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SHOULDER

Biologic and synthetic ligament reconstructions achieve better functional scores compared to osteosynthesis in the treatment of acute acromioclavicular joint dislocation

Maristella F. Saccomanno[1] · Giuseppe Sircana[1] · Valentina Cardona[1] · Valeria Vismara[1] · Alessandra Scaini[2] · Andrea G. Salvi[2] · Stefano Galli[3] · Giacomo Marchi[3] · Giuseppe Milano[2,3]

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Abstract

Purpose To systematically review the outcomes of surgical treatments of acute acromioclavicular joint dislocation.
Methods Studies were identified by electronic databases (Ovid, PubMed). All studies reporting functional and radiological outcomes of surgical treatments of acute acromioclavicular joint dislocations were included. Following data were extracted: authors and year, study design, level of evidence, number of patients, age, classification of acromioclavicular joint dislocation, time to surgery, surgical technique, follow-up, clinical and imaging outcomes, complications, and failures. Descriptive statistics was used, when a data pooling was not possible. Comparable outcomes were pooled to generate summary outcomes reported as frequency-weighted values. Quality appraisal was assessed through the MINORS checklist.
Results One hundred and thirty-three studies were included for a total of 4473 shoulders. Mean age of participants was 36.9 years. Mean follow-up was 42.06 months. Arthroscopy showed better ASES ($p < 0.0001$) and lower VAS pain score ($p = 0.0249$) compared to an open approach. Biologic and synthetic reconstructions demonstrated better results over osteosynthesis techniques. Biologic techniques showed overall better Constant ($p = 0.0001$) and DASH ($p = 0.0215$) scores, while synthetic reconstruction showed better UCLA score ($p = 0.0001$). Among suture buttons, triple button showed overall better results in Constant ($p = 0.0001$) and VAS ($p = 0.0001$) scores, while better results in DASH score ($p = 0.0003$) were achieved by 2 double button techniques. Overall, the level of evidence was low.
Conclusion Biological and synthetic reconstructions achieved better functional scores compared to osteosynthesis. Among suture buttons, the triple button showed better functional performance.
Level of evidence IV.

Keywords Acromioclavicular · Instability · Dislocation · Coracoclavicular ligament · Acromioclavicular ligament · Biologic · Synthetic · Tendon graft · Plate · Screws · Reconstruction

Introduction

Acromioclavicular (AC) joint dislocation is one of the most common traumatic injuries of the shoulder girdle, accounting for up to 12% of all injuries at this site [27]. AC joint dislocations mainly occur in young active men, especially athletes involved in contact sports, in their second decade of life [110]. Correct diagnosis and proper treatment strategy are paramount to achieve good functional results. General consensus supports nonoperative treatment in type-I and type-II injuries according to the Rockwood classification, whereas high-grade injuries, like type-IV and type-V dislocations, usually undergo surgical treatment. Management of type-III AC joint dislocation is still under debate and surgical treatment is recommended only in younger patients with high functional requirements or in chronic symptomatic cases [114].

Whenever a surgical treatment is recommended, literature is still lacking on the definition of acute setting in AC joint dislocation, even if it seems that the earlier the surgery, the

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✉ Maristella F. Saccomanno
maristellasaccomanno@hotmail.it

Extended author information available on the last page of the article

easier it is to obtain an accurate reduction and a better functional outcome [132].

Focusing on surgery, more than 100 surgical techniques have been described in the last decades, in both open and arthroscopic approaches, ranging from anatomic ligament reconstructions to osteosynthesis with plate and screws. Up to date, none of those techniques has demonstrated to be superior to the others [56]. Moreover, recent systematic reviews included both acute and chronic cases together, without making a distinction on results, further complicating the issue [53, 100].

The purpose of the present study was to systematically review the outcomes of surgical treatments of AC joint dislocation in an acute setting. The hypothesis of the study was that biologic AC joint reconstruction would result in better postoperative outcomes.

Materials and methods

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [101].

Literature search

Studies were identified by searching major electronic databases (Ovid, PubMed). There were no restrictions on the date of publication or the language. The search was applied to MEDLINE through Ovid and then adapted for PubMed. All databases were examined from their inception up to March 03, 2020. Full search strategies are available in Appendix 1 in Supplementary material.

All studies reporting functional and radiological outcomes as well as revision rates after surgical treatment of acute AC joint dislocation were included (level of evidence I–IV). Both open and arthroscopic approaches were included. Studies comparing surgical versus conservative treatment as well as studies including chronic or revision cases were also included, with only the data from the primary acute surgical cases included in the analysis. If separate data could not be extracted, studies were excluded. Similarly, studies reporting outcomes of patients with associated shoulder pathologies, whose data were not separable from the rest of the study population, were also excluded. Animal studies, biomechanical studies, case reports, technical notes, review articles, expert opinions, and editorial pieces were excluded.

Two authors independently selected eligible studies from title and abstract. Subsequently, they analyzed the full text to confirm the inclusion in the study. Additionally, all references within included studies were cross-referenced for potential inclusion if omitted from the initial search.

Titles of journals, names of authors, or supporting institutions were not masked at any stage. No attempt was made to contact trialists regarding trial methodology and findings. Disagreements at any stage of the review process were resolved by consensus or third-party adjudication by the senior author.

Data extraction and analysis

The following data were then extracted: authors, year of publication, study design (prospective or retrospective), level of evidence (LOE), number of shoulders, patients' age, type of dislocation (according to Rockwood classification) time elapsed from injury to surgery, surgical approach (open or arthroscopic), surgical technique, length of follow-up, functional and subjective outcomes, loss of reduction, revision, and complications. Data were extracted by one investigator and cross-checked by another investigator.

Although all functional outcomes were reported in the data extraction form, only the most commonly reported scores were used for data analysis.

