Management of Acromioclavicular Joint Injuries: A Historic Account

Liam A. Peebles, BA[a], Ramesses A. Akamefula, BS[a], Matthew J. Kraeutler, MD[b], Mary K. Mulcahey, MD[c,*]

KEYWORDS

- Acromioclavicular joint • Acromioclavicular reconstruction
- Coracoclavicular ligaments

KEY POINTS

- Treatment strategies for acromioclavicular (AC) joint injuries date back to the first century, and since then, major advancements in surgical and nonsurgical interventions to restore AC joint anatomy and biomechanics have been discovered.
- The original classification systems introduced and modified by Tossy (1963), Allman (1964), and Rockwood (1984) have stood the test of time and are still used in daily practice for the assessment and treatment of AC joint injuries.
- Although there is a historical consensus on treating Rockwood type I and II AC joint injuries nonoperatively, debate regarding the optimal management of type III injuries persists today.
- Early operative techniques for treating AC joint separation fall under several general classifications: (1) AC joint fixation or ligamentous repair; (2) CC ligament transfer involving transfer of the CA ligament to the distal clavicle; (3) CC ligament reinforcement with sutures, cerclage, sling, or screw fixation; and (4) free graft augmentation or reconstruction of the CC ligament complex.

INTRODUCTION

Acromioclavicular Joint Anatomy

The shoulder girdle consists of the scapula and the clavicle, giving rise to 5 major articulating regions that help with upper extremity movements.[1] One of these regions is the acromioclavicular (AC) joint, which is an articulation that helps attach the upper limb to the axial skeleton.[2] The AC joint can be described as a freely moving, diarthrodial joint

[a] Tulane University School of Medicine, 1430 Tulane Avenue, #2070, New Orleans, LA, USA; [b] Department of Orthopedics & Sports Medicine, Houston Methodist Hospital, 6445 Main Street, #2300, Houston, TX, USA; [c] Department of Orthopaedic Surgery and Rehabilitation, Loyola University Medical Center, Maywood, IL, USA
* Corresponding author. 2160 South 1st Avenue #3328, Maywood, IL 60153.
E-mail address: mary.mulcahey.md@gmail.com

Clin Sports Med 42 (2023) 539–556
https://doi.org/10.1016/j.csm.2023.05.001
sportsmed.theclinics.com

that is formed via the articulation between the medial border of the anterior side of the acromion and the distal end of the clavicle.[3] More specifically, this relationship consists of the medial facet of the clavicle, oriented posterior-laterally, that articulates with the acromion, which is oriented anterior-medially.[3] The overall shapes of these facets have been described in the literature as variable, but a concave or flattened-shaped acromial facet articulating with a convex clavicular facet seems to be the most common anatomy described.[4]

Current quantitative studies illustrate that the AC joint is about 9 mm in height in the superior-to-inferior direction, and 19 mm in depth in the anterior-to-posterior direction.[5] The width of the AC joint has also been quantified and appears to decline with age. On average, females have an AC joint space width between 1 mm and 6 mm, while males have a joint space width between 1 mm and 7 mm.[6] Finally, the plane of the AC joint formally slants between 20° and 30° relative to the anterior-medial and superior-lateral aspects of the joint.[7] However, variations exist in which the clavicle overrides the acromion, giving an almost horizontal orientation, or even a completely flush orientation leading to a vertical alignment.[7]

Acromioclavicular Ligament and Capsular Anatomy

The AC ligaments stabilize the AC joint, primarily functioning as a restraint to horizontal joint translation.[8,9] This stabilizing effect is about 3 times more prominent in the anterior-posterior direction when compared with the restraint it provides vertically.[8,9] In addition, the AC ligaments also function as clavicular restraints, keeping the clavicle from rotating posteriorly.

The AC ligament complex can be described as thickenings of the AC joint capsule itself, subsequently giving rise to multiple structures.[10] This complex of ligaments may further be divided into 2 major bundles, one oriented superiorly and posteriorly about the joint, and one bundle oriented anteriorly and inferiorly.[11,12] Running in an oblique manner, the superior-posterior (SP) bundle of the AC ligament complex reinforces the AC joint capsule and has been noted to be the stronger of the 2 bundles.[13] More specifically, the SP bundle reinforces the AC joint between the posterior aspect of the distal clavicle and the anterior aspect of the acromion.[14] Grossly, the superior portion of the AC capsule itself has been described as thicker when compared with the inferior capsule. This added thickness also comes with an acromial attachment that is wider compared with the inferior AC joint capsule.[14] The inferior-anterior (IA) bundle originates at the anterior aspect of the acromion or the AC joint capsule, with multiple insertions across the anterior and inferior portions of the joint capsule, and the distal clavicle along its anterior margin.[13] The IA bundle has greater variability in morphology and presence, with variations in origins and insertion points along the joint capsule, acromion, and clavicle.[15] Additionally, the IA bundle is typically smaller and contributes less to AC joint capsule stability when compared with the SP bundle.[16] Finally, compared with the superior portion, the inferior portion of the AC joint capsule consists of much thinner ligamentous tissues, thereby providing minimal reinforcement of the AC joint.[16]

Coracoclavicular Ligament Anatomy

The coracoclavicular (CC) ligaments are the primary stabilizers of the AC joint, predominantly working in the vertical plane when the shoulder girdle is in an uncompromised state.[8] In instances where the AC joint capsule is disrupted, the CC ligaments may also function secondarily as a primary AC joint stabilizer in the horizontal plane.[12] The larger of the 2 ligaments, the trapezoid ligament (TL) has a quadrilateral structure and inserts on the distal end of the clavicle adjacent to the trapezoidal ridge.[17,18] Quantitative

analysis illustrates that this insertion ranges between 1.5 cm and 3.0 cm from the AC joint.[17,18] Functionally, the TL resists clavicular displacement in the posterior direction, while additionally preventing AC joint compression.[1] Conical in shape, the conoid ligament traverses in a more vertical fashion and is positioned posterior-medially compared with the trapezoid ligament.[19] The conoid ligament fibers have been described as twisting as they ascend, eventually attaching to the conoid tubercle located on the inferior surface of the clavicle.[17] Functionally, the conoid ligament restrains the clavicle from translating superiorly.[17] Thus, the conoid ligament is a primary stabilizer of the AC joint in the vertical plane.[10,13–16]

Pathophysiology of Acromioclavicular Joint Injury

AC joint injuries can be divided into 2 distinct categories, those that are direct and those that are nondirect. The more common of the two, direct AC joint injuries result from an external force acting on the AC joint itself.[20] A common example of a direct AC joint injury may include an individual falling on the shoulder while the arm is adducted. This typically results in the scapula being forced inferiorly relative to the clavicle and at first disrupts the AC ligament, but can also cause injury to the CC ligaments following a more severe injury and greater displacement of the acromion.[9] Indirect AC joint injuries may also occur during a fall, but commonly arise while the individual tries to brace the fall with an extended, or outstretched arm and hand.[21] This mechanism forces the humerus superiorly and toward the acromion, thus disrupting the AC joint and its components. Indirect injuries often affect the AC ligaments, but commonly spare the CC ligaments, typically leading to a lower-grade injury (via Rockwood grading system).[22] Regardless of the mechanism of injury, AC joint injuries are often diagnosed based on patient history, physical examination, and imaging.[23]

Early Accounts of Acromioclavicular Joint Injury

Records of AC joint injuries can be traced as far back as 400 BC.[24] Historic accounts of Hippocrates (460–370 BC) have illustrated his commentary on the misdiagnosis of AC joint injuries for glenohumeral joint injuries.[24] Treatment strategies for AC joint injuries also date back to the first century and include tight bandaging. Since then, major advancements in surgical and nonsurgical interventions to restore AC joint anatomy and biomechanics have been discovered.

