Systematic Review

Acromioclavicular and Coracoclavicular Ligament Reconstruction for Acromioclavicular Joint Instability: A Systematic Review of Clinical and Radiographic Outcomes

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Purpose: To perform a systematic review of the available literature on clinical and radiographic outcomes after surgical treatment for acromioclavicular (AC) joint instability. **Methods:** A systematic review was performed according to PRISMA guidelines. Inclusion criteria were AC joint and coracoclavicular (CC) ligament reconstruction outcomes, English language, human studies, more than 10 patients in the study and a 2-year minimum follow-up. Exclusion criteria were animal studies, cadaveric studies, clinical studies without reported follow-up period or patient-reported outcomes, clinical studies of nonoperative treatment, AC reconstructions with concurrent lateral clavicle fracture, editorial articles, abstracts, presentations, reviews, case reports, and surveys. **Results:** The systematic review identified 34 studies (939 patients) after inclusion and exclusion criteria application. Postoperative American Shoulder and Elbow Surgeons (ASES) scores ranged from 93.8 to 96, 81.8 to 97.8, and 88.1 for free tendon graft, suspensory devices, and modified Weaver-Dunn techniques, respectively. Postoperative Constant scores were 76.4 to 96.0, 82.6 to 97.8, 85.9 to 97.0, 81 to 96 and 83.0 to 94.6 for free tendon graft, suspensory devices, synthetic ligament devices, modified Weaver-Dunn, and hook plate/K-wires techniques, respectively. All treatment modalities improved patient outcomes; however, hook plates and K-wires had the highest rate of complications (26.3%). Unplanned reoperation rates were 1.2%, 2.8%, 0.9%, 5.4%, and 2.6% in free tendon graft, suspensory devices, synthetic ligament devices, modified Weaver-Dunn, and hook plate/K-wires techniques, respectively. **Conclusions:** Comparable subjective outcomes after surgical treatment of AC joint instability was reported for all modalities, with relatively low unplanned reoperation rates. Treatment with hook plate/K-wires was associated with the highest complication rates, and modified Weaver-Dunn had the highest unplanned reoperation rates. **Level of Evidence:** Level IV, systematic review of Level I-IV studies.

Acromioclavicular (AC) joint injuries are common shoulder injuries among athletes participating in contact sports.[1-5] There is a general consensus that Rockwood grade I and II injuries should be treated nonoperatively, and grade IV to VI to be treated surgically. Grade III injuries are heterogeneous, and hence respond differently to nonoperative treatment; moreover, there is controversy on the treatment of these injuries. To help with the surgical decision making, grade III injuries have been further classified to

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horizontally stable (grade IIIA) and horizontally unstable (grade IIIB) categories, with operative intervention recommended for horizontally unstable (grade IIIB), IV, V, and VI injuries.[6]

Several surgical techniques have been described in the literature. Rockwood classified the early surgical treatments for AC joint instability into 4 groups: (1) AC ligament repairs, (2) CC ligaments repairs, (3) excision of the distal clavicle, and (4) dynamic muscle transfer.[7] In addition, K-wires, screws, and plates have been used for temporary fixation of the AC joint. A better understanding of the anatomy[8,9] and biomechanics of the AC joint and the coracoclavicular (CC) ligaments has led to advances in surgical techniques.[10-12] Anatomic reconstructions using free grafts have become popular in recent years. In addition, arthroscopically assisted procedures using cortical fixation devices have become more popular. LaPrade and Hilger were among the first to describe the use of a free semitendinosus graft for failed AC joint separation surgery in 2005.[13] In a systematic review by Beitzel et al., no difference in outcomes was found between anatomic and nonanatomic surgical techniques; however, the analysis then was based on a few studies.

Suture button systems and free grafts necessitate drilling tunnels in the clavicle and, at times, in the coracoid, thereby increasing the risk of fractures.[14-16] Meanwhile, using screws, plates, and K-wires has been associated with hardware complications. Some authors have advocated for different techniques depending on the chronicity of the injury, preferring soft tissue grafts in chronic injuries.[6] The purpose of this systematic review was to analyze the available literature on AC joint clinical and radiographic outcomes after surgical treatment for instability. It was hypothesized that surgical treatment of AC joint instability would lead to improved outcomes with low reoperation rates. Furthermore, it was hypothesized that newer anatomic techniques would have better radiologic outcomes.

Methods

Article Identification and Selection

This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement.[17] A systematic review of the literature regarding the existing evidence for the outcomes and complications of AC joint instability treatment approaches was performed in March 2017 using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1980-2017), Embase (1947-2017), and MEDLINE (1980-2017). The terms "acromioclavicular" AND "reconstruction" AND "outcomes" were used in all text fields to perform each search. Registration of this systematic review was performed in March 2017 using the PROSPERO International prospective register of systematic reviews (registration number CRD42017060757).

The search strategy inclusion criteria were AC and CC reconstruction surgical outcomes, English language, human studies, more than 10 patients within the study, and 2 years' minimum follow-up. Exclusion criteria were animal studies, cadaveric studies, clinical studies without reported follow-up period or patient-reported outcomes, clinical studies of nonoperative treatment, AC reconstructions with concurrent lateral clavicle fracture, editorial articles, abstracts, presentations, reviews, case reports, and surveys.

Two investigators (G.M. and B.M.K.) independently reviewed the abstracts from all identified articles. Full-text articles were obtained for review if necessary to allow further assessment of inclusion and exclusion criteria. Additionally, all references from the included studies were reviewed and reconciled to verify that no relevant articles were missing from the systematic review and that no duplicate articles were included in the final analysis.

Two authors (G.M. and J.C.) independently assessed the potential assessed risk of bias of the studies included using the MINORS, a methodological index for nonrandomized studies.[18] The items of the questionnaire were scored 0 if not reported, 1 when reported but inadequate, and 2 when reported and adequate. The ideal score was 16 for noncomparative studies and 24 for comparative studies. Studies with a MINORS score of 13 to 16 for noncomparative studies or 21 to 23 for comparative studies were considered at low risk of bias and those ≤12 for noncomparative studies or ≤20 for comparative studies at high risk of bias (Appendix Table 6, available at www.arthroscopyjournal.org).

Data Collection

The level of evidence of the studies was assigned according to the classification as specified by Wright et al.[19] The information was collected from the included studies. Patient demographics, follow-up, and objective and subjective outcomes were extracted and recorded. For continuous variables (e.g., age, timing, follow-up, outcome scores), the mean and range were collected if reported. Data were recorded into a custom table.[20] Because of the heterogeneity of the included studies, data pooling was not performed, and the range of the means from the different studies is reported.

Results

Study Selection

After the application of inclusion and exclusion criteria, 34 studies were included in the final analysis (Fig 1). The studies were grouped according to the following treatment methods: free graft reconstruction (Fig 2), suspensory devices including cortical button (Fig 3), ligament advanced reinforcement system, coracoacromial (CA) ligament transfer or modified Weaver-Dunn technique (Fig 4), and hook plates (Fig 5) or pins. Grouping according to treatment methods can aid surgeons in choosing the method of treatment based on outcomes and complications of each method. For studies reporting on the same cohort, the longest follow-up was used. Detailed data on the included studies can be found in Appendix Tables 1 to 5 (available at www.arthroscopyjournal.org).

CC Ligament Reconstruction With a Free Tendon Graft

Ten studies with a total of 165 patients (165 shoulders) reported on reconstruction of the CC ligaments using free tendon grafts.[21-30] Three studies reported an improvement between visual analog scale (VAS) scores preoperatively (4.9-8.1) and at final follow-up (0.4-2.3). Three studies reported a preoperative American Shoulder and Elbow Surgeons (ASES) shoulder score of 58.9 to 74, and the postoperative ASES shoulder score reported in 4 studies ranged from 93.8 to 96. Seven studies reported Constant score, all reporting improvement from preoperative (43.5-72.3) to postoperative (76.4-96). Two studies reported postoperative CC distance side-to-side differences of 1.1 and 3.1 mm on 10-kg stress radiographs, and 2 studies reported side-to-side differences of 1.02 and 2.3 mm on plain nonstress radiographs. Three studies reported postoperative CC distances of 11.7 to 12 mm on 10-kg stress radiographs. Patient-reported outcomes and radiographic outcomes are reported in Table 1.