Quality appraisal

The methodological assessment of included studies was performed by two authors independently, by evaluating the potential risk of bias, both in comparative and in non-comparative studies, using the MINORS checklist [131]. The index includes 12 items, 4 of which dedicated only to comparative studies. Each item was scored 0 if not reported, 1 when reported but inadequate, and 2 when reported and adequate. The ideal score was 16 for non-comparative studies and 24 for comparative studies. Studies with a MINORS score ≤ 12 and ≤ 20 for non-comparative and comparative studies, respectively, were considered at high risk of bias.

Statistical analysis

Descriptive statistics was applied when data pooling was not possible. Comparable outcome data from individual studies were pooled to generate summary outcomes reported as frequency-weighted values (weighted mean and standard deviation). A number of shoulders in individual studies were used to determine the weight of reported outcomes and used to calculate the weighted values. Between-group differences for continuous variables were analyzed with Student's t test. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using GraphPad Prism 8 (GraphPad Software, San Diego, CA, USA).

Results

Study selection

The electronic search resulted in 495 entries. After removing the duplicates, 371 studies remained. Of these, 191 were excluded based on their abstract and 47 additional studies were excluded based on the full-text article. One hundred and thirty-three [1, 2, 4, 5, 7–10, 12–15, 17–23, 25, 29, 30, 32–41, 43–46, 49–52, 54–61, 64–67, 69–73, 75–82, 86–95, 97–99, 102–109, 111, 113, 117, 118, 120, 122–130, 133, 135, 137–139, 143, 144, 146–156, 158, 160–162, 165–167, 170–177] were finally included in the review (Fig. 1).

Study characteristics

Included studies reported data on 4473 shoulders. Mean age of participants was 36.9 ± 5.17 years (range, 15–84 years). One thousand six-hundred and fifty shoulders suffered from a Rockwood type-III dislocation, 420 shoulders a type-IV dislocation, and 1614 shoulders a type-V dislocation. Patients underwent surgery within 1 week from dislocation in 20 studies [4, 41, 43, 49, 51, 56, 57, 75, 76, 78, 81, 82, 91, 138, 148, 151, 152, 156, 160, 176], 2 weeks in 52 studies [5, 7, 9, 10, 15, 19, 21, 30, 34–36, 44, 46, 58–60, 67, 70, 71, 87–90, 94, 97, 98, 105, 106, 108, 111, 122, 125–127, 129, 135, 139, 144, 147, 149, 153, 155, 158, 161, 162, 165, 166, 170–172, 174, 177], 3 weeks in 31 studies [2, 8, 12, 17, 20, 23, 25, 29, 33, 37, 50, 54, 61, 65, 66, 72, 77, 79, 95, 99, 109, 118, 123, 128, 130, 133, 143, 150, 155, 167, 175], 4 weeks in 13 studies [1, 14, 38, 39, 55, 64, 73, 93, 107, 120, 124, 137, 146], 6 weeks in six studies [22, 92, 102, 103, 117, 173], and 6 months in one study [104]. Time from injury to surgery was not reported in ten studies [13, 18, 32, 40, 52, 69, 80, 86, 113, 154]. The mean length of follow-up was 42.1 ± 32.9 months (range, 4–247 months).

Two studies [14, 93] reported different results of the same population of patients, as stated in the Methods section. Different data were collected, but patients were considered only once.

According to the LOE, only nine studies were level I [1, 14, 30, 43, 91, 93, 105, 106, 173] and five studies were level II [5, 65, 69, 129, 135].

Surgical techniques are summarized in Table 1.

Loss of reduction was reported on X-rays in 116 studies [2, 4, 7, 10, 12–15, 17–23, 25, 29, 30, 32–41, 43, 45, 46, 49–52, 54–61, 64–67, 69–73, 75–77, 86–88, 90–92, 94, 95, 97, 98, 102–104, 106–109, 111, 117, 118, 122–130, 133, 135, 137–139, 143, 144, 146–154, 156, 158, 160–162, 165–167, 170–177], computed tomography (CT) was used in one study [78], magnetic resonance (MR) in one study [89], and clinical evaluation was used in two studies [79, 80], while in 13 studies [1, 5, 8, 9, 44, 81, 82, 93, 99, 105, 113, 120, 155], it was not reported. Main definitions were summarized in Table 2.

Most commonly reported functional scores were: Constant score [26] in 94 studies, Visual Analogic Scale (VAS) for pain in 47 studies, Disabilities of the Arm, Shoulder and Hand (DASH) score [62] in 24 studies, University of California, Los Angeles (UCLA) shoulder rating scale [42] in 24 studies, and American Shoulder and Elbow Surgeons (ASES) society standardized shoulder assessment form [115] in 20 studies. Full list of clinical scores is reported in Table 3.

Single studies characteristics and outcomes are reported in detail in Appendix 2 in Supplementary material.

Surgical approach comparison: open vs arthroscopic

Main characteristics of studies based on surgical approach are reported in Table 4. One study [81] reported the results of open and arthroscopic techniques without providing separate data, which, therefore, was not included in the analyses. Functional outcomes of open and arthroscopic procedures are reported in Table 5. Statistically significant differences were found in VAS ($p = 0.0249$) and ASES ($p = 0.0001$) score, favoring arthroscopic techniques.

Biologic reconstruction vs synthetic reconstruction vs osteosynthesis

Main characteristics of different surgical techniques are summarized in Table 6. Clinical outcomes are reported in Table 7. Biologic and synthetic techniques demonstrated better results in all analyzed outcomes over osteosynthesis techniques. Biologic techniques showed overall better results in Constant ($p = 0.0001$) and DASH ($p = 0.0215$) score, while synthetic techniques scored better results in UCLA ($p = 0.0001$). No differences could be found between the biologic and synthetic group for VAS and ASES scores.

Pairwise comparisons of single techniques were attempted, but the paucity of studies analyzing the same technique, the consequent small number of patients, and the different outcomes considered prevented us from performing subgroup analysis of different surgical techniques except for the comparison between double and triple buttons.