Incidence, Etiology, and Epidemiology

Most AC joint injuries occur in young adults between the ages of 20 and 40 years.[25,26] Males sustain AC joint injuries at a rate 5 times higher than females.[25,26] Especially within athletic populations, AC joint injuries can be extremely common, and depending on the individual sport, may comprise up to 40% to 50% of shoulder injuries.[27] As illustrated previously, the most common etiology of AC joint pathology is a direct external force to the shoulder with the arm in an adducted position. This mechanism of injury frequently occurs in individuals participating in contact sports such as football, lacrosse, hockey, and rugby.[28]

Much of the current literature states that up to 9% of all shoulder injuries involve damage to the AC joint also.[29] However, some authors speculate that this statistic evolved from a book chapter that dates to 1958 and may overestimate the incidence of overall AC joint pathology when compared with more recent data that suggest AC joint injuries occur in only 4% of shoulder injuries.[30] Despite current suggestions, hospital data pertaining to the incidence of AC joint injuries may be inaccurate and underestimated, because of those patients with less severe (ie, Rockwood Type I and II injuries) AC joint injuries who do not pursue evaluation and treatment.[26]

ASSESSMENT OF ACROMIOCLAVICULAR INJURIES

Radiographic Evaluation

Typically, a standard shoulder trauma series of plain radiographs are used to evaluate AC joint injures.[31] The anterior-posterior (AP) and Zanca views are frequently used to evaluate the AC joint and distal clavicle, with the Zanca view accepted as the more accurate by many surgeons (**Fig. 1**).[32] Although the standard AP view illustrates the AC joint, oftentimes an angulated AP view must be applied for optimal visualization to avoid possible overpenetration as a result of increased radiolucency from overlapping structures.[33] For example, the Zanca view utilizes a 10° to 15° cephalad tilt to achieve a better view of the clavicle by decreasing the amount of scapula and clavicle superimposed on one another.[32,34] Additional views such as the lateral (or scapular Y) (**Fig. 2**) and dynamic axillary views (**Fig. 3**) may also be utilized, especially in the case of evaluating horizontal instability and differentiating between Type III and Type IV injuries.[35,36] Standard bilateral AP and bilateral Alexander views may also be used to increase diagnostic accuracy by using the contralateral AC joint to better determine native anatomy. Moreover, as opposed to solely using visual inspection, specific measurements of the contralateral noninjured AC and CC ligaments via radiographic imaging may also increase sensitivity and evaluation of pathology.[37]

Stress radiographs may also be used to assess AC joint injuries and can be performed while the patient is holding a weight in the hand of the affected side; however, many shoulder surgeons have noted that weightbearing radiographs are unnecessary in the evaluation of AC joint pathologies.[38–40] Standard motivations to use stress radiographs include increased sensitivity and detection of possible underlying joint pathology such as unmasking higher-grade AC joint injuries.[41] Despite this, in some studies, paradoxical CC joint narrowing has been seen while using weightbearing radiographs in 33% of healthy volunteers and up to 10% in those diagnosed with an AC joint injury.[42] A 1999 study by Yap and colleagues[39] surveyed 105 members of the American Shoulder and Elbow Society and found that most (85/105, 81%) respondents recommended against the use of weighted stress views, questioning the utility and practicality of the radiographs in the acute setting. The authors also reported that of the respondents who did use stress radiographs in their practice, most indicated that the results did not impact their treatment decision making. These trends are supported in more recent studies, as Shaw and colleagues[43] reported in a 2018 survey of 37 orthopedic surgeons that only 13% used weighted stress radiographs, and even fewer (10%) felt that their treatment plan would vary based on stress radiograph findings. In the senior author's practice, weightbearing radiographs are not typically ordered for the assessment of acute AC joint injuries. Finally, advanced diagnostic imaging modalities such as CT and MRI are not routinely employed when assessing the AC joint.[41,44] Although this is primarily because of their higher costs and poor

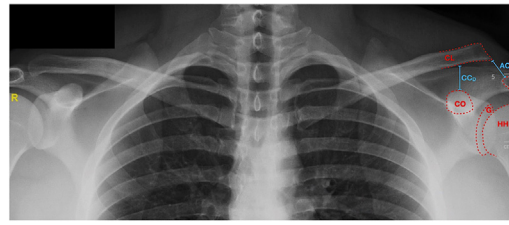

Fig. 1. Bilateral AP radiograph demonstrating Rockwood Type V AC joint injury. AC_D, AC distance; CC_D, coracoclavicular distance; CL, clavicle; CO, coracoid; G, glenoid; HH, humeral head.

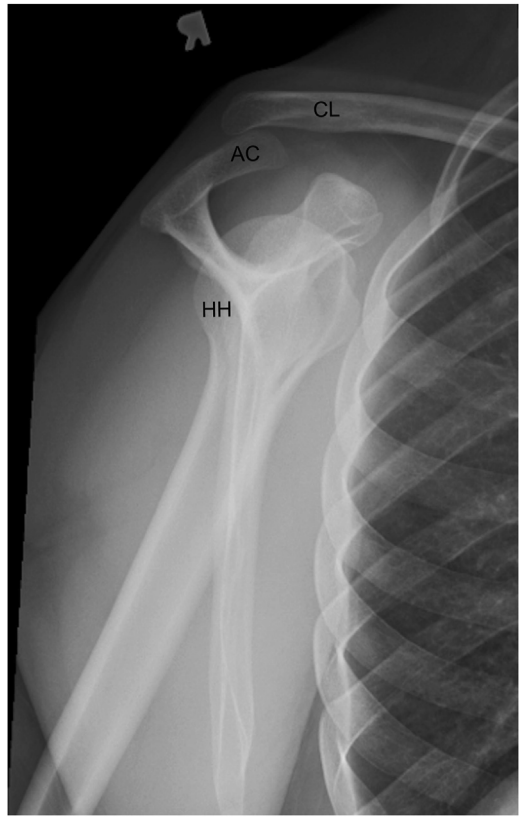

Fig. 2. Right shoulder in the scapular Y view demonstrating a Rockwood Type III A joint injury. AC, acromion; CL, clavicle; HH, humeral head.

availability, CT and MRI are thought to be of low diagnostic value in surgical planning for acute AC joint injuries, as there is normally no need to observe osseous or neurovascular structures in detail.[41,44]

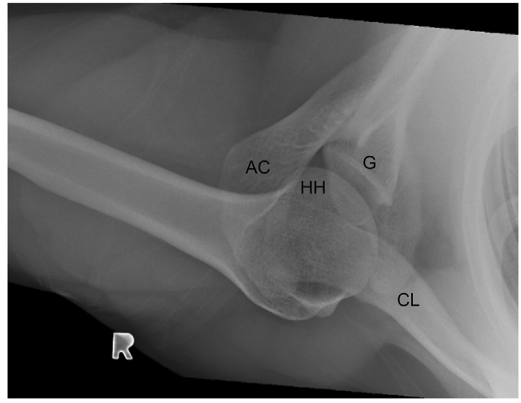

Fig. 3. Right shoulder in the axillary view depicting a Rockwood Type III AC joint injury. AC, acromion; CL, clavicle; HH, humeral head; G, glenoid.