Suspensory Devices

Sixteen studies with a total of 435 patients (435 shoulders) reported on reconstruction of the CC ligaments using suspensory devices (Table 2).[21,31-45] Preoperative pain VAS scores were 4.5 to 6.4 in 3 studies, and postoperatively it was 0.25 to 2.4 in 4 studies. Preoperative ASES shoulder score ranged from 25.3[33] to 57.2,[36] and postoperatively the ASES shoulder score was 81.8 to 97.8 in 4 studies. Postoperative Constant score ranged from 82.6 to 97.8 and postoperative University of California Los Angeles (UCLA) shoulder scores ranged from 31.4 to 33.5. The mean postoperative CC distance side-to-side differences ranged from 1.1 to 2.8 mm on nonstress radiographs, 6.0 ± 4.6 mm in 2 studies, and 2.2 and 6.0 mm in 2 studies with 10-kg stress. Three studies reported a postoperative CC distance on the injured side ranging from 13.2 to 13.9 mm with 10-kg stress. Patient-reported outcomes and radiographic outcomes are reported in Table 2.

Synthetic Ligament Devices

Three studies with a total of 114 patients (114 shoulders) reported on reconstruction of the CC ligaments using synthetic ligament devices.[26,46,47] No preoperative VAS scores were reported, and 2 studies reported postoperative VAS ranging from 8.9 ± 1.2 to 9.4 ± 1.0.

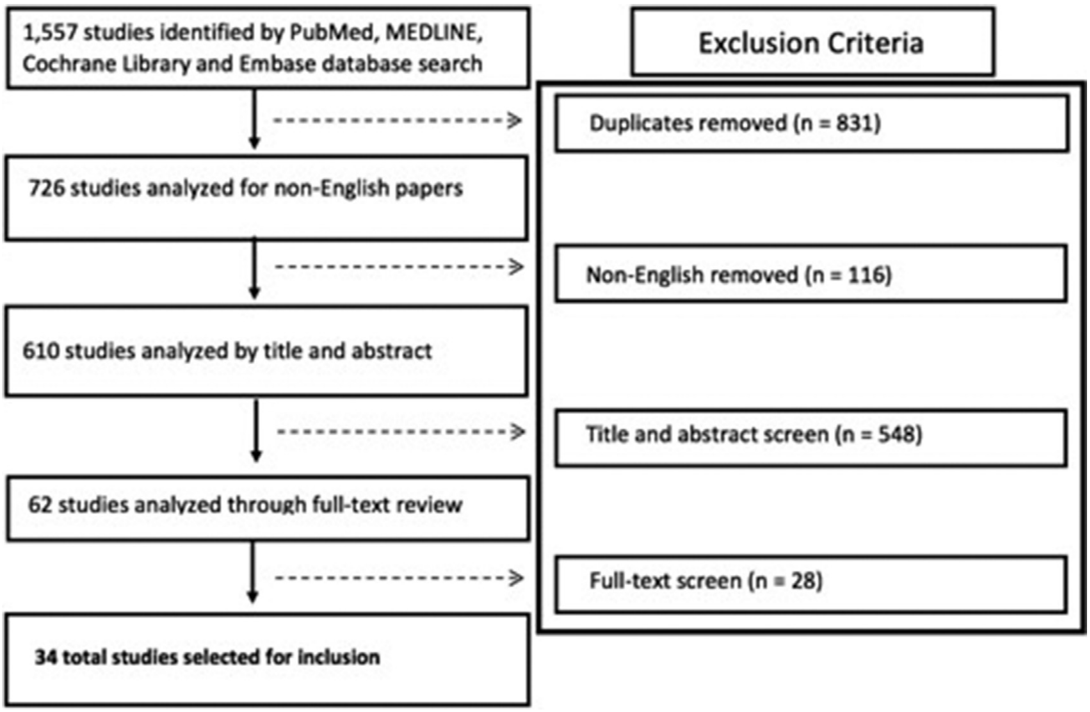

Fig 1. PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) flowchart showing application of selection criteria to the studies identified with the search strategy.

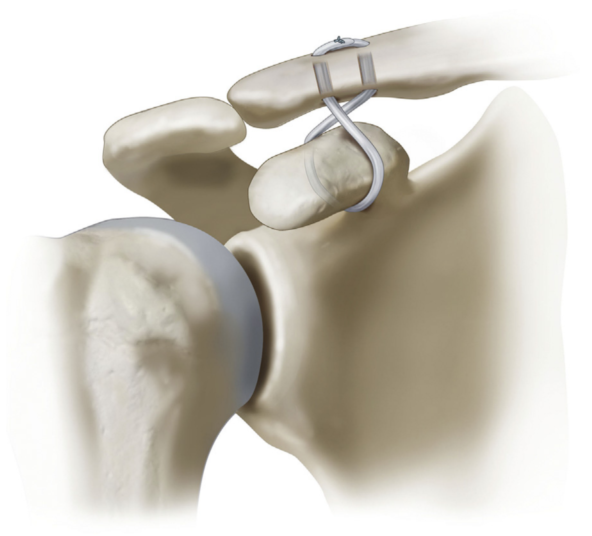

Fig 2. A right shoulder acromioclavicular joint dislocation treated with a free graft: the free graft can be looped around the base of the coracoid or fixed to the coracoid through a tunnel and a suspensory device. Different techniques can be used to fix the free graft to the clavicle.

The preoperative Constant score ranged from 44.05 ± 8.9 to 57.7 ± 12.0 in 2 studies,[26,46] and the postoperative scores were 85.9 ± 16 to 97 ± 6.1 in 3 studies (Table 3). None of the studies included reported radiographic outcomes.

Coracoacromial Ligament Transfer. Eight studies with a total of 149 patients (149 shoulders) reported on outcomes after AC ligament transfer or modified Weaver-Dunn procedure.[22,24,30,48-52] Only 2 studies reported VAS scores (Table 4).[22,51] Two studies[24,30] reported a preoperative ASES shoulder score of 64.1 and a mean postoperative ASES shoulder score of 88.1. Three studies[24,30,52] reported a mean preoperative Constant score of 56.6 to 75.1, and 6 studies[24,30,48,49,51,52] reported postoperative scores of 81 to 96. Two studies reported a CC distance side-to-side difference of 0.2 and 1.7 mm on nonstress radiographs, one study reported a side-to-side

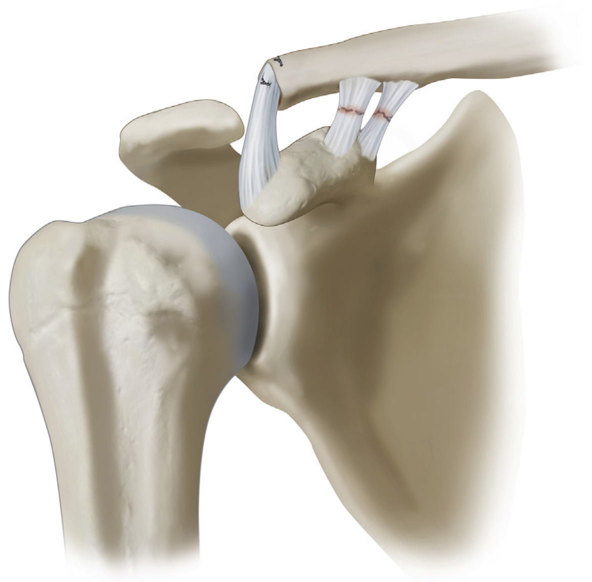

Fig 4. A right shoulder acromioclavicular joint dislocation treated with coracoacromial ligament transfer: several modifications of this technique are described.

