.Y. (1986) Biomechanical Study of the Ligamentous System of the Acromioclavicular Joint. *The Journal of Bone & Joint Surgery*, **68**, 434-440. https://doi.org/10.2106/00004623-198668030-00019

[14] Mazzocca, A.D., Spang, J.T., Rodriguez, R.R., Rios, C.G., Shea, K.P., Romeo, A.A., *et al.* (2008) Biomechanical and Radiographic Analysis of Partial Coracoclavicular Ligament Injuries. *The American Journal of Sports Medicine*, **36**, 1397-1402. https://doi.org/10.1177/0363546508315200

[15] Boehm, T.D., Kirschner, S., Fischer, A. and Gohlke, F. (2003) The Relation of the Coracoclavicular Ligament Insertion to the Acromioclavicular JointA Cadaver Study of Relevance to Lateral Clavicle Resection. *Acta Orthopaedica Scandinavica*, **74**, 718-721. https://doi.org/10.1080/00016470310018261

[16] Salzmann, G.M., Paul, J., Sandmann, G.H., Imhoff, A.B. and Schöttle, P.B. (2008) The Coracoidal Insertion of the Coracoclavicular Ligaments. *The American Journal of Sports Medicine*, **36**, 2392-2397. https://doi.org/10.1177/0363546508322887

[17] Rios, C.G., Arciero, R.A. and Mazzocca, A.D. (2007) Anatomy of the Clavicle and Coracoid Process for Reconstruction of the Coracoclavicular Ligaments. *The American Journal of Sports Medicine*, **35**, 811-817. https://doi.org/10.1177/0363546506297536

[18] Bosworth, B.M. (1949) Complete Acromioclavicular Dislocation. *New England Journal of Medicine*, **241**, 221-225. https://doi.org/10.1056/nejm194908112410601

[19] Martetschläger, F., Kraus, N., Scheibel, M., Streich, J., Venjakob, A. and Maier, D. (2019) The Diagnosis and Treatment of Acute Dislocation of the Acromioclavicular Joint. *Deutsches Ärzteblatt International*, **116**, 89-95. https://doi.org/10.3238/arztebl.2019.0089

[20] Maier, D., Jaeger, M., Reising, K., Feucht, M.J., Südkamp, N.P. and Izadpanah, K. (2016) Injury Patterns of the Acromioclavicular Ligament Complex in Acute Acromioclavicular Joint Dislocations: A Cross-Sectional, Fundamental Study. *BMC Musculoskeletal Disorders*, **17**, Article No. 385. https://doi.org/10.1186/s12891-016-1240-3

[21] Tossy, J.D., Mead, N.C. and Sigmond, H.M. (1963) 11 Acromioclavicular Separations. *Clinical Orthopaedics and Related Research*, **28**, 111-119. https://doi.org/10.1097/00003086-196300280-00012

[22] Rockwood Jr., C.A. (1984) Fractures and Dislocations of the Shoulder. In: *Fractures in Adults*, Lippincott, 860-910.

[23] Beitzel, K., Cote, M.P., Apostolakos, J., Solovyova, O., Judson, C.H., Ziegler, C.G., *et al.* (2013) Current Concepts in the Treatment of Acromioclavicular Joint Dislocations. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, **29**, 387-397. https://doi.org/10.1016/j.arthro.2012.11.023

[24] Beitzel, K., Mazzocca, A.D., Bak, K., Itoi, E., Kibler, W.B., Mirzayan, R., *et al.* (2014) ISAKOS Upper Extremity Committee Consensus Statement on the Need for Diversification of the Rockwood Classification for Acromioclavicular Joint Injuries. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, **30**, 271-278. https://doi.org/10.1016/j.arthro.2013.11.005

[25] Johansen, J.A., Grutter, P.W., McFarland, E.G. and Petersen, S.A. (2011) Acromioclavicular Joint Injuries: Indications for Treatment and Treatment Options. *Journal of Shoulder and Elbow Surgery*, **20**, S70-S82. https://doi.org/10.1016/j.jse.2010.10.030

[26] Weinstein, D.M., McCann, P.D., Mcllveen, S.J., Flatow, E.L. and Bigliani, L.U. (1995) Surgical Treatment of Complete Acromioclavicular Dislocations. *The American Journal of Sports Medicine*, **23**, 324-331. https://doi.org/10.1177/036354659502300313

[27] Bosworth, B.M. (1941) Acromioclavicular Separation. *Surgery Gynecology & Obstetrics*, **73**, 866-871.