Tossy and Allman Classification

Tossy and colleagues[45] first described a classification system for AC joint injuries in 1963. This characterized AC joint injuries into 3 types. Type I injuries included those in which there is sprain of the AC ligaments, but both the AC and CC ligaments are still intact. Type II injuries are those where the AC ligaments are ruptured, with partial tearing of the CC ligaments. Type III injuries demonstrate complete disruption of both the AC and CC ligaments, leading to vertical AC joint instability. In 1967, Allman further described a similar AC joint injury classification system as Tossy that included a 3-type classification system with virtually the same Type I and Type III class injuries. However, Allman described Type II injuries being characterized by rupturing of the AC ligaments with sprain of the CC ligaments.[46]

Rockwood Classification

Allman's classification system was modified and expanded in 1984, when Rockwood proposed a new 6-tier system to classify AC joint injuries.[45,47,48] The Rockwood classification allows clinicians to determine the severity of AC joint injury based on the ligament complexes involved, the degree of injury, and direction of displacement when evaluated using radiographic imaging.[47–49]

Type I

Low-grade injury caused by AC joint strain with no apparent displacement of the distal clavicle on radiographic imaging. AC ligaments are sprained, but CC ligaments and deltotrapezial complex are intact.[5]

Type II

Disruption of the AC ligaments and AC capsule is evident, resulting in horizontal instability and ability to displace the clavicle during palpation.[21] CC ligaments may be sprained, but remain functional and within range of normal anatomy (ie, CC ligaments maintain length between 10 mm and 13 mm).[48] Radiographic imaging may demonstrate AC joint widening of greater than 7 mm and inferior translation of the acromion relative to the clavicle.[33]

Type III

Evidence of disruption to the AC and CC ligaments. Radiographic imaging may demonstrate up to 100% displacement of the distal clavicle.[33,48] These injuries can be reduced passively during physical examination.

Type IV

Complete disruption of AC and CC ligament complexes with displacement of the distal clavicle posteriorly in the horizontal plane.[50] This injury commonly presents with AP instability and a punctured trapezial fascia.[48]

Type V

Complete disruption of the AC and CC ligament complexes with the CC joint distance more than 100%, but less than 300% compared with the uninjured, contralateral CC ligament length. Unlike Type III injuries, Type V injuries may not be reduced, typically because of buttonholing of the distal clavicle through the deltotrapezial fascia. This leads to another hallmark of Type V injuries, which includes significant disruption of the trapezius and deltoid muscles and fascia.[48,51,52]

Type VI

Complete disruption of the AC and CC ligament complexes with inferior translation of the distal clavicle. This type of injury is extremely rare and requires surgical intervention.[1,22,53]

Grade VI injuries may also be further divided depending on specific location of inferior clavicular displacement, which can either be subacromial (Type VIA), or subcoracoid (Type VIB).[20,48,54]

MANAGEMENT OF ACROMIOCLAVICULAR JOINT INJURIES

Nonoperative Management

Literature prior to the 1960s advocated for more aggressive nonoperative protocols focused on immobilization and reduction of the deformity for all AC joint injuries.[55] This is demonstrated in a 1946 study by Urist[55] and colleagues of 41 patients that reported on the conservative management of complete AC joint dislocations, which generally refers to Type III, IV, V, and VI injuries according to the Rockwood system. The authors noted that a key to successful conservative management was using splints capable of overcorrecting the joint deformity. Using this technique, Urist and colleagues[55] reported successful correction of the deformity and symptomatic relief in approximately 80% of patients treated nonoperatively. In the 20% of patients failing conservative management, deformity, pain, and range of motion (ROM) limitations were common indications for surgical intervention. Palpable posterior displacement and abnormal mobility of the distal clavicle after 3 weeks of nonoperative treatment in these patients were highly suggestive of failure and recurrence of the dislocation.[55]

As management trends evolved in the 1980s and 1990s, surgeons emphasized minimal intervention, treating patients with a sling and immobilization for shorter periods of time.[46,56] Anatomic reduction became a nonessential feature of management, and greater focus was placed on early ROM, strengthening, and return to activity. This was demonstrated in a 1992 survey by Cox and colleagues[57] that reported most surgeons (including 96% of team physicians) preferred to manage Type III injuries nonoperatively. A randomized controlled trial by Larsen and colleagues[58] in 1986 supported this updated approach to nonoperative management by comparing outcomes following conservative or operative treatment of AC joint dislocations. In 84 patients, it was found that most did as well, if not better, with nonoperative management and had significantly shorter rehabilitation periods.[58]

Optimal treatment for AC joint pathology has been heavily debated. Currently, the consensus among most surgeons is that treatment is generally type dependent, with Type IV, V, and VI injuries treated surgically.[59] Although the optimal management of Rockwood Type III AC joint injuries remains controversial, nonoperative treatment is recommended for Type I and II injuries and has yielded reliable outcomes historically.[46,56,60] Sling immobilization and analgesics have thus become mainstays in the nonoperative management of Type I and II injuries. With pain being the primary complaint of patients with these injuries, early treatment should prioritize rest and pain control prior to returning to activity. Rest and application of ice for 1 to 2 weeks or until resolution of symptoms are generally sufficient for Type I injuries, and athletes may be able to return to sport in as soon as 1 to 2 weeks or once they are asymptomatic. Type II AC joint injuries are similarly managed with ice and sling immobilization for 2 weeks; however, the period for return to full activity may take up to 6 to 8 weeks. Because of the increased sagittal plane translation associated with Type II injuries, patients are prone to developing more degenerative changes than those with Type I injuries and thus may require oral nonsteroidal anti-inflammatory drugs or steroid injections later in their treatment course.[9,60–62]

Evolution of Surgical Techniques

In Type IV, V, and VI injuries and some Type III AC joint injuries, surgical management is typically indicated. Techniques for AC joint reconstruction vary and involve different

approaches to restoring AC joint stability (**Table 1**). Early operative techniques for treating AC joint separation fall under several general classifications: (1) AC joint fixation or ligamentous repair; (2) CC ligament transfer involving transfer of the CA ligament to the distal clavicle; (3) CC ligament reinforcement with sutures, cerclage, sling, or screw fixation; and (4) free graft augmentation or reconstruction of the CC ligament complex.

Repair of the AC ligaments and reinforcement of the superior AC ligament with the joint meniscus was advocated for in a 1963 study by Sage and Salvatore,[63] and many authors have supplemented this technique with transarticular pins to support the repair.[36,64–66] This approach was popularized early on because of its ease of application and may be performed percutaneously or in an open manner with either smooth or threaded pins. Rigid fixation of the AC joint with a Kirschner wire (K-wire) allows healing of the disrupted CA ligaments by restoring the distance between the clavicle and the coracoid, although this approach has lost popularity because of a high incidence of pin migration, loss of reduction, and degenerative arthritis postoperatively.[67–69] Other authors have supported AC joint plating for management of AC joint separations to reduce the deformity and allow for soft tissue healing.[70–72] Although good-to-excellent results have been reported in up to 90% of cases, hook plating of the AC joint may be associated with impingement on subacromial structures and the development of rotator cuff lesions.[20,73,74]

A 1968 study by Neviaser[75] provided one of the earliest accounts of CA ligament transfer to the distal clavicle to restore AC joint stability without repair of the CC ligaments, and multiple variations of this technique have since been proposed.[64,76] CA ligament transfer with CC ligament screw fixation has also demonstrated reliable outcomes, although some authors have viewed this approach as inadequate for more severe AC joint injuries.[77–79] In the landmark study by Weaver and Dunn in 1972, the authors treated 15 patients with Type III injuries with distal clavicle resection and CC ligament reconstruction using the CA ligament.[80] The original technique has been shown to provide adequate stabilization of the AC joint and pain reduction in most patients.[81,82] Multiple variations of the Weaver-Dunn procedure have since been proposed, including augmentation of the transferred CA ligament with cerclage suture, wire, metal fixation, bone block transfer, or soft tissue autografts and allografts.[82–84] These techniques aim to address persistent pain and recurrent subluxation that has been associated with the traditional Weaver-Dunn procedure.