Double button vs triple button

Main characteristics of studies reporting button techniques are summarized in Table 8. Studies reporting button

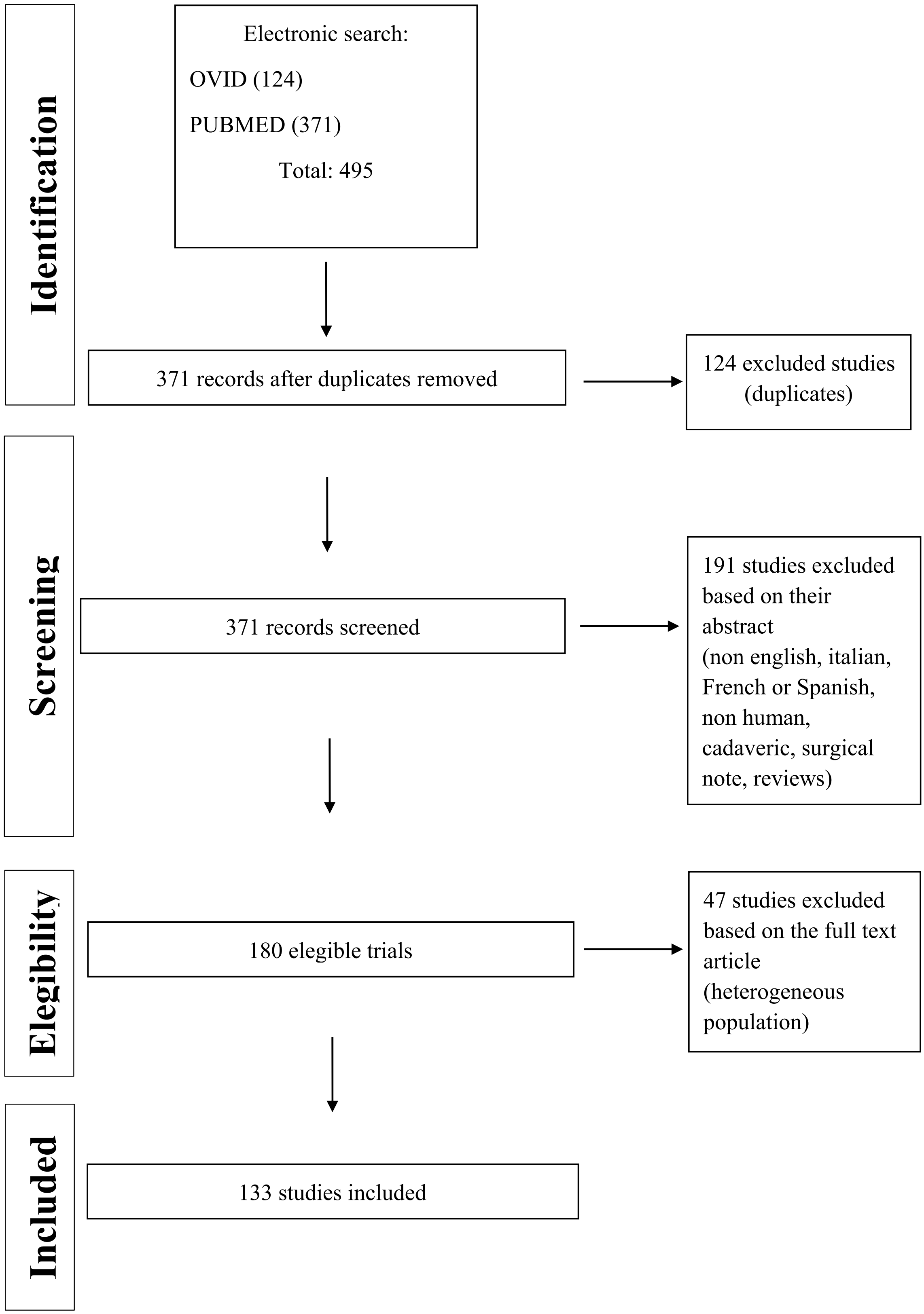

Fig. 1 Study selection based on PRISMA flowchart

Table 1 Surgical techniques

Biologic	Synthetic	Internal fixation
Autograft CC reconstruction [22, 76, 174]	Double-button [1, 2, 7, 9, 20, 25, 30, 34, 35, 40, 44–46, 52, 59, 60, 64, 67, 71, 87, 89, 91, 98, 102, 107, 111, 118, 124, 125, 127, 133, 137, 138, 144, 148, 155, 156, 170]	Hook plate [9, 14, 49, 58, 61, 70, 81, 93, 98, 109, 113, 144, 175, 177]
Autograft AC reconstruction [51]	Double-button and AC reconstruction [77, 82, 106]	Hook plate augmented with AC repair [19, 38, 173]
Autograft CC reconstruction augmented with K-wires [94]	Double-button augmented with pins [21]	Hook plate augmented with CC repair [105]
Autograft CC reconstruction augmented with synthetic ligaments [143]	Two double buttons [60, 69, 97, 105, 107, 108, 120, 123, 135, 138, 150, 170, 176]	Hook plate augmented with AC and CC repair [19, 32, 160]
Allograft CC and AC reconstruction [77, 104, 160]	Two double buttons and AC reconstruction [56, 97, 171]	Hook plate augmented with biologic reconstruction [99, 158, 173]
Modified Weaver-Dunn [55, 165, 167]	Triple buttons [12, 15, 44, 91, 126, 166]	AC plate fixation [86]
Modified Cadenat [17]	Synthetic ligament reconstruction [50, 57, 66, 92, 95, 147, 149, 152, 175]	Bosworth screw [5, 30, 139]
Cadenat augmented with K-wires [37]	Synthetic ligament reconstruction augmented with K-wires [154]	Bosworth screw augmented with ligament repair [4, 18, 90]
Cadenat augmented with suture anchors [128]	Synthetic tape reconstruction [33, 61, 73]	Bosworth screw augmented with temporary K-wire [129, 177]
Dewar–Barrington [130]	Synthetic CC cerclage [36, 54, 107]	CC wire cerclage [39, 49, 172]
Dewar–Barrington augmented with K-wires [162]	Synthetic CC cerclage and AC reconstruction [41, 72, 80, 122]	AC screw fixation [43, 153]
Coraco-acromial ligament transfer augmented with K-wires [103]	Synthetic CC cerclage augmented with K-wires [8, 94, 117, 151, 155]	K-wire fixation [60, 153]
	Suture anchor CC reconstruction [23, 29, 44, 78, 107, 146]	K-wire fixation with CC repair [18, 60]
		K-wire fixation with AC repair [43, 65, 88]
		K-wire fixation with AC and CC repair [10, 13, 79, 80]
		Tension band fixation [10, 75]
		Knowles pin and CC cerclage [161]