[28] Bucholz, R.W., *et al.* (2006) Rockwood and Green's Fractures in Adults. 6th Edition, Lippincott Williams & Wilkins.

[29] Tsou, P.M. (1989) Percutaneous Cannulated Screw Coracoclavicular Fixation for Acute Acromioclavicular Dislocations. *Clinical Orthopaedics and Related Research*, **243**, 112-121. https://doi.org/10.1097/00003086-198906000-00017

[30] Yin, J., Yin, Z., Gong, G., Zhu, C., Sun, C. and Liu, X. (2018) Comparison of Hook Plate with versus without Double-Tunnel Coracoclavicular Ligament Reconstruction for Repair of Acute Acromioclavicular Joint Dislocations: A Prospective Randomized Controlled Clinical Trial. *International Journal of Surgery*, **54**, 18-23. https://doi.org/10.1016/j.ijsu.2018.04.017

[31] Yoon, J.P., Lee, B., Nam, S.J., Chung, S.W., Jeong, W., Min, W., *et al.* (2015) Comparison of Results between Hook Plate Fixation and Ligament Reconstruction for Acute Unstable Acromioclavicular Joint Dislocation. *Clinics in Orthopedic Surgery*, **7**, 97-103. https://doi.org/10.4055/cios.2015.7.1.97

[32] Verstift, D.E., Somford, M.P., van Deurzen, D.F.P. and van den Bekerom, M.P.J. (2021) Review of Weaver and Dunn on Treatment of Acromioclavicular Injuries, Especially Complete Acromioclavicular Separation. *Journal of ISAKOS*, **6**, 116-119. https://doi.org/10.1136/jisakos-2019-000299

[33] Tauber, M., Gordon, K., Koller, H., Fox, M. and Resch, H. (2009) Semitendinosus Tendon Graft versus a Modified Weaver-Dunn Procedure for Acromioclavicular Joint Reconstruction in Chronic Cases. *The American Journal of Sports Medicine*, **37**, 181-190. https://doi.org/10.1177/0363546508323255

[34] Fraschini, G., Ciampi, P., Scotti, C., Ballis, R. and Peretti, G.M. (2010) Surgical Treatment of Chronic Acromioclavicular Dislocation: Comparison between Two Surgical Procedures for Anatomic Reconstruction. *Injury*, **41**, 1103-1106. https://doi.org/10.1016/j.injury.2010.09.023

[35] Mazzocca, A.D., Santangelo, S.A., Johnson, S.T., Rios, C.G., Dumonski, M.L. and Arciero, R.A. (2006) A Biomechanical Evaluation of an Anatomical Coracoclavicular Ligament Reconstruction. *The American Journal of Sports Medicine*, **34**, 236-246. https://doi.org/10.1177/0363546505281795

[36] Carofino, B.C. and Mazzocca, A.D. (2010) The Anatomic Coracoclavicular Ligament Reconstruction: Surgical Technique and Indications. *Journal of Shoulder and Elbow Surgery*, **19**, 37-46. https://doi.org/10.1016/j.jse.2010.01.004

[37] Pauly, S., Gerhardt, C., Haas, N.P. and Scheibel, M. (2009) Prevalence of Concomitant Intraarticular Lesions in Patients Treated Operatively for High-Grade Acromioclavicular Joint Separations. *Knee Surgery, Sports Traumatology, Arthroscopy*, **17**, 513-517.