The native distance between the coracoid and clavicle may also be restored with rigid screw fixation or by using nonrigid synthetic materials. CC ligament repair with percutaneous screws was first described by Bosworth and colleagues[85] in 1941, although this approach has since been shown to be associated with a relatively high technical failure rate.[86] Kennedy and colleagues[87] reported on the use of CC screws with AC joint debridement and trapeziodeltoid repair in 1968, and subsequent studies documented outcomes following CC ligament repair with Bosworth screw fixation.[88–90] Numerous other studies have also advocated for CC ligament repair with cerclage techniques using absorbable and nonabsorbable synthetic devices.[91–96] CC ligament repair with a suture sling has been shown to provide inadequate joint reduction, and the efficacy of polydioxanone (PDS) cerclage has been investigated in multiple comparative studies.[93–95] A 1993 study by Gohring and colleagues[94] reported on 64 complete AC joint dislocations treated with either tension band, hook plate, or braided PDS cord and found the incidence of early postoperative complications to be 43%, 58%, and 17%, respectively. At a mean follow-up time of 35 months, the authors reported recurrent AC joint instability in 32% of patients in the tension band group, 50% in those treated with hook plates, and 24% in the PDS cord group.[94]

Table 1
Classification of original surgical techniques for acromioclavicular joint stabilization

Treatment Classification	Technique	Original Authors, Year
AC joint fixation or ligamentous repair	AC ligament repair and superior AC ligament reinforcement with meniscus	Sage and Salvatore,[63] 1963
	AC ligament repair with transarticular pins	Ahstrom,[64] 1971; Bearden et al,[36] 1973; Augereau et al,[65] 1981; Bartonicek et al,[66] 1988
	AC joint fixation with Wolter, Crook, or Hook plating	Broos et al,[70] 1997; Habernek et al,[71] 1993; Henkel et al,[72] 1997
CC ligament repair with coracoacromial ligament (CAL) transfer to distal clavicle	CAL transfer without CC ligament repair	Neviaser et al,[75] 1968
	CAL transfer with CC ligament screw fixation	Verhaven et al,[79] 1993; Kumar et al,[78] 1995; Guy et al,[77] 1998;
	Distal clavicle resection with CC ligament reconstruction using the CAL	Weaver and Dunn,[80] 1972
	Modified Weaver-Dunn procedure	Kawabe et al,[83] 1984; Shoji et al,[84] 1986; LaPrade et al,[82] 2005
CC ligament repair with sutures, cerclage, sling, screw fixation	CC ligament repair with percutaneous screws	Bosworth et al,[85] 1941
	CC ligament screws with AC joint debridement	Kennedy et al,[87] 1968
	CC ligament repair with cerclage	Gohring et al,[94] 1993; Gollwitzer [95] 1993; Hessman et al,[92] 1995; Colosimo et al,[91] 1996; Clayer et al,[93] 1997
	CC ligament repair with suture sling	Gohring et al,[94] 1993; Gollwitzer [95] 1993; Clayer et al,[93] 1997
CC ligament graft augmentation or reconstruction	Anatomic AC and CC reconstruction with semitendinosus allograft	Jones et al,[97] 2001; Tauber et al,[101] 2009
	Arthroscopic AC and CC reconstruction with gracilis autograft and suture-button tapes	Martetschläger et al,[110] 2016
	Arthroscopic AC reconstruction with double TightRope system	Scheibel et al, 2011
	Arthroscopic CC and AC reconstruction with semitendinosus allograft and clavicular screws	Tauber et al,[111] 2016
	Open all-suture anchor AC reconstruction closing the circle technique	Ângelo et al,[114] 2022
	Open AC reconstruction with semitendinosus or gracilis allograft and interference screws	Aliberti et al,[113] 2020
	Open AC reconstruction with 2 holes in the clavicle all suture technique	Mardani-Kivi et al,[112] 2022

Lastly, anatomic reconstruction of the CC ligamentous complex with soft tissue grafts has risen in popularity over the last 2 decades. Jones and colleagues[97] were the first to describe this technique in 2001 to anatomically recreate the AC and CC ligament complexes. This approach involves drilling 2 clavicular tunnels at the conoid and trapezoid footprints, passing the graft through each tunnel and through the base of coracoid and using the remaining graft limb to reconstruct the AC ligaments. Several in vitro studies have provided biomechanical evidence to support this approach, and it has been shown to be superior to the traditional Weaver-Dunn technique with arthroscopic suture fixation.[98–100] By using a semitendinosus allograft to reconstruct the CC ligament complex, Tauber and colleagues[101] reported significantly better clinical and radiographic outcomes of this approach compared with a modified Weaver-Dunn technique in a series of 24 patients with complete AC joint dislocations.

Emerging Techniques to Address Horizontal Acromioclavicular Joint Instability

The presence of horizontal AC joint instability has been identified as a predictor of inferior clinical outcomes, regardless of operative technique, and thus greater emphasis has been placed on addressing the injured ligamentous anatomy.[50] Although multiple techniques have been proposed to restore vertical joint integrity with CC ligament reconstruction, recent studies have recognized the AC capsule as a contributor to horizontal and rotational stability.[50,102–105] More specifically, the superior aspect of the AC ligament complex has been identified in cadaveric and biomechanical studies as the primary resistor to vertical and rotational translation.[61,103,106,107] Furthermore, there is new biomechanical evidence that suggests anatomic reconstruction of the CC ligaments results in a significantly higher stability of the AC joint in the horizontal plane than reconstruction of the CC ligaments in a nonanatomic configuration.[108] Emerging techniques for open and arthroscopic reconstruction of the AC and CC ligaments have also demonstrated improved clinical and radiographic outcomes and the ability to restore native horizontal stability.[109–114]

In the setting of chronic AC separation, Martetschläger and colleagues[110] proposed an arthroscopically assisted AC and CC ligament reconstruction technique that employs gracilis autograft protected by suture-button tapes (Dog Bone and FiberTape, Arthrex, Naples, FL, USA) to improve horizontal and vertical stability. By looping the graft in front of the clavicle and using fewer, smaller drill holes in the clavicle and coracoid, this technique reduces the risk of weakening the native bony architecture. In theory, this approach mitigates the potential for complications associated with previous graft augmentation techniques such as rupture of the graft, hardware failure, and fracture of the clavicle or coracoid through bone tunnels caused by decreased bone strength.[115–117] Scheibel and colleagues[118] described an arthroscopically assisted AC joint reconstruction technique using a double TightRope (Arthrex) system, consisting of a round clavicular and an oblong coracoid titanium button connected by nonabsorbable Number 5 Fiberwire suture (Arthrex) to augment the torn conoid and trapezoid ligaments in acute AC joint injuries. This technique yielded good-to-excellent outcomes in 28 patients at a mean follow-up of 26.5 months (range, 20.1–32.8 months), although patients with failed correction of horizontal instability were found to have inferior clinical outcomes.[118] In contrast, Tauber and colleagues[111] found that combined anatomic arthroscopic CC ligament reconstruction plus AC ligament reconstruction with a semitendinosus tendon and clavicular interference screw fixation better restored horizontal stability and provided superior clinical and radiographic outcomes when compared with isolated CC reconstruction using the AC Graf-tRope system (Arthrex) with a gracilis tendon.