CC coracoclavicular, *AC* acromioclavicular

techniques associated with AC reconstruction and augments were excluded from this analysis.

Functional outcomes are reported in Table 9. Triple button showed overall better results in Constant ($p = 0.0001$) and VAS ($p = 0.0001$) scores, while better results in DASH score ($p = 0.0003$) were achieved by 2 double buttons techniques. Double and triple button demonstrated better results in ASES ($p = 0.0003$) and UCLA ($p = 0.0001$) score over two double-button reconstruction.

Risk of bias within studies

The methodological quality of the included studies was low. The results of the MINORS checklist are reported in Appendix 3 in Supplementary material.

Eighty-two non-comparative studies [2, 4, 7, 8, 12, 15, 17, 20, 22, 23, 25, 29, 32, 33, 36–41, 45, 46, 50–52, 54, 55, 57, 58, 64, 66, 67, 72, 73, 75, 76, 82, 86–90, 95, 97, 99, 102, 103, 111, 113, 117, 118, 120, 122–124, 126–128, 130, 133, 137, 139, 143, 146–154, 158, 161, 162, 165–167, 171, 172, 174, 176] were at high risk of bias and only six [56, 70, 71, 78, 92, 104] were at low risk of bias; 34 comparative studies [5, 10, 13, 18, 19, 21, 34, 35, 43, 44, 49, 59, 60, 69, 77, 79–81, 91, 93, 94, 98, 106–109, 125, 144, 155, 156, 160, 170, 173, 175] were at high risk of bias, while only 11 [1, 9, 14, 30, 61, 65, 105, 129, 134, 138, 177] were at low risk of bias.

Discussion

Main findings of the present review showed that an open approach to the AC joint is still the most common adopted option. However, arthroscopy definitely presented some advantages in terms of lower VAS pain score and, somehow, in functional performance, at least when evaluated through the ASES score. Moreover, the percentage of postoperative OA was lower if an arthroscopic approach was used.

Table 2 Main definitions of "reduction"

Definition	Radiologic evaluation
Vertical distance between the inferior border of the clavicle and the tip of the coracoid: Anatomic: < 2 mm Slight loss: 2–4 mm Partial loss: 4–8 mm Complete loss: > 8 mm	Radiograph [23, 92, 142, 147, 158]
Vertical distance between the highest point of the clavicle and the acromion: Anatomic: < 2 mm Slight loss: 2–4 mm Partial loss: 4–8 mm Complete loss: > 8 mm	Radiograph [21, 86, 149]
Vertical distance between the inferior border of the clavicle and the acromion: Minimal displacement: < 2 mm Mild displacement: 2–4 mm Moderate displacement: 4–6 mm Marked displacement: > 6 mm	Radiograph [174]
Translation measured on the AP width of the clavicle: Slight loss: < 50% Obvious loss or dislocation: > 50%	Radiograph [91, 98, 138, 153]
Side-to-side difference: Anatomic: no difference Partial loss: less than the width of the clavicle Complete loss: more than the width of the clavicle	Radiograph [4, 33, 162, 167]
Translation measured on the AP width of the clavicle: Anatomic: no displacement Subluxation: > 50% Dislocation: > 100%	Radiograph [153]
Side-to-side difference measured on the height of the acromion: Anatomic: no displacement Subluxated: < 50% Dislocated: > 50%	Radiograph [13, 72, 108, 109]
Superior translation of the clavicle in relation to the acromion: 0% displacement 25% displacement 50% displacement 75% displacement 100% displacement	Radiograph [94] MRI [89]
Side-to-side difference in CC distance: Mild loss: 0–50% Subluxation: 50–100% Redislocation: > 100%	Radiograph [61, 127, 127, 128]
Side-to-side difference in CC distance: Slight loss: 25–90% Complete loss: > 90%	Radiograph [23]
Side-to-side difference: Reduced: symmetric Not reduced: not symmetric	Radiograph [14]
Upward translation of the clavicle: Recurrent subluxation: < 1 cm Complete redislocation: > 1 cm	Radiograph [35]
AC joint step-off: Mild subluxation: < 25% Moderate subluxation: 25–50% Severe subluxation: > 50%	Radiograph [66]
Increase in CC length by 25–100% compared to the contralateral side	Radiograph [15, 173]
Increase in CC distance > 50%	Radiograph [71, 126]
Side-to-side difference in CC distance ≥ 2 mm	Radiograph [125]
Side-to-side difference in CC distance ≥ 3 mm	Radiograph [151]
Side-to-side difference in CC distance ≥ 5 mm	Radiograph [156]

Table 2 (continued)

Definition	Radiologic evaluation
CC distance increase from the initial postoperative radiographs ≥ 2 mm	Radiograph [20]
CC distance increase from the initial postoperative radiographs ≥ 5 mm	Radiograph [77]
50% difference in CC distance between the two shoulders	Radiograph [30]
Translation in the vertical plane greater than 50% of the clavicle shaft width	Radiograph [17, 41, 118, 124]
Translation in the vertical plane greater than 100% of the clavicle shaft width	Radiograph [59]
Posterior displacement: a clavicle not in line with the acromion	TC [102]
25% increase in CC distance from the immediate postoperative radiograph	Radiograph [22]
CC distance > 100% compared to the contralateral side	Radiograph [54]
CC distance ratio with contralateral shoulder > 150%	Radiograph [19]
Partial vertical and horizontal failure: CC distance > 25% Posterior translation of the clavicle less than clavicle width Total horizontal failure: Posterior translation of the clavicle of more than a clavicle width	Radiograph [56, 97]
CC distance ratio > 1.2	Radiograph [64]
AC distance > 20 mm	Radiograph [75]