https://doi.org/10.1007/s00167-008-0666-z

[38] Tischer, T., Salzmann, G.M., El-Azab, H., Vogt, S. and Imhoff, A.B. (2009) Incidence of Associated Injuries with Acute Acromioclavicular Joint Dislocations Types III through V. *The American Journal of Sports Medicine*, **37**, 136-139. https://doi.org/10.1177/0363546508322891

[39] Boileau, P., Gastaud, O., Wilson, A., Trojani, C. and Bronsard, N. (2019) All-Arthroscopic Reconstruction of Severe Chronic Acromioclavicular Joint Dislocations. *Arthroscopy*: *The Journal of Arthroscopic & Related Surgery*, **35**, 1324-1335. https://doi.org/10.1016/j.arthro.2018.11.058

[40] Markel, J., Schwarting, T., Malcherczyk, D., Peterlein, C., Ruchholtz, S. and El-Zayat, B.F. (2017) Concomitant Glenohumeral Pathologies in High-Grade Acromioclavicular Separation (Type III-V). *BMC Musculoskeletal Disorders*, **18**, Article No. 439. https://doi.org/10.1186/s12891-017-1803-y

[41] Jensen, G., Millett, P.J., Tahal, D.S., Al Ibadi, M., Lill, H. and Katthagen, J.C. (2017) Concomitant Glenohumeral Pathologies Associated with Acute and Chronic Grade III and Grade V Acromioclavicular Joint Injuries. *International Orthopaedics*, **41**, 1633-1640. https://doi.org/10.1007/s00264-017-3469-3

[42] Natera-Cisneros, L., Sarasquete-Reiriz, J., Escolà-Benet, A. and Rodriguez-Miralles, J. (2016) Acute High-Grade Acromioclavicular Joint Injuries Treatment: Arthroscopic Non-Rigid Coracoclavicular Fixation Provides Better Quality of Life Outcomes than Hook Plate ORIF. *Orthopaedics & Traumatology*: *Surgery & Research*, **102**, 31-39. https://doi.org/10.1016/j.otsr.2015.10.007

[43] Stein, T., Müller, D., Blank, M., Reinig, Y., Saier, T., Hoffmann, R., *et al.* (2018) Stabilization of Acute High-Grade Acromioclavicular Joint Separation: A Prospective Assessment of the Clavicular Hook Plate versus the Double Double-Button Suture Procedure. *The American Journal of Sports Medicine*, **46**, 2725-2734. https://doi.org/10.1177/0363546518788355

[44] Vrgoč, G., Japjec, M., Jurina, P., Gulan, G., Janković, S., Šebečić, B., *et al.* (2015) Operative Treatment of Acute Acromioclavicular Dislocations Rockwood III and V—Comparative Study between K-Wires Combined with Fibertape® vs. Tightrope System®. *Injury*, **46**, S107-S112. https://doi.org/10.1016/j.injury.2015.10.053

[45] Li, F.L., *et al.* (2015) Arthroscopic Coracoclavicular Ligament Reconstruction versus Open Modified Weaver-Dunn Procedure for Acromioclavicular Joint Dislocations: Comparison of Curative Effect. *Journal of Peking University* (*Health Sciences*), **47**, 253-257.

[46] Faggiani, M., Vasario, G.P., Mattei, L., Calò, M.J. and Castoldi, F. (2016) Comparing Mini-Open and Arthroscopic Acromioclavicular Joint Repair: Functional Results and Return to Sport. *Musculoskeletal Surgery*, **100**, 187-191. https://doi.org/10.1007/s12306-016-0411-6

[47] Behrens, A., Behrendt, P., Heintzen, M.J., Finn, J., Seekamp, A., Mader, K., *et al.* (2024) Mid-Term Clinical and Sonographic Outcomes of Minimally Invasive Acromioclavicular Joint Reconstruction: Mini-Open versus Arthroscopically Assisted. *Archives of Orthopaedic and Trauma Surgery*, **144**, 807-814. https://doi.org/10.1007/s00402-023-05110-7