Multiple open techniques for AC joint reconstruction to correct horizontal instability have also been described in the literature.[112–114] Ângelo and colleagues[114] recently published an all-suture anchor technique that stabilizes the AC joint vertically, horizontally, and rotationally. Using 2 vertical tunnels in the coracoid and clavicle and anterior-to-posterior horizontal tunnels in the acromion and clavicle, this technique reconstructed a circle of stability brought together by the lateral clavicle, the acromion, the coracoid process and the CC, AC, and coracoacromial (CA) ligaments. Aliberti and colleagues[113] also described a novel open reconstruction technique that utilizes a semitendinosus or gracilis allograft with interference screw fixation to restore horizontal stability of the AC joint. The graft is passed across the AC joint in a Figure-8 fashion and fixed to the acromion and clavicle posteriorly to reconstruct the posterior AC capsule, and the native capsule and ligaments are repaired with an additional figure-eight suture over the top of the allograft reconstruction. In a 2022 randomized controlled trial, Mardani-Kivi and colleagues[112] examined acute AC joint horizontal instability following complete dislocation and repair in 104 patients using 1 of 2 Ethibond suture techniques, the loop technique, or the 2 holes in the clavicle technique.

The 2-hole technique involves 2 vertical tunnels in the distal clavicle 1 cm apart, passing a Number 5 Ethibond suture through the first tunnel and looping it around the coracoid to exit through the second tunnel with subsequent flat pinning of the acromion to the clavicle and AC joint capsular repair. The loop technique loops the anchor suture around the clavicle and coracoid instead of passing through a drilled tunnel, and the AC joint is again stabilized with a similar flat pin and capsular repair.

Although both techniques provide significant improvements in Constant Score and Taft Scores at 3, 9, and 12 months, the 2-hole technique resulted in better horizontal stabilization radiographically at all follow-up periods up to 1 year.[112]

SUMMARY

The current and historic literature indicate a rapid and multifaced evolution in best practice management of AC joint injuries. AP, Zanca, scapular Y, and dynamic axillary radiographic views provide optimal visualization of the joint and may reliably assess for the presence of horizontal AC instability. The severity of AC joint pathology is typically classified according to the 6-tier Rockwood scoring system, which was previously adapted from the Tossy and Allman classifications and includes the degree of injury and direction of displacement on radiographs. Over 160 surgical techniques have been described for AC joint repair and reconstruction in the last decade; thus determining the optimal treatment algorithm has become increasingly challenging secondary to the lack of consistently excellent clinical outcomes. Future clinical studies should aim to assess patient outcomes and residual horizontal instability following open AC and CC ligament reconstruction with soft tissue allografts.

CLINICS CARE POINTS

- Careful clinical evaluation with a thorough clinical examination is crucial in determining the severity of AC joint injuries and guides treatment decision making. Imaging studies such as radiographs (AP, Zanca, scapular Y, and dynamic axillary views) and MRI may be useful in further characterizing the injury.
- Optimal management of AC joint injuries should be further guided by the Rockwood classification system, which considers ligament complexes involved, the degree of injury, and direction of displacement when evaluated using radiographic imaging.

- Nonoperative management is generally appropriate for Type I and II AC joint injuries, which involves rest, ice, and physical therapy. This approach typically involves a period of sling immobilization followed by physical therapy to restore ROM and strength.
- Physical therapy for AC joint injuries may include exercises to strengthen the rotator cuff, scapular stabilizers, and other muscles surrounding the shoulder joint. In some cases, corticosteroid injections may be used in the management of persistent pain and inflammation.
- Surgical management may be necessary for more severe AC joint injuries, including Type III, IV, V, and VI injuries. Surgical stabilization options include AC joint fixation or ligamentous repair; CC ligament transfer involving transfer of the CA ligament to the distal clavicle; CC ligament reinforcement with sutures, cerclage, sling, or screw fixation; and free graft augmentation or reconstruction of the CC ligament complex.
- Postoperative management should include adequate pain control, monitoring for signs of infection or hardware failure, and physical therapy to restore ROM, strength, and dynamic stability. Rehabilitation should be tailored to the severity of the injury and the specific surgical technique used, with a gradual progression of activities and return to play to minimize the risk of postoperative complications.
- Long-term outcomes of AC joint injuries typically vary depending on injury severity and the treatment modality used, with surgical management generally resulting in better outcomes for more severe injuries (Type IV to VI).

DISCLOSURES

M.K. Mulcahey is a paid speaker/presenter for Arthrex, Inc. All other authors (L.A. Peebles, R.A. Akamefula, M.J. Kraeutler) have no disclosures to report.

REFERENCES

1. Lee KW, Debski RE, Chen CH, et al. Functional evaluation of the ligaments at the acromioclavicular joint during anteroposterior and superoinferior translation. Am J Sports Med 1997;25(6):858–62.
2. Ludewig PM, Phadke V, Braman JP, et al. Motion of the shoulder complex during multiplanar humeral elevation. J Bone Joint Surg Am 2009;91(2):378–89.
3. Depalma AF. Surgical anatomy of acromioclavicular and sternoclavicular joints. Surg Clin North Am 1963;43:1541–50.
4. Yoo Y. Acromioclavicular joint. In: Bain GI, Itoi E, diGiacomo G, et al, editors. Normal and Pathological anatomy of the shoulder. Heidelberg, Germany: Springer Berlin; 2015. p. 159–69.
5. Frank RM, Cotter EJ, Leroux TS, et al. Acromioclavicular joint injuries: evidence-based treatment. J Am Acad Orthop Surg 2019;27(17):e775–88.
6. Petersson CJ, Redlund-Johnell I. Radiographic joint space in normal acromioclavicular joints. Acta Orthop Scand 1983;54(3):431–3.
7. Renfree KJ, Wright TW. Anatomy and biomechanics of the acromioclavicular and sternoclavicular joints. Clin Sports Med 2003;22(2):219–37.
8. Fukuda K, Craig EV, An KN, et al. Biomechanical study of the ligamentous system of the acromioclavicular joint. J Bone Joint Surg Am 1986;68(3):434–40.
9. Debski RE, Parsons IM 3rd, Fenwick J, et al. Ligament mechanics during three degree-of-freedom motion at the acromioclavicular joint. Ann Biomed Eng 2000;28(6):612–8.
10. Stine IA, Vangsness CT Jr. Analysis of the capsule and ligament insertions about the acromioclavicular joint: a cadaveric study. Arthroscopy 2009;25(9):968–74.