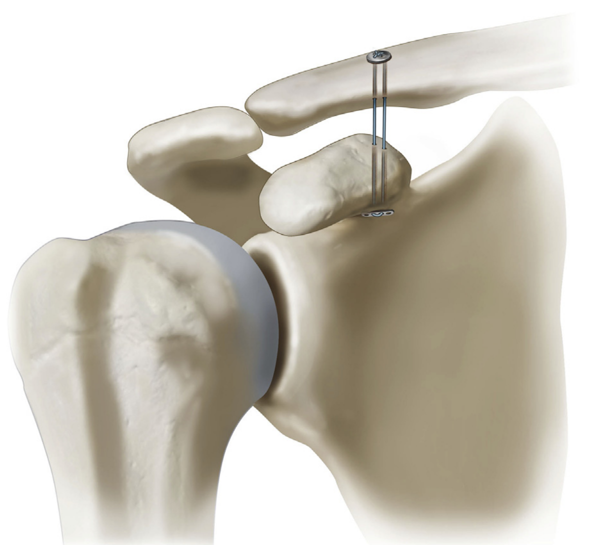

Fig 3. A right shoulder acromioclavicular joint dislocation treated with a suspensory device: a Y-configuration of a suspensory device with 2 fixation points on the clavicle to replicate the trapezoid and conoid ligaments attachments have been described.

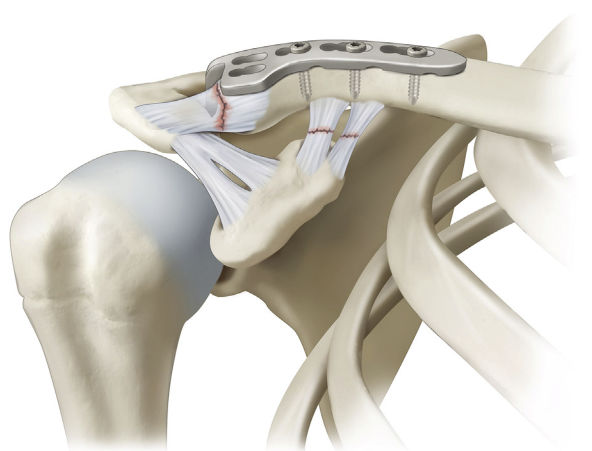

Fig 5. A right shoulder acromioclavicular joint dislocation treated with a hook plate: the hook of the plate goes under the acromion laterally, and the acromioclavicular joint is reduced. A second surgery to remove the hook plate is usually performed when the coracoclavicular ligaments and coracoacromial ligaments are healed.

Table 1. Summary of Patient-Reported Outcome Scores and Radiographic Parameters for All Included Studies Using Free Graft Reconstruction Techniques

			Subjective Outcome Scores				Radiographic Outcomes		
Author, Year	LOE	No. of Patients (Shoulders)	ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	CC Distance, mm	CC Side-to-Side Difference, mm	Mean Follow-up, Months
Tauber et al., 2016[21]	II	12 (12)	Pre-op: N/R Post-op: 95.3 ± 6.9	Pre-op: 71.6 ± 11.7 Post-op: 88.8 ± 9.5[*]	N/R	N/R	Post-op: Injured: 10.7 ± 5.0 Contralateral: 7.6 ± 3.2[†]	Post-op: 3.1 ± 3.3[†]	27.1 ± 6.4
Hegazy et al., 2016[22]	IV	10 (10)	N/R	N/R	N/R	Pre-op: 49 ± 3 Post-op: 4 ± 2 mm	Post-op: Injured: 11.7 ± 3 mm[†]	N/R	27.7 (24-32)
Parnes et al., 2015[23]	IV	12 (12)	N/R	Pre-op: 58.4 (51-76) Post-op: 96 (88-100)[*‡]	N/R	Pre-op: 8.1 (7-10) Post-op: 0.58 (0-2)[*]	N/R	Post-op: 1.02 (0-3)[§]	30.4 (24-42)
Tauber et al., 2009[24]	II	12 (12)	Pre-op: 74 ± 4 Post-op: 96 ± 5[*]	Pre-op: 71 ± 5 Post-op: 93 ± 7[*]	N/R	N/R	Post-op: Injured: 11.4 ± 3 Injured: 11.8 ± 3 Contralateral: 10.8 ± 2[†]	N/R	34.9 (24-48)
Millett et al., 2015[25]	IV	31 (31)	Pre-op: 58.9 ± 27.3 Post-op: 93.8 ± 9.1[*]	N/R	N/R	N/R	Pre-op: Injured: 21.0 (10.6-31.9) Contralateral: 9.3 (5.2-15.7) Post-op: Injured: 12.0 (3.3-25.0) Uninjured: 8.9 (5.9-12.4)[§]	Pre-op: 6.6 (−5.8 to 17.9) Post-op: 2.3 (−6.1 to 14.7)[§]	42 (24-74)
Fauci et al., 2013[26]	I	20 (20)	N/R	Pre-op: 43.5 ± 6.1 Post-op: 94.2 ± 4.9[*‡]	Pre-op: N/R Post-op: 18.2 ± 1.7	N/R	N/R	N/R	Minimum: 48
Saccomanno et al., 2014[27]	IV	18 (18)	N/R	Pre-op: 58.5 ± 7.2 Post-op: 90.3 ± 4.9[*]	N/R	N/R	N/R	N/R	26.4 ± 2.3 (24-30)
Tauber et al., 2007[28]	IV	12 (12)	N/R	Pre-op: 61.3 (41-69) Post-op: 76.4 (46-91)[*]	N/R	Pre-op: 6.2 (3-9) Post-op: 2.3 (0-6)[*]	Pre-op: Injured: 16 (10-26) Contralateral: 13 (10-16) Post-op: Injured: 12 (9-22)[†]	N/R	49.5 (26-96)
Takase and Yamamoto, 2016[29]	IV	22 (22)	N/R	N/R	Pre-op: Post-op: 28.4 (24-30)	N/R	N/R	N/R	38 (24-63)

(continued)

Table 1. Continued

Author, Year	LOE	No. of Patients (Shoulders)	Subjective Outcome Scores: ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	Radiographic Outcomes: CC Distance, mm	CC Side-to-Side Difference, mm	Mean Follow-up, Months
Kocaoglu et al., 2017[30]	III	16 (16)	Pre-op: 73.1 (68-78) Post-op: 94.5 (90-98)*	Pre-op: 72.3 (66-82) Post-op: 93.1 (90-98)*	N/R	N/R	Post-op: Injured: 13.9 (10.2-18.2) Contralateral: 12.8 (10.3-16.8)†	Post-op: 1.1†	42 (29-54)
Total (mean ranges)		165 (165)	Pre-op: 58.9-74.0 Post-op: 93.8-96	Pre-op: 43.5-72.3 Post-op: 76.4-96	Pre-op: N/R Post-op: 18.2-28.4	Pre-op: 49-81 Post-op: 0.4-23	Pre-op: Injured: 16-21.0 Post-op: Injured: 10.7-13.9	Pre-op: N/R Post-op: 1.02-3.1	Mean range: 27.1-49.5

NOTE. All scores are reported as means ± standard deviation (range) unless otherwise noted.

ASES, American Shoulder and Elbow Surgeons; CC, coracoclavicular; LOE, level of evidence; N/R, not reported; Post-op, postoperative; Pre-op, preoperative; UCLA, University of California Los Angeles; VAS, Visual Analog Scale.

*Statistically significant difference between the study preoperative and postoperative findings.

†10-kg stress view.

‡Constant-Murley score.