AC acromioclavicular, *AP* antero-posterior, *CC* coracoclavicular

On the contrary, the open approach showed lower rate of loss of reduction and revisions. Looking deeper into surgical techniques, regardless of the approach, biologic and synthetic reconstructions showed better functional scores compared to osteosynthesis techniques. Particularly, biologic reconstructions showed the best Constant and DASH score overall, thus partially accepting the hypothesis of the study. Osteosynthesis techniques showed the lowest rate of loss of reduction, but the highest percentage of postoperative OA. Surprisingly, although the percentages were not high, biologic reconstructions showed the highest revision rate among the three groups. Taking into account that biologic reconstructions showed at the same time the best Constant score, but also the highest revision rate, a subgroup analysis, e.g., between anatomic and non-anatomic techniques, could have surely been helpful for a better understanding of the results. Unfortunately, available data did not allow any further comparison. On the contrary, a deeper investigation into the results of synthetic reconstructions was possible. According to the current available literature, suture buttons seemed the favored choice in the acute setting. Interestingly, triple button showed the best functional performance in terms of pain reduction and Constant score. Triple button also displayed a very low rate of postoperative OA and revisions, even if it showed the highest percentage of loss of reduction compared to double buttons.

Arthroscopic techniques are growing in volume and efficiency. Main advantages are related to: first, the opportunity to check the status of the glenohumeral joint and the subacromial space to rule out, and eventually treat, concomitant pathologies; second, ease of access to the undersurface of the base of the coracoid, which it is surely the trickiest part when an anatomic coracoclavicular (CC) ligament reconstruction with tendon graft, suture, or tape is attempted. However, as the approach has never been regarded as a real issue in AC joint surgery and considering the ease of access to the joint, probably, a room for an open approach will always stay.

Definition of "acute" setting still remains a controversial issue. As recent reviews [53, 100], focused on clinical and imaging outcomes after AC joint reconstruction, included both acute and chronic cases, it cannot be denied that the two settings exhibit different biological characteristics, and then, surgical management should be dissimilar. According to the papers included in the present review, the acute setting mostly ranges from 3 days [43, 56, 81, 152, 160, 176], up to 6 weeks [22, 92, 102, 103, 117, 173] after trauma. Recently, some authors clearly stated that 3 weeks can set the separation line to achieve better results, maximizing the biological support from injured and surrounding tissues [47, 96]. Therefore, if 3 weeks can be considered "the golden hour", 3–6 weeks can also be regarded as the gray zone or the subacute phase, before shifting into the chronic setting [47].

Anyhow, the aim of surgery should always be the restoration of normal anatomy and kinematic of the joint. Therefore, it is not a surprise that biological and synthetic reconstruction achieved better functional results compared to osteosynthesis devices. The previous reviews [3, 159] compared suture buttons and hook plate, as they are the most common devices in synthetic and osteosynthesis group, respectively. The authors showed that suture buttons resulted in better functional scores and lower VAS pain score. However, while Arirachakaran et al. [3] found a higher loss of reduction in the suture button group, no

Table 3 Reported functional outcome scores

Score	*N* studies	References
Constant score [26]	94	[1, 2, 7–9, 12, 14, 15, 17, 18, 20, 23, 25, 30, 32, 34, 36, 38, 40, 41, 44–46, 49, 50, 54, 56, 58, 64, 65, 67, 69–72, 75, 76, 78–80, 82, 86, 87, 89, 91, 92, 94, 95, 98, 99, 102–104, 108, 109, 111, 113, 117, 118, 120, 122–124, 126–129, 133, 135, 137, 138, 144, 147–151, 153–156, 158, 160–162, 166, 170–177]
Visual Analogic Scale (VAS) for pain	47	[1, 2, 7, 12, 17–19, 35, 50, 58, 60, 61, 64, 72, 75, 80–82, 89, 91, 92, 94, 107–109, 113, 122, 126, 133, 138, 144, 147, 148, 150, 153, 155, 156, 162, 166, 170–177]
Disabilities of the Arm, Shoulder and Hand (DASH) score [62]	24	[2, 4, 7, 12, 14, 30, 35, 46, 51, 54, 72, 73, 106–109, 122, 144, 147, 148, 151, 153, 154, 176]
University of California, Los Angeles (UCLA) shoulder rating scale [42]	24	[4, 12, 19, 21–23, 34, 41, 45, 52, 60, 61, 65, 70, 71, 107, 137, 143, 144, 147, 149, 154, 160, 162]
American Shoulder and Elbow Surgeons (ASES) society standardized shoulder assessment form [115]	20	[4, 19, 21, 22, 34, 41, 60, 77, 79–81, 102, 122, 125, 126, 137, 144, 147, 149, 173]
Simple Shoulder Test (SST) [85]	11	[44, 60, 65, 104, 137, 138, 144, 147, 150, 151, 153]
Subjective Shoulder Value (SSV) [48]	11	[21, 35, 54, 56, 58, 64, 69, 75, 97, 123, 124]
AcromioClavicular Joint Instability (ACJI) score [123]	9	[8, 15, 34, 56, 69, 97, 98, 123, 124]
Taft score [142]	8	[56, 69, 97, 98, 118, 123, 124, 135]
Oxford Shoulder Score (OSS) [31]	6	[30, 44, 55, 61, 106, 155]
Quick-DASH [6]	6	[58, 64, 75, 89, 120, 156]
36-item Short-Form health survey (SF-36) [164]	6	[93, 107–109, 147, 150]
Imatani score [63]	3	[13, 139, 165]
Shoulder Pain And Disability Index (SPADI) [116]	3	[58, 79, 80]
German Extra Short Musculoskeletal Function Assessment Questionnaire (XSMFA-D) [169]	2	[79, 80]
Numeric Analog Scale (NAS)	2	[105, 135]
Tegner activity scale [145]	2	[106, 120]
Athletic Shoulder Outcome Scoring System (ASOSS) [134]	1	[105]
Japan Shoulder Society Acromioclavicular Joint Function Assessment (JSS-ACJ) score	1	[57]
Korean shoulder scoring system (KSS) [141]	1	[125]
Larsen score [74]	1	[65]
L'Insalata score [84]	1	[38]
Musculoskeletal Function Assessment (MFA) [140]	1	[67]
Patte score [112]	1	[37]
Rowe score [119]	1	[104]
Shoulder Sport Activity Score (SSAS) [134]	1	[105]
Single Assessment Numeric Evaluation (SANE) [168]	1	[77]
Subjective Patient Outcome for Return to Sports (SPORTS) score [11]	1	[44]
12-item Short-Form health survey (SF-12) [163]	1	[106]
Western Ontario Shoulder Instability Index (WOSI) [68]	1	[60]