11. Nakazawa M, Nimura A, Mochizuki T, et al. The orientation and variation of the acromioclavicular ligament: an anatomic study. Am J Sports Med 2016;44(10):2690–5.
12. Provencher MT, LeClere L, Romeo AA, et al. Avoiding and managing complications of surgery of the acromioclavicular joint. In: Meislin R, Halbrecht J, editors. Complications in knee and shoulder surgery: management and treatment options for the sports medicine orthopedist. England: Springer London; 2009. p. 245–64.
13. Nolte PC, Ruzbarsky JJ, Midtgaard KS, et al. Quantitative and qualitative surgical anatomy of the acromioclavicular joint capsule and ligament: a cadaveric study. Am J Sports Med 2021;49(5):1183–91.
14. Peebles LA, Aman ZS, Kraeutler MJ, et al. Qualitative and quantitative anatomic descriptions of the coracoclavicular and acromioclavicular ligaments: a systematic review. Arthrosc Sports Med Rehabil 2022;4(4):e1545–55.
15. Boehm TD, Kirschner S, Fischer A, et al. The relation of the coracoclavicular ligament insertion to the acromioclavicular joint: a cadaver study of relevance to lateral clavicle resection. Acta Orthop Scand 2003;74(6):718–21.
16. Chahla J, Marchetti DC, Moatshe G, et al. Quantitative assessment of the coracoacromial and the coracoclavicular ligaments with 3-dimensional mapping of the coracoid process anatomy: a cadaveric study of surgically relevant structures. Arthroscopy 2018;34(5):1403–11.
17. Renfree KJ, Riley MK, Wheeler D, et al. Ligamentous anatomy of the distal clavicle. J Shoulder Elbow Surg 2003;12(4):355–9.
18. Harris RI, Vu DH, Sonnabend DH, et al. Anatomic variance of the coracoclavicular ligaments. J Shoulder Elbow Surg 2001;10(6):585–8.
19. Flores DV, Goes PK, Gomez CM, et al. Imaging of the acromioclavicular joint: anatomy, function, pathologic features, and treatment. Radiographics 2020;40(5):1355–82.
20. Mazzocca AD, Arciero RA, Bicos J. Evaluation and treatment of acromioclavicular joint injuries. Am J Sports Med 2007;35(2):316–29.
21. Bontempo NA, Mazzocca AD. Biomechanics and treatment of acromioclavicular and sternoclavicular joint injuries. Br J Sports Med 2010;44(5):361–9.
22. Li X, Ma R, Bedi A, et al. Management of acromioclavicular joint injuries. J Bone Joint Surg Am 2014;96(1):73–84.
23. Saccomanno MF, Ieso DE, Milano G. Acromioclavicular joint instability: anatomy, biomechanics and evaluation. Joints 2014;2(2):87–92.
24. Rockwood CA, Young DC. Disorders of the acromioclavicular joint. In: Rockwood CA, Matsen FAI, editors. The shoulder. Philadelphia, PA, USA: WB Saunders; 1990. p. 413–76.
25. Pallis M, Cameron KL, Svoboda SJ, et al. Epidemiology of acromioclavicular joint injury in young athletes. Am J Sports Med 2012;40(9):2072–7.
26. Fraser-Moodie JA, Shortt NL, Robinson CM. Injuries to the acromioclavicular joint. J Bone Joint Surg Br 2008;90(6):697–707.
27. Sirin E, Aydin N, Mert Topkar O. Acromioclavicular joint injuries: diagnosis, classification and ligamentoplasty procedures. EFORT Open Rev 2018;3(7):426–33.
28. Millett PJ, Braun S, Gobezie R, et al. Acromioclavicular joint reconstruction with coracoacromial ligament transfer using the docking technique. BMC Musculoskelet Disord 2009;10:6.
29. Chillemi C, Franceschini V, Dei Giudici L, et al. Epidemiology of isolated acromioclavicular joint dislocation. Emerg Med Int 2013;2013:171609.

30. Beitzel K, Cote MP, Apostolakos J, et al. Current concepts in the treatment of acromioclavicular joint dislocations. Arthroscopy 2013;29(2):387–97.
31. Petri M, Warth RJ, Greenspoon JA, et al. Clinical results after conservative management for Grade III acromioclavicular joint injuries: does eventual surgery affect overall outcomes? Arthroscopy 2016;32(5):740–6.
32. Zanca P. Shoulder pain: involvement of the acromioclavicular joint. (Analysis of 1,000 cases). Am J Roentgenol Radium Ther Nucl Med 1971;112(3):493–506.
33. Vaatainen U, Pirinen A, Makela A. Radiological evaluation of the acromioclavicular joint. Skeletal Radiol 1991;20(2):115–6.
34. Waldrop JI, Norwood LA, Alvarez RG. Lateral roentgenographic projections of the acromioclavicular joint. Am J Sports Med 1981;9(5):337–41.
35. Tauber M, Koller H, Hitzl W, et al. Dynamic radiologic evaluation of horizontal instability in acute acromioclavicular joint dislocations. Am J Sports Med 2010;38(6):1188–95.
36. Bearden JM, Hughston JC, Whatley GS. Acromioclavicular dislocation: method of treatment. J Sports Med 1973;1(4):5–17.
37. Schneider MM, Balke M, Koenen P, et al. Inter- and intraobserver reliability of the Rockwood classification in acute acromioclavicular joint dislocations. Knee Surg Sports Traumatol Arthrosc 2016;24(7):2192–6.
38. Sluming VA. A comparison of the methods of distraction for stress examination of the acromioclavicular joint. Br J Radiol 1995;68(815):1181–4.
39. Yap JJ, Curl LA, Kvitne RS, et al. The value of weighted views of the acromioclavicular joint. Results of a survey. Am J Sports Med 1999;27(6):806–9.
40. Beitzel K, Mazzocca AD, Bak K, et al. ISAKOS upper extremity committee consensus statement on the need for diversification of the Rockwood classification for acromioclavicular joint injuries. Arthroscopy 2014;30(2):271–8.
41. Pogorzelski J, Beitzel K, Ranuccio F, et al. The acutely injured acromioclavicular joint - which imaging modalities should be used for accurate diagnosis? A systematic review. BMC Musculoskelet Disord 2017;18(1):515.
42. Bossart PJ, Joyce SM, Manaster BJ, et al. Lack of efficacy of 'weighted' radiographs in diagnosing acute acromioclavicular separation. Annals of Emergency Medicine 1988;17(1):20–4.
43. Shaw KA, Synovec J, Eichinger J, et al. Stress radiographs for evaluating acromioclavicular joint separations in an active-duty patient population: What have we learned? J Orthop 2018;15(1):159–63.
44. Berthold DP, Muench LN, Dyrna F, et al. Current concepts in acromioclavicular joint (AC) instability - a proposed treatment algorithm for acute and chronic AC-joint surgery. BMC Musculoskelet Disord 2022;23(1):1078.
45. Tossy JD, Mead NC, Sigmond HM. Acromioclavicular separations: useful and practical classification for treatment. Clin Orthop Relat Res 1963;28:111–9.
46. Allman FL Jr. Fractures and ligamentous injuries of the clavicle and its articulation. J Bone Joint Surg Am 1967;49(4):774–84.
47. Gorbaty JD, Hsu JE, Gee AO. Classifications in brief: Rockwood classification of acromioclavicular joint separations. Clin Orthop Relat Res 2017;475(1):283–7.
48. Rockwood C. 2nd edition. Injuries to the acromioclavicular joint, vol. 1. Philadelphia, PA, USA: JB Lippincott; 1984. Fractures in adults.
49. Kraeutler MJ, Williams GR Jr, Cohen SB, et al. Inter- and intraobserver reliability of the radiographic diagnosis and treatment of acromioclavicular joint separations. Orthopedics 2012;35(10):e1483–7.
50. Aliberti GM, Kraeutler MJ, Trojan JD, et al. Horizontal instability of the acromioclavicular joint: a systematic review. Am J Sports Med 2020;48(2):504–10.