§Plain (nonstress) radiographs.

difference of 1.1 mm with 4-kg stress radiographs, and 3 studies reported on only the postoperative CC distance on the injured side, ranging from 13.3 to 15.6 mm.

Hook Plate and K-Wires. Three studies[45,53,54] with a total of 76 patients (76 shoulders) reported on outcomes after treatment with hook plates or K-wires. The weighted mean age in the included studies was 40.9 years (range, 30-53 years). Postoperative Constant scores ranged from 83 to 94.6. University of California Los Angeles; Disabilities of the Arm, Shoulder and Hand; and Oxford scores were reported in 1 study each (Table 5). One study reported a postoperative CC distance side-to-side difference of 2.3 mm using nonstress radiographs. One study reported a postoperative CC distance of 14.1 mm on stress radiographs, and the last study reported a postoperative AC distance of 3.4 mm on nonstress radiographs (Table 5).

Complications. Hook plate/K-wire treatment had the highest rate of complications (26.3%), and unplanned reoperation rates were 1.2%, 2.8%, 0.9%, 5.4%, and 2.6% in free tendon graft, suspensory devices, synthetic ligament devices, modified Weaver-Dunn, and hook plate/K-wires techniques, respectively. Most of the complications in the osteosynthesis group were associated with the hardware, including plate loosening, acromial erosions, and broken K-wire. Superficial infections were a common complication in all groups. Table 6 summarizes the complications reported in the included studies for each treatment group.

Discussion

The most important finding of this study was that improved outcomes after surgical treatment of AC joint dislocation could be achieved at a minimum 2 years' follow-up. Of the previously published systematic reviews on the treatment of AC joint dislocations, none has summarized the results of more than 2 treatment methods.[55-59] Although there are a number of comparative studies, there is still no clear consensus as to which treatment method is preferable. All surgical treatments evaluated in this review reported improved subjective patient-reported outcomes and low unplanned reoperation rates, and free graft reconstruction provided the highest subjective scores and fewest complications. The 3 studies including hook plates and K-wires reported the highest rates of complications. The technique using the hook plate or K-wires requires an additional surgery to remove the hardware, which is one of the major disadvantages with this technique.

The patients included in this systematic review had grade III to grade V Rockwood AC joint dislocation.

Table 2. Summary of Patient-Reported Outcome Scores and Radiographic Parameters for All Included Studies Using Suspensory Devices

			Subjective Outcome Scores				Radiographic Outcomes		
Author, Year	LOE	No. of Patients (Shoulders)	ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	CC distance, mm	CC Side-to-Side Difference, mm	Mean Follow-up in Months ± SD (Range)
Tauber et al., 2016[21]	II	14 (14)	Pre-op: N/R Post-op: 88.0 ± 11.1	Pre-op: 67.8 ± 10.7 Post-op: 82.6 ± 11.6[*]			Pre-op: N/R Post-op: Injured: 13.1 ± 5.4 Contralateral: 7.1 ± 1.5[†]	Post-op: 6.0 ± 4.6[†]	31.2 ± 10.0
Shin and Kim, 2015[31]	IV	18 (18)		Pre-op: N/R Post-op: 97.5 ± 3.4 (88-100)			Pre-op: Injured: 16.1 ± 2.7 Contralateral: 8.1 ± 1.0 Post-op: Injured: 8.1 ± 1.1 Contralateral: 10.5 ± 2.5[‡]		27.8 (24-40)
Struhl and Wolfson, 2015[32]	IV	35 (35)	Pre-op: N/R Post-op: 97.8 ± 3.3	Pre-op: N/R Post-op: Raw: 97.6 ± 3.2 Modified: 99.6 ± 1.0	Pre-op: N/R Post-op: 33.5 ± 2.2		Pre-op: N/R Post-op: Injured: 8.3 ± 2.5 Contralateral: 7.5 ± 1.9[§]	Post-op: 1.1 ± 1.2[§]	62 (27-144)
Sobhy, 2012[33]	IV	17 (17)	Pre-op: 25.29 ± 9.9 Post-op: 81.77 ± 10.3[*]	Pre-op: 21.2 ± 3.6 Post-op: 84.94 ± 8.7[*]		Pre-op: 6.41 ± 1.7 Post-op: 2.41 ± 1.42[*]			28 (24-40)
Choi et al., 2016[34]	IV	43 (43)		Pre-op: N/R Post-op: 91.2 (74-100)	Pre-op: N/R Post-op: 31.4 (24-35)		Pre-op: Injured: 19.7 ± 5.2 Contralateral: 7.3 ± 1.8 Post-op: Injured: 6.8 ± 2.3[‖]		59.6 (40-97)
Cisneros and Reiriz, 2017[35]	IV	12 (12)		Pre-op: N/R Post-op: 95.50 ± 2.58		Pre-op: N/R Post-op: 0.92 ± 0.79			26.50 (25-32)
El Shewy and El Azizi, 2011[36]	IV	21 (21)	Pre-op: 57.2 ± 8.3 Post-op: 95.0 ± 8.2[*]	Pre-op: 63.3 ± 9.3 Post-op: 97.8 ± 6.2[*]	Pre-op: 18.5 ± 2.6 Post-op: 33.2 ± 2.9[*]				92 (72-114)
Ladermann et al., 2011[37]	IV	37 (37)		Pre-op: N/R Post-op: 96 ± 7.7 (63-100)		Pre-op: N/R Post-op: 0.8 ± 1.5 (0-6)		Post-op: 2.8 ± 3.1 (−3 to 10)[§]	54 ± 30 (24-126)
Salzmann et al., 2010[38]	IV	23 (23)		Pre-op: 34.3 ± 6.9 (22-44) Post-op: 94.3 ± 3.2 (88-98)[*]		Pre-op: 4.5 ± 1.9 (1-7) Post-op: 0.25 ± 0.5 (0-1)[*]			30.6 ± 5.4 (24-40)

(continued)

Table 2. Continued

			Subjective Outcome Scores				Radiographic Outcomes		
Author, Year	LOE	No. of Patients (Shoulders)	ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	CC distance, mm	CC Side-to-Side Difference, mm	Mean Follow-up in Months ± SD (Range)
Kraus et al., 2013[39]	II	15 (15)		Pre-op: N/R Post-op: 92.4 (84-100)			Pre-op: Injured: 20.5 (14-25) Contralateral: 9.3 (5-15) Post-op: Injured: 13.9 (5-19)[†]		
		13 (13)		Pre-op: N/R Post-op: 90.5 (84-98)			Pre-op: Injured: 23.6 (14-36) Contralateral: 9.4 (5-12) Post-op: 13.4 (6-27)[†]		
Jeon et al., 2007[40]	IV	11 (11)		Pre-op: N/R Post-op: 92.3 (range, 64-100)					55 (40-80)
Greiner et al., 2009[41]	IV	50 (50)		Pre-op: N/R Post-op: 91.7 ± 8.7 (62-100)				Post-op: 2.2 ± 2.8[†]	70 (30-121)
Katsenis et al., 2015[42]	IV	50 (50)		Pre-op: N/R Post-op: 93.04 (84-100)			Pre-op: Injured: 12.8 (9.5-15) Stress: 13.3 (10-15) Contralateral: 8.8 (8.5-9.2) Stress: 9.3 (8.8-9.7) Post-op: Injured: 9.2 (8.7-10.2) Stress: 9.5 (8.9-10.6)[¶]		42 (36-49)
Saier et al., 2016[43]	IV	42 (42)		Pre-op: 36 ± 17 (12-90) Post-op: 94 ± 4 (86-100)[*]					31.3 (24-61)
Metzlaff et l., 2016[45]	III	24 (24)		Pre-op: N/R Post-op: 93.6 ± 3.4[**]			Pre-op: N/R Post-op: 13.2 (11.7-24)[†]		

(continued)

Table 2. Continued

			Subjective Outcome Scores				Radiographic Outcomes		
Author, Year	LOE	No. of Patients (Shoulders)	ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	CC distance, mm	CC Side-to-Side Difference, mm	Mean Follow-up in Months ± SD (Range)
Li et al., 2013[44]	IV	10 (10)		Pre-op: 25.2 ± 6.6 Post-op: 92.4 ± 6.5*		Pre-op: 5.9 ± 1.5 Post-op: 1.2 ± 0.92*			33.6 (24-40)
Total		435 (435)	Pre-op: 25.29-57.2 Post-op: 81.77-97.8	Pre-op: 21.2-67.8 Post-op: 82.6-97.8	Pre-op: 18.5 Post-op: 31.4-33.5	Pre-op: 4.5-6.41 Post-op: 0.25-2.4	Pre-op: Injured: 12.8-23.6 Post-op: Injured: 6.8-13.9	Pre-op: N/R Post-op: 1.1-6.0	Mean Range: 26.5-92

NOTE. All scores are means ± standard deviation (range) unless otherwise noted.