[48] Saier, T., Venjakob, A.J., Minzlaff, P., Föhr, P., Lindell, F., Imhoff, A.B., *et al.* (2015) Value of Additional Acromioclavicular Cerclage for Horizontal Stability in Complete Acromioclavicular Separation: A Biomechanical Study. *Knee Surgery, Sports Traumatology, Arthroscopy*, **23**, 1498-1505. https://doi.org/10.1007/s00167-014-2895-7

[49] Geaney, L.E., Miller, M.D., Ticker, J.B., Romeo, A.A., Guerra, J.J., Bollier, M., *et al.*

(2010) Management of the Failed AC Joint Reconstruction. *Sports Medicine and Arthroscopy Review*, **18**, 167-172. https://doi.org/10.1097/jsa.0b013e3181eaf6f7

[50] Tomlinson, D.P., Altchek, D.W., Davila, J. and Cordasco, F.A. (2008) A Modified Technique of Arthroscopically Assisted AC Joint Reconstruction and Preliminary Results. *Clinical Orthopaedics & Related Research*, **466**, 639-645. https://doi.org/10.1007/s11999-007-0085-3

[51] Rolla, P.R., Surace, M.F. and Murena, L. (2004) Arthroscopic Treatment of Acute Acromioclavicular Joint Dislocation. *Arthroscopy*: *The Journal of Arthroscopic & Related Surgery*, **20**, 662-668. https://doi.org/10.1016/j.arthro.2004.03.012

[52] Defoort, S. and Verborgt, O. (2010) Functional and Radiological Outcome after Arthroscopic and Open Acromioclavicular Stabilization Using a Double-Button Fixation System. *Acta Orthopaedica Belgica*, **76**, 585-591.

[53] Cook, J.B., Shaha, J.S., Rowles, D.J., Bottoni, C.R., Shaha, S.H. and Tokish, J.M. (2012) Early Failures with Single Clavicular Transosseous Coracoclavicular Ligament Reconstruction. *Journal of Shoulder and Elbow Surgery*, **21**, 1746-1752. https://doi.org/10.1016/j.jse.2012.01.018

[54] Kany, J., Amaravathi, R.S., Guinand, R. and Valenti, P. (2012) Arthroscopic Acromioclavicular Joint Reconstruction Using a Synthetic Ligament Device. *European Journal of Orthopaedic Surgery & Traumatology*, **22**, 357-364. https://doi.org/10.1007/s00590-011-0856-0

[55] Venjakob, A.J., Salzmann, G.M., Gabel, F., Buchmann, S., Walz, L., Spang, J.T., *et al.* (2013) Arthroscopically Assisted 2-Bundle Anatomic Reduction of Acute Acromioclavicular Joint Separations. *The American Journal of Sports Medicine*, **41**, 615-621. https://doi.org/10.1177/0363546512473438

[56] Woodmass, J., Esposito, J., Ono, Y., Nelson, A., Boorman, R., Thornton, G., *et al.* (2015) Complications Following Arthroscopic Fixation of Acromioclavicular Separations: A Systematic Review of the Literature. *Open Access Journal of Sports Medicine*, **6**, 97-107. https://doi.org/10.2147/oajsm.s73211

[57] Milewski, M.D., Tompkins, M., Giugale, J.M., Carson, E.W., Miller, M.D. and Diduch, D.R. (2012) Complications Related to Anatomic Reconstruction of the Coracoclavicular Ligaments. *The American Journal of Sports Medicine*, **40**, 1628-1634. https://doi.org/10.1177/0363546512445273

[58] Chen, K., Xu, B., Lao, Y. and Yang, Y. (2021) Risk Factors Related to the Loss of Reduction after Acromioclavicular Joint Dislocation Treated with the Endobutton Device. *Annals of Translational Medicine*, **9**, 345-345. https://doi.org/10.21037/atm-21-404

[59] Cook, J.B., Shaha, J.S., Rowles, D.J., Bottoni, C.R., Shaha, S.H. and Tokish, J.M. (2012) Clavicular Bone Tunnel Malposition Leads to Early Failures in Coracoclavicular Ligament Reconstructions. *The American Journal of Sports Medicine*, **41**, 142-148. https://doi.org/10.1177/0363546512465591