differences could be noticed by Wang et al. [159]. The results of the present study confirmed the findings of Arirachakaran et al. [3]. Although the loss of reduction is somehow related to failure, the results of the present study not only showed a high variability in the definition of loss of reduction, but also showed that loss of reduction and functional outcomes did not correlate most of the times. On the contrary, the higher rate of OA noticed by the present study in the osteosynthesis group could probably well explain the worse results at the VAS pain score.

Costic et al. [28] stated that the anatomic reconstruction of CC ligaments more closely approximates joint kinematics than non-anatomic surgical techniques, and the incorporation of the biologic graft might improve the overall mechanical properties once healing occurred. Nonetheless,

Table 4 Main characteristics of included studies based on the surgical approach: open vs arthroscopy

	Open techniques	Arthroscopic techniques
Number of studies	102 [1, 2, 4, 5, 7–10, 12–15, 17–19, 21–23, 29, 30, 32, 34, 36–39, 41, 43, 44, 49, 50, 54, 55, 58–61, 65–67, 70–73, 75–77, 79–81, 86, 88, 90–95, 98, 99, 102–107, 109, 113, 117, 118, 122, 124, 128–130, 135, 137–139, 144, 146–149, 151–155, 158, 160–162, 165–167, 171–173, 175–177]	36 [1, 9, 20, 25, 33, 35, 40, 44–46, 52, 56, 57, 64, 69, 82, 87, 89, 97, 105, 107, 108, 111, 120, 123, 125–127, 133, 135, 143, 150, 155, 156, 170, 174]
Number of patients	3490	937
Loss of reduction	482/2925 (16.5%)	158/663 (23.8%)
Revision	70/1910 (3.7%)	39/623 (6.3%)
Osteoarthritis	271/1806 (15%)	20/240 (8.3%)
Complications	CC calcifications (373) Undefined heterotopic ossification (78) Infection (74) Hardware mobilization (72) Persistence of pain (63) Lateral clavicle osteolysis (50) Osteolysis around the hardware (47) Acromial erosion (33) Hardware breakage (25) Keloids (21) Clavicle erosion (17) ROM reduction (10) AC calcifications (7) Impingement syndrome (7) Coracoid fracture (6) Shoulder stiffness (6) Clavicle fracture (5) Scapular dyskinesis (2) Transient plexus lesion (1) Basilic vein thrombosis (1) Olecranon bursitis (1)	CC calcifications (99) Hardware migration (68) Persistence of pain (14) Tunnel widening (8) Scapular dyskinesis (8) Clavicle erosion (7) Infection (6) Keloids (4) Shoulder stiffness (3) Hardware breakage (2) Coracoid fracture (1) Ulnar nerve pain (1) Clavicle fracture (1) Coracoid fracture (1) Osteolysis around the hardware (1)

AC acromioclavicular; *CC* coracoclavicular

synthetic reconstructions remain the most common choice at least in the acute setting.

The double-button technique was first introduced by Struhl [136], thus mimicking the conoid ligament. One year later, the triple button was first introduced by Lim et al. [83] to provide an anatomic reconstruction of CC ligament complex. A recent biomechanical study [24] proved the triple button to be stronger and more stable than the double button, since the absence of the reconstructed "trapezoid ligament" increased the posterior displacement of the distal clavicle during the forward flexion. From a clinical standpoint, the results of the present study confirmed the superiority of the triple button over the double button at least for the most commonly used scores (Constant and VAS score). Since the double button was mostly used by performing only two tunnels (one in the clavicle and one in the coracoid), available data did not allow a further analysis comparing the triple button and the double button combined with a second hole in the distal clavicle tied by simple suture to recreate the trapezoid ligament, as originally described by Struhl et al. [136].

In 2010, Salzmann et al. [121] introduced the use of two double buttons. The technique was supported by a previous biomechanical study [157], which showed that two double buttons resulted with equal or even higher forces than native ligaments. The present review could not show better clinical outcomes for the two double buttons over double and triple buttons, except for the DASH score.

Finally, although biomechanics [16] and clinical findings [123] warranted the reconstruction or at least the repair of the AC ligament complex to manage horizontal instability, only a few studies [15, 33, 41, 50, 51, 56, 61, 72, 73, 80, 82, 94, 97, 103, 104, 106, 122, 149, 160, 171] took care of it in both biologic and synthetic groups.