ASES, American Shoulder and Elbow Surgeons; CC, coracoclavicular; LOE, level of evidence; N/R, not reported; Post-op, postoperation; Pre-op, preoperation; UCLA, University of California Los Angeles; VAS, visual analog scale.

*Statistically significant difference between the study preoperative and postoperative findings.

†10-kg stress view.

§Plain (nonstress) radiographs.

‡4-kg stress view.

||Stress view with unknown weight.

¶5-kg stress view.

**Constant-Murley score.

It is generally accepted that Rockwood grade I and II AC joint injuries should be treated conservatively, and high-grade injuries (IV, V, and VI) should be surgically addressed in a timely manner to yield satisfactory outcomes. However, type 3 injuries constitute a challenge for the surgeon since nonoperative and surgical treatments have been reported in the literature with good, comparable results. Specifically, Korsten et al.[55] conducted a systematic review of 8 studies comparing operative to nonoperative treatment of type III AC joint dislocations. The authors found that objective and subjective shoulder function outcomes were better in the operative group, especially in young adults, though the rate of complications and radiographic abnormalities were higher in this group. The rehabilitation time was shorter in the nonoperative group, yet the cosmetic outcome was worse. Approximately 17% to 28% of patients receiving nonoperative treatment will have disability with pain, weakness, fatigue, impingement, and AC instability.[57] Smith et al.[58] performed a systematic review and reported on a total of 380 patients in which operative treatment had greater cosmetic benefit, but the time of sick leave was longer than nonoperative treatment. Although a recent systematic review reported that more than 150 variations have been described to treat symptomatic AC joint dislocations,[60] to date, no reconstruction technique can duplicate the stability and physiology of a native, intact AC joint complex.[61] However, anatomic procedures, such as those described by Mazzocca et al., have shown promising early clinical results.[62,63]

We found that hook plates and K-wires had the highest rate of complications (26.3%), and unplanned reoperation rates were 1.2%, 2.8%, 0.9%, 5.4%, and 2.6% in free tendon graft, suspensory devices, synthetic ligament devices, modified Weaver-Dunn, and hook plate/K-wires techniques, respectively. Previous studies have reported complication rates for these procedures to be as high as 30%,[61] and include loss of reduction (29%),[64] clavicle fracture (18%),[65] infection (6%),[62] and hardware-related issues (4%).[15] In a study by Song et al. analyzing the complication rates of early versus delayed surgical treatment for AC joint dislocations, no significant differences were found; however, a higher prevalence of complications was reported for delayed procedures (12.5% vs 17.7%, respectively). Martetschlager et al.[15] reported on 59 patients who underwent an anatomic CC ligament reconstruction. The survivorship reported were 86.2% at 1 year and 83.2% at 2 years, with an overall complication rate of 27.1%.

Suspensory devices and synthetic ligament techniques had the lowest rates of complications at 6.2% and 4.4%, respectively. Most of the complications in

Table 3. Summary of Patient-Reported Outcome Scores and Radiographic Parameters for All Included Studies Using Synthetic Ligament Devices

			Subjective Outcome Scores				Radiographic Outcomes		
Author, Year	LOE	No. of Patients (Shoulders)	ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	CC Distance, mm	CC Side-to-Side Difference, mm	Mean Follow-up, Months
Marcheggiani et al., 2016[46]	II	22 (22)	N/R	Pre-op: 57.7 ± 12.0 Post-op: 96.6 ± 5.3*	N/R	Pre-op: N/R Post-op: 9.4 ± 1.0	N/R	N/R	28.2 ± 7.3
Marcheggiani et al., 2016[46]	II	21 (21)	N/R	Pre-op: 45.7 ± 23.1 Post-op: 90.8 ± 9.0*	N/R	Pre-op: N/R Post-op: 8.9 ± 1.2	N/R	N/R	
Fauci et al., 2013[26]	I	20 (20)	N/R	Pre-op: 44.05 ± 8.9 Post-op: 85.9 ± 16*†	Pre-op: N/R Post-op: 15.4 ± 4.2	N/R	N/R	N/R	48
Motta et al., 2012[47]	IV	51 (51)	N/R	Pre-op: N/R Post-op: 97 ± 6.1	N/R	N/R	N/R	N/R	Median: 60 (24-108)
Total (mean ranges)		114 (114)	Pre-op: N/R Post-op: N/R	Pre-op: 44.05-57.7 Post-op: 85.9-97	Pre-op: N/R Post-op: 15.4	Pre-op: N/R Post-op: 8.9-9.4	N/R	N/R	

NOTE. All scores are means ± standard deviation (range) unless otherwise noted. Marcheggiani et al. divided the patients into professionals and nonprofessionals, and they are reported separately in the table.

ASES, American Shoulder and Elbow Surgeons; CC, coracoclavicular; LOE, level of evidence; N/R, not reported; Post-op, postoperation; Pre-op, preoperation; UCLA, University of California Los Angeles; VAS, visual analog scale.

*Statistically significant difference between the study preoperative and postoperative findings.

†Constant-Murley score.

the osteosynthesis group were wound problems and hardware related. A recent systematic review showed that patients who underwent arthroscopic fixation procedures have lower rates of postoperative pain and recurrence compared with hook plate techniques.[59] In addition, the authors noted that pin fixation techniques can be prone to complications from the breakage and migration of implants. Arirachakaran et al.[56] conducted a systematic review of loop suspensory device versus hook plate fixation. The authors reported higher shoulder function scores and lower postoperative pain with loop suspensory fixation compared with hook plate fixation. However, the complication rates were higher with loop suspensory device fixation than hook plate fixation.

Limitations

The authors acknowledge some limitations to the present study. First, there was heterogeneity in the reporting of subjective and objective outcomes after the surgical procedure. Furthermore, some of the studies included concomitant pathology and/or other procedures, which may have altered the final outcome. As with all systematic reviews, it is possible that relevant articles or patient populations were not identified with our search criteria. The generalizability of the findings in this study is limited by heterogeneity in surgical technique, patient characteristics, and reporting of different outcome measures. There is an increasing interest in treating AC joint dislocations surgically; however, the current literature does not support any form of treatment over the other. Most of the studies on the treatment of AC joint dislocations are level IV, making it difficult to draw definitive conclusions. Future studies should be randomized comparative studies of the different surgical techniques using standardized outcome measures. Another important limitation of this systematic review was that different radiographic methods were used to evaluate the AC joint postoperatively, with some studies using no stress whereas others used between 4- and 10-kg stress radiographs. It is recommended that future studies standardize the radiographs used to evaluate both the AC and CC distances for side-to-side comparisons.

Conclusions

Comparable subjective outcomes after surgical treatment of AC joint instability was reported for all modalities, with relatively low unplanned reoperation rates. Treatment with hook plate/K-wires was associated with the highest complication rates, and modified Weaver-Dunn had the highest unplanned reoperation rates.