[60] Oh, C., Jeon, I., Kyung, H., Park, B., Kim, P. and Ihn, J. (2002) The Treatment of Double Disruption of the Superior Shoulder Suspensory Complex. *International Orthopaedics*, **26**, 145-149. https://doi.org/10.1007/s00264-001-0325-1

[61] Rosso, C., Martetschläger, F., Saccomanno, M.F., Voss, A., Lacheta, L., Ângelo, A.C., *et al.* (2021) High Degree of Consensus Achieved Regarding Diagnosis and Treatment of Acromioclavicular Joint Instability among ESA-ESSKA Members. *Knee Surgery, Sports Traumatology, Arthroscopy*, **29**, 2325-2332. https://doi.org/10.1007/s00167-020-06286-w

[62] Vetter, P., Bellmann, F., Eckl, L., Lazaridou, A. and Scheibel, M. (2024) Clavicular Tunnel Widening in Chronic Acromioclavicular Joint Instabilities after Primary versus Re-

vision Arthroscopically-Assisted Acromio- and Coracoclavicular Stabilization. *Journal of Experimental Orthopaedics*, **11**, e12114. https://doi.org/10.1002/jeo2.12114

[63] Turman, K.A., Miller, C.D. and Miller, M.D. (2010) Clavicular Fractures Following Coracoclavicular Ligament Reconstruction with Tendon Graft. *The Journal of Bone and Joint Surgery-American Volume*, **92**, 1526-1532. https://doi.org/10.2106/jbjs.i.00410

[64] Spiegl, U.J., Smith, S.D., Euler, S.A., Dornan, G.J., Millett, P.J. and Wijdicks, C.A. (2014) Biomechanical Consequences of Coracoclavicular Reconstruction Techniques on Clavicle Strength. *The American Journal of Sports Medicine*, **42**, 1724-1730. https://doi.org/10.1177/0363546514524159

[65] Chernchujit, B. and Artha, A. (2020) High Grade Acromioclavicular Injury: Comparison of Arthroscopic Assisted Acromioclavicular Joint Fixation and Anatomic Acromioclavicular Joint Reconstruction. *Journal of Orthopaedics*, **22**, 151-157. https://doi.org/10.1016/j.jor.2020.04.007

[66] Saccomanno, M., De Ieso, C. and Milano, G. (2014) Acromioclavicular Joint Instability: Anatomy, Biomechanics and Evaluation. *Joints*, **2**, 87-92. https://doi.org/10.11138/jts/2014.2.2.087

[67] Geaney, L.E., Beitzel, K., Chowaniec, D.M., Cote, M.P., Apostolakos, J., Arciero, R.A., *et al.* (2013) Graft Fixation Is Highest with Anatomic Tunnel Positioning in Acromioclavicular Reconstruction. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, **29**, 434-439. https://doi.org/10.1016/j.arthro.2012.10.010

[68] Dyrna, F., Imhoff, F.B., Haller, B., Braun, S., Obopilwe, E., Apostolakos, J.M., *et al.* (2018) Primary Stability of an Acromioclavicular Joint Repair Is Affected by the Type of Additional Reconstruction of the Acromioclavicular Capsule. *The American Journal of Sports Medicine*, **46**, 3471-3479. https://doi.org/10.1177/0363546518807908

[69] Qiu, X., Wang, X., Zhang, Y., Zhu, Y., Guo, X. and Chen, Y. (2016) Anatomical Study of the Clavicles in a Chinese Population. *BioMed Research International*, **2016**, Article ID: 6219761. https://doi.org/10.1155/2016/6219761

[70] Gavrilă, T.M. and Cristea, Ş. (2018) Open versus Arthroscopic Surgery in Acromioclavicular Separation. *Journal of Clinical and Investigative Surgery*, **3**, 82-87. https://doi.org/10.25083/2559.5555/3.2/82.87