The present study presents some limitations and potential biases. The methodological quality of the included studies was low, possibly reducing the strength of evidence: only nine level I studies were included, while most included papers were level IV studies. Only 45 of the included studies were comparative in nature. Most of the included studies were retrospective case series. Despite the considerable number of patients included, many different surgical

Table 5 Clinical outcomes of open vs arthroscopic approach

Functional scores	Open techniques		Arthroscopic techniques		*P* values
	Included studies	Weighted mean ± SD	Included studies	Weighted mean ± SD	
Constant	71 [1, 2, 7–9, 12, 14, 15, 17, 18, 23, 30, 32, 34, 36, 38, 41, 44, 49, 50, 54, 58, 65, 67, 70–72, 75, 76, 79, 80, 86, 91, 92, 94, 95, 98, 99, 102–104, 109, 113, 117, 118, 122, 124, 128, 129, 135, 137, 138, 144, 147–149, 151, 153–155, 158, 160–162, 166, 171–173, 175–177]	91.8 ± 5	28 [1, 9, 20, 25, 40, 44–46, 56, 64, 69, 78, 82, 87, 89, 108, 111, 120, 123, 126, 127, 133, 135, 150, 155, 156, 170, 174]	91.7 ± 3.9	ns
VAS	36 [1, 2, 7, 12, 17–19, 50, 58, 60, 61, 72, 75, 80, 81, 91, 92, 94, 107, 109, 113, 122, 138, 144, 147, 148, 153, 155, 162, 166, 171–173, 175–177]	12.2 ± 11.7	14 [1, 35, 64, 82, 89, 107, 108, 126, 133, 150, 155, 156, 170, 174]	10.7 ± 6.2	0.0249
DASH	21 [2, 4, 7, 12, 14, 30, 51, 54, 72, 73, 106, 107, 109, 122, 144, 147, 148, 151, 153, 154, 176]	6.5 ± 9.1	4 [35, 46, 107, 108]	7 ± 2.3	ns
ASES	18 [4, 19, 21, 22, 34, 41, 60, 77, 79–81, 102, 122, 137, 144, 147, 149, 173]	76.2 ± 28	2 [125, 126]	91.2 ± 5.4	0.0001
UCLA	21 [4, 12, 19, 21–23, 34, 41, 60, 61, 65, 70, 71, 107, 137, 144, 147, 149, 154, 160, 162]	31.5 ± 2.7	4 [45, 52, 107, 143]	31.6 ± 2.4	ns

approaches and techniques have been included in the analysis, that could not be easily grouped and compared. Furthermore, the authors used different outcome measurements. Particularly, very few studies used AC joint-specific scores, thus reducing the possibility to highlight meaningful clinical differences. Moreover, different definitions of loss of reduction were provided. All these differences increased heterogeneity and hindered the pooling and comparison of data, thus impairing the external validity of our study. The scarce quality of the obtained evidence advocates the need for devising new high-quality studies that can clarify the subject.

Finally, from a clinical standpoint, results of the present review strongly recommend favoring anatomic reconstructions over osteosynthesis techniques in the treatment of acute AC joint dislocations.

Conclusion

Surgical treatment of acute high-grade (type-III–V) AC joint dislocations produces good clinical results. Based on the available data, biological and synthetic reconstructions achieved better functional scores compared to osteosynthesis. Synthetic reconstruction techniques represent the most common option in the acute setting. Particularly, triple button displayed a better constant and lower VAS pain scores, compared to double buttons.

Table 6 Main characteristics of included studies based on surgical technique

	Biologic	Synthetic	Internal fixation
Number of studies	18 [17, 22, 37, 51, 55, 76, 77, 94, 103, 104, 128, 130, 143, 160, 162, 165, 167, 174]	83 [1, 2, 7–9, 12, 15, 20, 21, 23, 25, 29, 30, 33–36, 40, 41, 44–46, 50, 52, 54, 56, 57, 59–61, 64, 66, 67, 69, 71–73, 77, 78, 80, 82, 87, 89, 91, 92, 94, 95, 97, 98, 102, 105–108, 111, 118, 120, 122–127, 133, 135, 137, 138, 144, 146–152, 154–156, 166, 170, 171, 175, 176]	45 [4, 5, 9, 10, 13, 14, 18, 19, 30, 32, 38, 39, 43, 49, 58–61, 65, 70, 75, 79–81, 86, 88, 90, 93, 98, 99, 105, 109, 113, 129, 135, 139, 144, 153, 158, 160, 161, 172, 173, 175, 177]
Number of patients	486	2,528	1,459
Loss of reduction	67/447 (15%)	446/2,006 (22.2%)	139/1140 (12.2%)
Revisions	16/134 (11.9%)	74/1711 (4.3%)	19/723 (2.6%)
Osteoarthritis	12/311 (3.9%)	108/990 (10.9%)	168/780 (21.5%)
Complications	CC calcifications (57) Infection (25) Keloids (11) Hardware mobilization (6) Hardware breakage (5) Coracoid fracture (4) Clavicle fracture (4) Persistence of pain (3) Tunnel widening (2) Olecranon bursitis (1) Clavicle erosion (1)	CC calcifications (312) Hardware migration (74) Osteolysis around the Hardware (51) Undefined heterotopic Ossifications (49) infection (31) Distal clavicle osteolysis (26) Persistence of pain (20) Hardware breakage (16) Keloids (15) Scapular dyskinesis (8) Tunnel widening (6) Shoulder stiffness (6) Coracoid fracture (4) Clavicle fracture (2) Ulnar nerve pain (1) Transient plexus lesion (1) Basilic vein thrombosis (1)	CC calcifications (110) Hardware mobilization (58) Distal clavicle osteolysis (49) Undefined heterotopic ossifications (36) Persistence of pain (33) Acromial erosions (32) Infection (24) Hardware breakage (21) Keloids (11) AC calcifications (7) Aesthetic deformity (7) Impingement syndrome (7) Shoulder stiffness (3) Acromion and distal clavicle sclerosis (3) Scapular dyskinesis (2) Clavicular fracture (1)