Table 4. Summary of Patient-Reported Outcome Scores and Radiographic Parameters for All Included Studies Using Coracoacromial Ligament Transfers

			Subjective Outcome Scores				Radiographic Outcomes	
Author, Year	LOE	No. of Patients (Shoulders)	ASES Shoulder Score	Constant Score	UCLA Shoulder Score	VAS	CC Distance, mm	Mean Follow-up, Months
Lee et al., 2015[48]	IV	18 (18)	N/R	Pre-op: N/R Post-op: Injured: 90.7 (70-97) Contralateral: 94.7 (88-100)[*]	Pre-op: N/R Post-op: 18.1 (13-20)	N/R	Pre-op: N/R Post-op: Injured: 11.9 (9.7-21.4) Contralateral: 10.2 (9.5-10.9)[†]	35.3 (24-49)
Shin et al., 2009[49]	IV	29 (29)	N/R	Pre-op: N/R Post-op: 96 (88-100)	N/R	N/R	Pre-op: Injured: 16.9 ± 4.3 Uninjured: 6.6 ± 1.9 Post-op: Injured: 7.6 ± 3.1 Uninjured: 6.5 ± 2.1[‡]	27.8 (24-40)
Kim et al., 2012[50]	IV	12 (12)	N/R	N/R	Pre-op: N/R Post-op: 18.5 ± 2.1 (12-20)	N/R	Pre-op: N/R Injured: 20.3 ± 3.0 Uninjured: 8.7 ± 0.8 Post-op: Injured: 8.9 ± 1.6[†§]	31.2 ± 9.5 (24-51)
Bostrom et al., 2010[51]	III	23 (18 re-examined, 5 phone)	N/R	Pre-op: N/R Post-op: 85 (60-100) Re-examined: 85 (61-100) Phone: 83 (60-98)		Pre-op: N/R Post-op: At rest: 0.7 (0-5.2) Re-examined: 0.7 (0-4.2) Phone: 0.4 (0-2.0) Movement: 1.0 (0-4.7) Re-examined: 1.0 (0-4.7) Phone: 0.4 (0-2.0)		Re-examined: 99 (51-155) Phone: 114 (69-156)
Kocaoglu et al., 2017[30]	III	16 (16)	Pre-op: 76.9 (68-84) Post-op: 89.7 (78-96)[§]	Pre-op: 75.1 (60-86) Post-op: 89.9 (80-98)[§]			Pre-op: N/R Post-op: Injured: 15.6 (12.8-26.5) Contralateral: 12.3 (8.9-22.8)[‖]	47.8 (33-60)

(continued)

Table 4. Continued

Author, Year	LOE	No. of Patients (Shoulders)	Subjective Outcome Scores: ASES Shoulder Score	Subjective Outcome Scores: Constant Score	Subjective Outcome Scores: UCLA Shoulder Score	Subjective Outcome Scores: VAS	Radiographic Outcomes: CC Distance, mm	Mean Follow-up, Months
Tauber et al., 2009[24]	II	12 (12)	Pre-op: 74 ± 7 Post-op: 86 ± 8[§]	Pre-op: 70 ± 8 Post-op: 81 ± 8[§]			Pre-op: N/R Post-op: Injured: 12.3 ± 4[†] Injured: 14.9 ± 6[‖] Uninjured: 11.1 ± 2[‖]	39.8 (24-58)
Bezer et al., 2009[52]	IV	29 (29)		Pre-op: 56.62 ± 18.63 (22-77) Post-op: 89.93 ± 10.79 (63-100)[§]				69.48 ± 35.41 (25-143)
Hegazy et al., 2016[22]	IV	10 (10)				Pre-op: 4.8 ± 1.0 Post-op: 1.0 ± 0.3	Pre-op: N/R Post-op: Injured: 13.3 ± 3[‖]	27.9 (24-32)
Total (mean ranges)		149 (149)	Pre-op: 74-76.9 Post-op: 86-89.7	Pre-op: 56.62-75.1 Post-op: 81-96	Pre-op: N/R Post-op: 18.1-18.5	Pre-op: 4.8 Post-op: 1.0-1.4	Pre-op: Injured: 16.9 Post-op: Injured: 7.6-15.6	Mean range: 27.8-114

NOTE. All scores are reported as means ± standard deviation (range) unless otherwise noted.

ASES, American Shoulder and Elbow Surgeons; CC, coracoclavicular; LOE, level of evidence; N/R, not reported; Post-op, postoperation; Pre-op, preoperation; UCLA, University of California Los Angeles shoulder score; VAS, visual analog scale.

*Constant-Murley score.

†Plain (non-stress) radiographs.

‡4-kg stress view.

§Statistically significant difference between the study preoperative and postoperative findings.

‖10-kg stress view.

Table 5. Summary of Patient-Reported Outcome Scores and Radiographic Parameters for All Included Studies Using Osteosynthesis Techniques for Stabilization

			Subjective Outcome Scores				Radiographic Outcomes		
Author, Year	LOE	No. of Patients (Shoulders)	Constant Score	UCLA Shoulder Score	DASH Score	Oxford Score	CC Distance, mm	AC Distance, mm	Mean Follow-up, Months
Canadian Orthopedic Trauma Society, 2015[54]	I	40 (40)	Pre-op: N/R Post-op: 94.63 ± 5.59		Pre-op: 1.7 ± 3.54 Post-op: 4.5 ± 5.37		Pre-op: Contralateral: 9.5 Injured: 21.5 Post-op: Injured: 11.8[*†]		24
Joukainen, 2014[53]	II	16 (16)	Pre-op: N/R Post-op: 83 ± 16	Pre-op: N/R Post-op: 25 ± 5.4				Post-op: Injured: 3.4 ± 2.9[†]	224.4 ± 8.8
Metzlaff et al., 2016[45]	III	20 (20)	Pre-op: N/R Post-op: 92.8 ± 3.8[‡]				Pre-op: N/R Post-op: Injured: 14.1 (12.1-23)[§]		Median: 32 (24-51)
Total (mean ranges)		76 (76)	Pre-op: N/R Post-op: 83-94.63	Pre-op: N/R Post-op: 25	Pre-op: 1.7 Post-op: 4.5	Pre-op: N/R Post-op: 54.7	Pre-op: Injured: 21.5 Post-op: Injured: 11.8-14.1[†]	Pre-op: N/R Post-op: Injured: 3.4	Mean Range: 24-224.4

NOTE. All scores are reported means ± standard deviation (range) unless otherwise noted.

ASES, American Shoulder and Elbow Surgeons; CC, coracoclavicular; DASH, Disabilities of the Arm, Shoulder and Hand; LOE, level of evidence; N/R, not reported; Post-op, postoperation; Pre-op, preoperation; UCLA, University of California Los Angeles.

*Statistically significant difference between the study preoperative and postoperative findings.

†Plain (nonstress) radiographs.

‡Constant-Murley score.

§10-kg stress view.