51. Simovitch R, Sanders B, Ozbaydar M, et al. Acromioclavicular joint injuries: diagnosis and management. J Am Acad Orthop Surg 2009;17(4):207–19.
52. Willimon SC, Gaskill TR, Millett PJ. Acromioclavicular joint injuries: anatomy, diagnosis, and treatment. Phys Sportsmed 2011;39(1):116–22.
53. Strobel K, Pfirrmann CW, Zanetti M, et al. MRI features of the acromioclavicular joint that predict pain relief from intraarticular injection. AJR Am J Roentgenol 2003;181(3):755–60.
54. Gerber C, Galantay RV, Hersche O. The pattern of pain produced by irritation of the acromioclavicular joint and the subacromial space. J Shoulder Elbow Surg 1998;7(4):352–5.
55. Urist MR. Complete dislocations of the acromiclavicular joint; the nature of the traumatic lesion and effective methods of treatment with an analysis of forty-one cases. J Bone Joint Surg Am 1946;28(4):813–37.
56. Lemos MJ. The evaluation and treatment of the injured acromioclavicular joint in athletes. Am J Sports Med 1998;26(1):137–44.
57. Cox JS. Current method of treatment of acromioclavicular joint dislocations. Orthopedics 1992;15(9):1041–4.
58. Larsen E, Bjerg-Nielsen A, Christensen P. Conservative or surgical treatment of acromioclavicular dislocation. A prospective, controlled, randomized study. J Bone Joint Surg Am 1986;68(4):552–5.
59. Bergfeld JA, Andrish JT, Clancy WG. Evaluation of the acromioclavicular joint following first- and second-degree sprains. Am J Sports Med 1978;6(4):153–9.
60. Bradley JP, Elkousy H. Decision making: operative versus nonoperative treatment of acromioclavicular joint injuries. Clin Sports Med 2003;22(2):277–90.
61. Debski RE, Parsons IMt, Woo SL, et al. Effect of capsular injury on acromioclavicular joint mechanics. J Bone Joint Surg Am 2001;83(9):1344–51.
62. Nuber GW, Bowen MK. Acromioclavicular Joint Injuries and Distal Clavicle Fractures. J Am Acad Orthop Surg 1997;5(1):11–8.
63. Sage FP, Salvatore JE. Injuries of the acromioclavicular joint: a study of results in 96 patients. South Med J 1963;56:486–95.
64. Ahstrom JP Jr. Surgical repair of complete acromioclavicular separation. JAMA 1971;217(6):785–9.
65. Augereau B, Robert H, Apoil A. [Treatment of severe acromio-clavicular dislocations. A coraco-clavicular ligamentoplasty technique derived from Cadenat's procedure (author's transl)]. Ann Chir 1981;35(9 Pt 1):720–2. Traitement des luxations acromio-claviculaires de stade III. Ligamentoplastie a partir du ligament acromio-coracoidien selon une technique derivee de celle de Cadenat.
66. Bartonicek J, Jehlicka D, Bezvoda Z. [Surgical treatment of acromioclavicular luxation]. Acta Chir Orthop Traumatol Cech 1988;55(4):289–309. Operacni lecba akromioklavikularni luxace.
67. Leidel BA, Braunstein V, Kirchhoff C, et al. Consistency of long-term outcome of acute Rockwood Grade III acromioclavicular joint separations after K-wire transfixation. J Trauma 2009;66(6):1666–71.
68. Lizaur A, Sanz-Reig J, Gonzalez-Parreno S. Long-term results of the surgical treatment of type III acromioclavicular dislocations: an update of a previous report. J Bone Joint Surg Br 2011;93(8):1088–92.
69. Norrell H Jr, Llewellyn RC. Migration of a threaded Steinmann pin from an acromioclavicular joint into the spinal canal. A case report. J Bone Joint Surg Am 1965;47:1024–6.
70. Broos P, Stoffelen D, Van de Sijpe K, et al. [Surgical management of complete Tossy III acromioclavicular joint dislocation with the Bosworth screw or the

Wolter plate. A critical evaluation]. Unfallchirurgie 1997;23(4):153–9 ; discussion 160. Operative Versorgung der vollstandigen AC-Luxation Tossy III mit der Bosworth-Schraube oder der Wolter-Platte. Eine Kritische Betrachtung.
71. Habernek H, Weinstabl R, Schmid L, et al. A crook plate for treatment of acromioclavicular joint separation: indication, technique, and results after one year. J Trauma 1993;35(6):893–901.
72. Henkel T, Oetiker R, Hackenbruch W. [Treatment of fresh Tossy III acromioclavicular joint dislocation by ligament suture and temporary fixation with the clavicular hooked plate]. Swiss Surg 1997;3(4):160–6. Die Behandlung der frischen AC-Luxation Tossy III durch Bandnaht und temporare Fixation mit Klavikula-Hakenplatte.
73. Lin HY, Wong PK, Ho WP, et al. Clavicular hook plate may induce subacromial shoulder impingement and rotator cuff lesion–dynamic sonographic evaluation. J Orthop Surg Res 2014;9:6.
74. Phadke A, Bakti N, Bawale R, et al. Current concepts in management of ACJ injuries. J Clin Orthop Trauma 2019;10(3):480–5.
75. Neviaser JS. Acromioclavicular dislocation treated by transference of the coraco-acromial ligament. A long-term follow-up in a series of 112 cases. Clin Orthop Relat Res 1968;58:57–68.
76. Auge WK 2nd, Fischer RA. Arthroscopic distal clavicle resection for isolated atraumatic osteolysis in weight lifters. Am J Sports Med 1998;26(2):189–92.
77. Guy DK, Wirth MA, Griffin JL, et al. Reconstruction of chronic and complete dislocations of the acromioclavicular joint. Clin Orthop Relat Res 1998;(347):138–49.
78. Kumar S, Sethi A, Jain AK. Surgical treatment of complete acromioclavicular dislocation using the coracoacromial ligament and coracoclavicular fixation: report of a technique in 14 patients. J Orthop Trauma 1995;9(6):507–10.
79. Verhaven E, DeBoeck H, Haentjens P, et al. Surgical treatment of acute type-V acromioclavicular injuries in athletes. Arch Orthop Trauma Surg 1993;112(4):189–92.
80. Weaver JK, Dunn HK. Treatment of acromioclavicular injuries, especially complete acromioclavicular separation. J Bone Joint Surg Am 1972;54(6):1187–94.
81. Rauschning W, Nordesjo LO, Nordgren B, et al. Resection arthroplasty for repair of complete acromioclavicular separations. Arch Orthop Trauma Surg 1980;97(3):161–4.
82. LaPrade RF, Hilger B. Coracoclavicular ligament reconstruction using a semitendinosus graft for failed acromioclavicular separation surgery. Arthroscopy 2005;21(10):1277.
83. Kawabe N, Watanabe R, Sato M. Treatment of complete acromioclavicular separation by coracoacromial ligament transfer. Clin Orthop Relat Res 1984;185:222–7.
84. Shoji H, Roth C, Chuinard R. Bone block transfer of coracoacromial ligament in acromioclavicular injury. Clin Orthop Relat Res 1986;208:272–7.
85. Bosworth B. Acromioclavicular separation: a new method of repair. Surg Gynecol Obstet 1941;73:866–71.
86. Tsou PM. Percutaneous cannulated screw coracoclavicular fixation for acute acromioclavicular dislocations. Clin Orthop Relat Res 1989;243:112–21.
87. Kennedy JC. Complete dislocation of the acromioclavicular joint: 14 years later. J Trauma 1968;8(3):311–8.
88. Lowe GP, Fogarty MJ. Acute acromioclavicular joint dislocation: results of operative treatment with the Bosworth screw. Aust N Z J Surg 1977;47(5):664–7.