AC acromioclavicular, *CC* coracoclavicular

Table 7 Clinical outcomes of surgical techniques

Functional scores	Biologic		Synthetic		Internal fixation		*P* values
	Included studies	Weighted mean ± SD	Included studies	Weighted mean ± SD	Included studies	Weighted mean ± SD	
Constant	9 [17, 76, 94, 103, 104, 128, 160, 162, 174]	94.9 ± 2.4*	65 [1, 2, 7–9, 12, 15, 20, 23, 25, 30, 34, 36, 40, 41, 44–46, 50, 54, 56, 64, 67, 69, 71, 72, 78, 80, 82, 87, 89, 91, 92, 94, 95, 98, 102, 108, 111, 117, 118, 120, 122–124, 126, 127, 133, 135, 137, 138, 144, 147–151, 154–156, 166, 170, 171, 175, 176]	92.5 ± 4.1	29 [9, 14, 18, 30, 32, 38, 49, 58, 65, 70, 75, 79, 80, 86, 98, 99, 109, 113, 129, 135, 144, 153, 158, 160, 161, 172, 173, 175, 177]	89.1 ± 5.5	0.0001
VAS	4 [17, 94, 162, 174]	10.6 ± 7.5*	33 [1, 2, 7, 12, 35, 50, 60, 61, 64, 72, 80, 82, 89, 91, 92, 94, 107, 108, 122, 126, 133, 138, 144, 147, 148, 150, 155, 156, 166, 170, 171, 175, 176]	8.8 ± 8.3*	16 [18, 19, 58, 60, 61, 75, 80, 81, 109, 113, 144, 153, 172, 173, 175, 177]	17.4 ± 13.2	0.0001
DASH	1 [51]	3 ± 1.8*	19 [2, 7, 12, 30, 35, 46, 54, 72, 73, 106–108, 122, 144, 147, 148, 151, 154, 176]	6.2 ± 5.6	6 [4, 14, 30, 109, 144, 153]	7.9 ± 14.8	0.0215
ASES	2 [22, 77]	93.9 ± 2.1*	14 [21, 34, 41, 60, 77, 80, 102, 122, 125, 126, 137, 144, 147, 149]	91.1 ± 15.5*	8 [4, 19, 60, 79–81, 144, 173]	64.1 ± 30.3	0.0001
UCLA	4 [22, 143, 160, 162]	30.7 ± 2	16 [12, 21, 23, 34, 41, 45, 52, 60, 61, 71, 107, 137, 144, 147, 149, 154]	31.9 ± 2.6*	8 [4, 19, 60, 61, 65, 70, 144, 160]	31.2 ± 3	0.0001

*Best score

Table 8 Main characteristics of studies reporting button techniques

	Double button	Triple button	Two double buttons
Number of studies	34 [1, 2, 7, 9, 20, 25, 30, 34, 35, 40, 44–46, 52, 59, 60, 64, 67, 71, 87, 89, 98, 102, 107, 118, 124, 125, 127, 133, 138, 148, 155, 156, 170]	5 [12, 44, 91, 126, 166]	12 [60, 69, 105, 107, 108, 120, 123, 135, 138, 150, 170, 176]
Number of patients	893	152	318
Loss of reduction	102/657 (15.5%)	39/129 (30.2%)	44/208 (21.2%)
Revision	42/618 (6.8%)	3/152 (2%)	2/190 (1.1%)
Osteoarthritis	26/267 (9.7%)	4/105 (3.8%)	9/64 (14.1%)

Table 9 Clinical outcomes of double vs triple vs two-double buttons

Functional scores	Double Button		Triple Button		2 Double Buttons		*P* values
	Included studies	Weighted mean ± SD	Included studies	Weighted mean ± SD	Included studies	Weighted mean ± SD	
Constant	27 [1, 2, 7, 9, 20, 25, 30, 34, 40, 45, 46, 64, 67, 71, 87, 89, 98, 102, 118, 124, 127, 133, 138, 148, 155, 156, 170]	92 ± 4.3	5 [12, 44, 91, 126, 166]	94.1 ± 1.5*	9 [69, 108, 120, 123, 135, 138, 150, 170, 176]	93.3 ± 1.3	0.0001
VAS	14 [1, 2, 7, 35, 60, 64, 89, 107, 133, 138, 148, 155, 156, 170]	11.3 ± 9.9	4 [12, 91, 126, 166]	5.5 ± 3.8*	7 [60, 107, 108, 138, 150, 170, 176]	10.6 ± 12.6	0.0001
DASH	7 [2, 7, 30, 35, 46, 107, 148]	6.6 ± 5.3	1 [12]	9.1 ± 14.3	3 [107, 108, 176]	2.5 ± 2.9*	0.0003
ASES	4 [34, 60, 102, 125]	94.4 ± 6.9*	1 [126]	95.7 ± 3.6*	1 [60]	84.2 ± 23.1	0.0003
UCLA	6 [34, 45, 52, 60, 71, 107]	32.4 ± 1.7*	1 [12]	31 ± 4.9*	2 [60, 107]	29.8 ± 2.2	0.0001

*Best score

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Affiliations

Maristella F. Saccomanno[1] · Giuseppe Sircana[1] · Valentina Cardona[1] · Valeria Vismara[1] · Alessandra Scaini[2] · Andrea G. Salvi[2] · Stefano Galli[3] · Giacomo Marchi[3] · Giuseppe Milano[2,3]

Giuseppe Sircana
gsirca@hotmail.it

Valentina Cardona
valentina.cardona1819@gmail.com

Valeria Vismara
vale.vismara@gmail.com

Alessandra Scaini
alescaini@yahoo.it

Andrea G. Salvi
andreasalvi88@yahoo.it

Stefano Galli
elaste@libero.it

Giacomo Marchi
gmarchi73@gmail.com

Giuseppe Milano
giuseppe.milano@outlook.it

[1] Orthopaedics Institute, Fondazione Policilinico A. Gemelli IRCCS, Largo A. Gemelli 8, 00168 Rome, Italy

[2] University of Brescia, Brescia, Italy

[3] Department of Bone and Joint Surgery, Spedali Civili, Brescia, Italy