Table 6. Summary of Complications for All Included Studies

Treatment	No. of Complications (%)	Complications	No. of Unplanned Reoperations (%)	Additional Surgeries
Free graft reconstruction	17/165 (10.3)	5 superficial infections 3 clavicle fractures 2 graft rupture/attenuation 2 distal clavicle hypertrophy 1 adhesive capsulitis 1 complete loss of reduction without revision surgery 1 mild hyperesthesia of the donor leg 1 mild hypesthesia of the donor leg 1 local hypesthesia on the skin in the infraclavicular area	2/165 (1.2)	2 revision AC reconstruction: 1 with allograft looped around coracoid and tied over distal clavicle 1 with revision DCE, as well as re-revision AC reconstruction and DCE Other surgeries: Clavicle ORIF Revision DCE Revision DCE and hardware removal Lysis of adhesions and hardware removal
Suspensory devices	27/435 (6.2)	4 local skin irritation at incision without infection 3 complete loss of reduction without revision surgery 3 clavicular bony erosion 2 mild hypesthesia of the donor leg 2 failure of the coracoid button 2 shoulder pain secondary to arthrosis 2 superficial wound infection 1 failure of the clavicular button 1 fracture of the distal clavicle at the clavicular hole 1 suture break leading to recurrence of deformity 1 skin irritation secondary to suture knots 1 transitory postoperative plexus lesion 1 loss of reduction due to loosening of clavicular button 1 experienced ongoing tenderness above the cranial implant buttons while carrying a backpack 1 coracoid process fracture 1 loss of reduction after coracoid button slipped into coracoid drill hole with refusal of revision surgery	12/435 (2.7)	6 revision surgeries for the following reasons: Redislocation from a motor vehicle accident 10 weeks post-op Suture breakage necessitated revision surgery with open reduction and CA ligament transposition using the Weaver-Dunn technique Skin irritation Loss of reduction due to loosening of clavicular button Coracoid process fracture Superficial wound infection 4 other surgeries: Suture knot removal under local anesthesia Subacromial decompression for persistent impingement symptoms and removal of clavicular screw due to irritation Lateral clavicle trimming Resection after severe CC calcification 2 additional patients required surgical revision, and 1 developed postoperative infection with hardware removal but were excluded from the study (Salzmann et al.)
LARS	5/114 (4.4)	2 recurrent dislocations without revision surgery 1 coracoid fracture 1 superficial wound infection 1 loosening of the lateral screw, fracture of the distal end of the clavicle, and incomplete rupture of the synthetic ligament	1/114 (0.9)	1 removal of the ligament and stabilization using coracoacromial ligament transposition according to a modified Weaver-Dunn procedure

(continued)

Table 6. Continued

Treatment	No. of Complications (%)	Complications	No. of Unplanned Reoperations (%)	Additional Surgeries
Coracoacromial ligament transfer	19/149 (12.8)	7 superficial wound infection 4 persistent shoulder pain with activity 3 loss of reduction treated with revision 2 mild internal rotation and flexion limitations 2 draining fistulas over the clavicle 1 redislocation of the clavicle after 3 weeks	8/149 (5.4)	4 revision surgeries: 3 revision surgeries treated with semitendinosus reconstruction 1 revision with a hook plate 6 weeks after redislocation
Hook plate/K-wires	20/76 (26.3)	4 superficial wound infections 4 with loss of optimal position with K-wire 4 with peri-incisional numbness 2 plate loosenings 2 acromial erosions 1 clavicular fracture 1 stiff shoulder 1 deep wound infection 1 broken K-wire	2/76 (2.6)	1 I&D and plate removal owing to deep infection 1 premature plate removal (at 6 weeks) for acromial erosion

AC, acromioclavicular; CA, coracoacromial; CC, coracoclavicular; DCE, distal clavicle excision; I&D, irrigation and debridement; LARS, ligament advanced reinforcement system; ORIF, open reduction and internal fixation.

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Appendix Table 1. Patient Demographic Data Summary for the Included Studies Using Free Graft Reconstruction Techniques

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)	Allo- vs Autograft Type
Tauber et al., 2016[21]	II	12 (12)	41.3 ± 11.6	N/R	Acute: 0 Chronic: 12 9.2 ± 5.8 months	III: 0 IV: 0 V: 12 VI: 0	Sport: 9 Traffic accident: 2 Fall, unspecified: 1	27.1 ± 6.4	Allograft/semitendinosus
Hegazy et al., 2016[22]	IV	10 (10)	37.9 (26-56)	M: 8 F: 2	Acute: 0 Chronic: 10 18.2 months (10-27)	III: 0 IV: 0 V: 10 VI: 0	Traffic accident: 6 Fall, unspecified: 4	27.7 (24-32)	Autograft/semitendinosus
Parnes et al., 2015[23]	IV	12 (12)	25 (20-35)	M: 12 F: 0	Acute: 0 Chronic: 12	III: 0 IV: 0 V: 12 VI: 0	Sport: 11 Motorcycle accident: 1	30.4 (24-42)	Allograft/semitendinosus
Tauber et al., 2009[24]	II	12 (12)	41.58 (24-58)	M: 6 F: 6	Acute: 0 Chronic: 12 31.5 months (6-144)	III: 5 IV: 3 V: 4 VI: 0	Sport: 8 Motorcycle accident: 1 Car accident: 1 Fall, unspecified: 2	34.9 (24-48)	Autograft/semitendinosus
Millett et al., 2015[25]	IV	31 (31)	43.9 (21-71)	M: 31 F: 0	<30 days after injury: 14 >30 days after injury: 17	III: 9 IV: 0 V: 22 VI: 0	Ski/snowboarding: 15 Bicycle accident: 10 Other: 6	42 (24-74)	Allograft/29 tibialis anterior 2 peroneus longus
Fauci et al., 2013[26]	I	20 (20)	36 ± 4.3	M: 15 F: 5	Acute: 0 Chronic: 20	III: 8 IV: 12 V: 0 VI: 0	N/R	48	Allograft/semitendinosus
Saccomanno et al., 2014[27]	IV	18 (18)	27.5 ± 8.2	M: 17 F: 1	Acute: 0 Chronic: 18	III: 8 IV: 4 V: 6 VI: 0	Sport: 4 Traffic accident: 8 Fall, unspecified: 6	26.4 ± 2.3 (24-30)	Autograft/semitendinosus
Tauber et al., 2007[28]	IV	12 (12)	51.2 (29-63)	M: 7 F: 5	Acute: 0 Chronic: 12 51 months (12-192)	III: 6 IV: 4 V: 2 VI: 0	Sport: 9 Fall from height: 3	49.5 (26-96)	Autograft/semitendinosus
Takase and Yamamoto, 2016[29]	IV	22 (22)	38.1 (21-71)	M: 19 F: 3	Acute: 12 Chronic: 0 13.2 days (7-21)	III: 0 IV: 0 V: 22 VI: 0	N/R	38 (24-63)	Autograft/palmaris longus
Kocaoglu et al., 2017[30]	III	16 (16)	41.4 (26-58)	M: 13 F: 3	Acute: 0 Chronic: 16	III: 12 IV: 2 V: 1 VI: 1	Sport: 6 Bicycle accident: 5 Fall, unspecified: 5	42 (29-54)	Autograft/palmaris longus

(continued)

Appendix Table 1. Continued

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)	Allo- vs Autograft Type
Total		165 (165)	38.6	M: 128 F: 25 N/R: 12	Acute: 26 Chronic: 139	III: 48 IV: 25 V: 91 VI: 1	Sports: 47 Traffic accident: 16 Bicycle accident: 15 Fall, unspecified: 18 Fall from height: 3 Motorcycle accident: 2 Car accident: 1 Ski/snowboarding: 15 Other: 6 N/R: 42	37.7	

F, female; M, male; N/R, not reported; SD, standard deviation.