89. Tiefenboeck TM, Popp D, Boesmueller S, et al. Acromioclavicular joint dislocation treated with Bosworth screw and additional K-wiring: results after 7.8 years - still an adequate procedure? BMC Musculoskelet Disord 2017;18(1):339.
90. Esenyel CZ, Ozturk K, Bulbul M, et al. Coracoclavicular ligament repair and screw fixation in acromioclavicular dislocations. Acta Orthop Traumatol Turc 2010;44(3):194–8.
91. Colosimo AJ, Hummer CD 3rd, Heidt RS Jr. Aseptic foreign body reaction to Dacron graft material used for coracoclavicular ligament reconstruction after type III acromioclavicular dislocation. Am J Sports Med 1996;24(4):561–3.
92. Hessmann M, Gotzen L, Gehling H. Acromioclavicular reconstruction augmented with polydioxanonsulphate bands. Surgical technique and results. Am J Sports Med 1995;23(5):552–6.
93. Clayer M, Slavotinek J, Krishnan J. The results of coraco-clavicular slings for acromio-clavicular dislocation. Aust N Z J Surg 1997;67(6):343–6.
94. Gohring U, Matusewicz A, Friedl W, et al. [Results of treatment after different surgical procedures for management of acromioclavicular joint dislocation]. Chirurg 1993;64(7):565–71. Behandlungsergebnisse nach unterschiedlichen Operationsverfahren zur Versorgung einer Schultereckgelenksprengung.
95. Gollwitzer M. [Surgical management of complete acromioclavicular joint dislocation (Tossy III) with PDS cord cerclage]. Aktuelle Traumatol 1993;23(8): 366–70. Operative Versorgung der kompletten Schultereckgelenkluxation (Tossy III) mit PDS-Kordel.
96. Kiefer H, Claes L, Burri C, et al. The stabilizing effect of various implants on the torn acromioclavicular joint. A biomechanical study. Arch Orthop Trauma Surg 1986;106(1):42–6.
97. Jones HP, Lemos MJ, Schepsis AA. Salvage of failed acromioclavicular joint reconstruction using autogenous semitendinosus tendon from the knee. Surgical technique and case report. Am J Sports Med 2001;29(2):234–7.
98. Costic RS, Labriola JE, Rodosky MW, et al. Biomechanical rationale for development of anatomical reconstructions of coracoclavicular ligaments after complete acromioclavicular joint dislocations. Am J Sports Med 2004;32(8):1929–36.
99. Grutter PW, Petersen SA. Anatomical acromioclavicular ligament reconstruction: a biomechanical comparison of reconstructive techniques of the acromioclavicular joint. Am J Sports Med 2005;33(11):1723–8.
100. Mazzocca AD, Santangelo SA, Johnson ST, et al. A biomechanical evaluation of an anatomical coracoclavicular ligament reconstruction. Am J Sports Med 2006; 34(2):236–46.
101. Tauber M, Gordon K, Koller H, et al. Semitendinosus tendon graft versus a modified Weaver-Dunn procedure for acromioclavicular joint reconstruction in chronic cases: a prospective comparative study. Am J Sports Med 2009; 37(1):181–90.
102. Voss A, Imhoff AB. Editorial commentary: why we have to respect the anatomy in acromioclavicular joint surgery and why clinical shoulder scores might not give us the information we need. Arthroscopy 2019;35(5):1336–8.
103. Dawson PA, Adamson GJ, Pink MM, et al. Relative contribution of acromioclavicular joint capsule and coracoclavicular ligaments to acromioclavicular stability. J Shoulder Elbow Surg 2009;18(2):237–44.
104. Dyrna F, Imhoff FB, Haller B, et al. Primary stability of an acromioclavicular joint repair is affected by the type of additional reconstruction of the acromioclavicular capsule. Am J Sports Med 2018;46(14):3471–9.

105. Dyrna FGE, Imhoff FB, Voss A, et al. The integrity of the acromioclavicular capsule ensures physiological centering of the acromioclavicular joint under rotational loading. Am J Sports Med 2018;46(6):1432–40.
106. Morikawa D, Dyrna F, Cote MP, et al. Repair of the entire superior acromioclavicular ligament complex best restores posterior translation and rotational stability. Knee Surg Sports Traumatol Arthrosc 2019;27(12):3764–70.
107. Klimkiewicz JJ, Williams GR, Sher JS, et al. The acromioclavicular capsule as a restraint to posterior translation of the clavicle: a biomechanical analysis. J Shoulder Elbow Surg 1999;8(2):119–24.
108. Schobel T, Theopold J, Fischer JP, et al. Anatomical versus non-anatomical configuration of double coraco-clavicular tunnel technique in acromioclavicular joint reconstruction. Arch Orthop Trauma Surg 2022;142(4):641–8.
109. Teixeira Ramos J, Silva Gomes D, Quinaz Neto P, et al. Arthroscopic-assisted acromioclavicular joint dislocation repair: a modified technique for horizontal stabilization using suture anchors. Arthrosc Tech 2021;10(2):e283–8.
110. Martetschlager F, Tauber M, Habermeyer P, et al. Arthroscopically assisted acromioclavicular and coracoclavicular ligament reconstruction for chronic acromioclavicular joint instability. Arthrosc Tech 2016;5(6):e1239–46.
111. Tauber M, Valler D, Lichtenberg S, et al. Arthroscopic stabilization of chronic acromioclavicular joint dislocations: triple- versus single-bundle reconstruction. Am J Sports Med 2016;44(2):482–9.
112. Mardani-Kivi M, Asadi K, Leili EK, et al. Horizontal instability after acromioclavicular joint reduction using the two-hole technique is preferred over the loop technique: a single-blind randomized clinical trial. Clin Shoulder Elb 2022;25(3):224–9.
113. Aliberti GM, Mulcahey MK, Brown SM, et al. Restoring horizontal stability of the acromioclavicular joint: open acromioclavicular ligament reconstruction and repair with semitendinosus allograft. Arthrosc Tech 2020;9(10):e1619–26.
114. Angelo AC, Maia Dias C, de Campos Azevedo C. Combined vertical, horizontal, and rotational acromioclavicular joint stabilization: "closing the circle" technique. Arthrosc Tech 2022;11(8):e1479–86.
115. Spiegl UJ, Smith SD, Euler SA, et al. Biomechanical consequences of coracoclavicular reconstruction techniques on clavicle strength. Am J Sports Med 2014;42(7):1724–30.
116. Martetschlager F, Saier T, Weigert A, et al. Effect of coracoid drilling for acromioclavicular joint reconstruction techniques on coracoid fracture risk: a biomechanical study. Arthroscopy 2016;32(6):982–7.
117. Martetschlager F, Horan MP, Warth RJ, et al. Complications after anatomic fixation and reconstruction of the coracoclavicular ligaments. Am J Sports Med 2013;41(12):2896–903.
118. Scheibel M, Droschel S, Gerhardt C, et al. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations. Am J Sports Med 2011;39(7):1507–16.