Appendix Table 2. Patient Demographic Data Summary for the Included Studies Using Suspensory Device Techniques

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)	Device Used
Tauber et al., 2016[21]	II	14 (14)	51.3 ± 12.3	N/R	Acute: 0 Chronic: 14 22.8 ± 30.8 months	III: 3 IV: 1 V: 10 VI: 0	Sport: 7 Traffic accident: 3 Fall, unspecified: 4	31.2 ± 10.0	GraftRope
Shin and Kim, 2015[31]	IV	18 (18)	45.4 (30-66)	M: 17 F: 1	Acute: 18 Chronic: 0 6.1 days (1-14)	III: 3 IV: 1 V: 14 VI: 0	Sport: 6 Traffic accident: 3 Bicycle accident: 5 Fall from height: 4	27.8 (24-40)	TightRope
Struhl and Wolfson, 2015[32]	IV	35 (35)	42.4 (25-70)	M: 31 F: 4	Acute: 9 Chronic: 26 (acute >4 weeks), 196 days (4-1,096)	III: 19 IV: 2 V: 14 VI: 0	Sport: 6 Traffic accident: 6 Fall, unspecified: 8 Motorcycle or bicycle accident: 14 Direct trauma: 1	62 (27-144)	Closed-loop double EndoButton device
Sobhy, 2012[33]	IV	17 (17)	31 ± 9.9 (18-55)	M: 11 F: 6	Acute: 17 Chronic: 0 15.9 ± 11 days (2-35)	III: 7 IV: 3 V: 7 VI: 0	N/R	28 (24-40)	Nylon tape
Choi et al., 2016[34]	IV	43 (43)	42.6 (23-73)	M: 40 F: 3	Acute: 43 Chronic: 0 11.2 days (1-21)	III: 0 IV: 8 V: 35 VI: 0	Sport: 9 Traffic accidents: 10 Fall, unspecified: 24	59.6 (40-97)	TightRope
Cisneros and Reiriz, 2017[35]	IV	12 (12)	31 (19-45)	M: 12 F: 0	Acute: 12 Chronic: 0 8 days (5-15)	III: 3 IV: 2 V: 7 VI: 0	N/R	26.5 (25-32)	
El Shewy and El Azizi, 2011[36]	IV	21 (21)	31.8 (22.3-39.5)	M: 16 F: 5	Acute: 21 Chronic: 0 2.14 days (1-5)	III: 0 IV: Yes, but unspecified number V: Yes, but unspecified number VI: 0	Sport: 10 Traffic accident: 4 Fall, unspecified: 7	92 (72-114)	No. 5 nonabsorbable suture
Ladermann et al., 2011[37]	IV	37 (37)	33.6 ± 8.9 (18-55)	M: 35 F: 2	Acute: 37 Chronic: 0 4.8 ± 5.1 days (0-20)	III: 6 IV: 12 V: 19 VI: 0	Sport: 14 Fall, unspecified: 10 Traffic accident: 13	54 ± 30 (24-126)	
Salzmann et al., 2010[38]	IV	23 (23)	37.5 ± 10.2 (21-59)	M: 21 F: 2	Acute: 23 Chronic: 0 11.3 ± 9.1 days (1-21)	III: 3 IV: 3 V: 17 VI: 0	Sport: 9 Traffic accident: 3 Fall, unspecified: 4 Bicycle accident: 6 Fall from horse: 1	30.6 ± 5.4 (24-40)	TightRope

(continued)

Appendix Table 2. Continued

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)	Device Used
Kraus et al., 2013[39]	II	15 (15)	37.7 (18-66)	M: 14 F: 1	Acute: 15 Chronic: 0	III: 0 IV: 0 V: 15 VI: 0	Sports: 6 Bicycle accident: 5 Traffic accident: 4	24	Double TightRope with V-shaped orientation drill holes
		13 (13)	40.9 (21-59)	M: 12 F: 1	Acute: 13 Chronic: 0	III: 0 IV: 0 V: 13 VI: 0	Sports: 6 Bicycle accident: 3 Traffic accident: 4	24	Double TightRope with parallel drill holes
Jeon et al., 2007[40]	IV	11 (11)	39 (20-61)	M: 11 F: 0	Acute: 0 Chronic: 11	III: 9 IV: 1 V: 1 VI: 0	Sport: 2 Traffic accident: 2 Fall, unspecified: 4 Bicycle accident: 3	55 (40-80)	Nottingham Surgilig
Greiner et al., 2009[41]	IV	50 (50)	35.3 ± 10.2 (15-56)	M: 43 F: 7	Acute: 50 Chronic: 0	III: 5 IV: 1 V: 44 VI: 0	N/R	70 (30-121)	Polydioxansulfate cerclage augmentation
Katsenis et al., 2015[42]	IV	50 (50)	35.5 (20-71)	M: 38 F: 12	Acute: 50 Chronic: 0	III: 0 IV: 29 V: 21 VI: 0	Sport: 14 Traffic accident: 9 Fall from height: 27	42 (36-49)	Flipptack Fixation Button
Saier et al., 2016[43]	IV	42 (42)	34.5 (18-45)	M: 39 F: 3	Acute: 42 Chronic: 0	III: 0 IV: 0 V: 42 VI: 0	Sport: 42	31.3 (24-61)	Two TightRope Devices
Metzlaff et l., 2016[45]	III	24 (24)	N/R for individual group	N/R for individual group	Acute: 24 Chronic: 0	III: 8 IV: 6 V: 10 VI: 0	N/R for individual group	>24	Minimally invasive reconstruction (MINAR)
Li et al., 2013[44]	IV	10 (10)	46.4 ± 13.1	M: 5 F: 5	Acute: 10 Chronic: 0	III: 0 IV: 7 V: 3 VI: 0	Sport: 1 Fall, unspecified: 4 Traffic accident: 5	33.6 (24-40)	AC ligament reconstruction in combination with double EndoButton for CC ligament reconstruction
Total		435 (435)	37.7	M: 346 F: 51 N/R: 38	Acute: 384 Chronic: 51	III: 66 IV: 76 V: 272 VI: 0 N/R: 21	Sports: 132 Traffic accident: 66 Fall, unspecified: 65 Fall from height: 31 Fall from horse: 1 Bicycle accident: 22 Motorcycle or bicycle accident: 14 Direct trauma: 1 N/R: 103	49.5	

F, female; M, male; N/R, not reported.

Appendix Table 3. Patient Demographic Data Summary for the Included Studies Using LARS Devices

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)
Marcheggiani et al., 2016[46]	II	22 (22)	Median: 28 (19-33)	M: 22 F: 0	Acute: 0 Chronic: 22 N/R	III: 12 IV: 3 V: 7 VI: 0	N/R	28.2 ± 7.3
Marcheggiani et al., 2016[46]	II	21 (21)	Median: 30 (22-54)	M: 21 F: 0	Acute: 0 Chronic: 21 N/R	III: 11 IV: 2 V: 8 VI: 0	N/R	28.2 ± 7.3
Fauci et al., 2013[26]	I	20 (20)	34 ± 2.8	M: 10 F: 10	Acute: 0 Chronic: 20	III: 6 IV: 14 V: 0 VI: 0	N/R	48
Motta et al., 2012[47]	III	51 (51)	36 (19-65)	M: 50 F: 1	Acute: 34 Chronic: 17 Chronic ranged from 3 weeks to 2 years (acute <3 weeks)	III: 38 IV: 11 V: 2 VI: 0	Sport: 24 Road accident: 19 Fall, unspecified: 8	Median: 60 (24-108)
Total		114 (114)	35.4 (does not include medians)	M: 103 F: 11	Acute: 34 Chronic: 80	III: 67 IV: 30 V: 17 VI: 0	Sport: 24 Road accident: 19 Fall, unspecified: 8 N/R: 63	34.5 (does not include median follow-up)

LARS, ligament advanced reinforcement system; M, male; N/R, not reported.

Appendix Table 4. Patient Demographic Data Summary for the Included Studies Using Coracoacromial Ligament Transfer Techniques

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)
Lee et al., 2015[48]	IV	18 (18)	36.5 (24-52)	M: 14 F: 4	Acute: 0 Chronic: 18 N/R	III: 5 IV: 2 V: 11 VI: 0	Sports: 5 Traffic accidents: 6 Fall, unspecified: 7	35.3 (24-49)
Shin et al., 2009[49]	IV	29 (29)	39.7 (18-56)	M: 26 F: 3	Acute: 29 Chronic: 0 6.8 days (1-21)	III: 0 IV: 0 V: 29 VI: 0	Sports: 8 Motor vehicle accidents: 7 Fall from height: 8 Bicycle accident: 6	27.8 (24-40)
Kim et al., 2012[50]	IV	12 (12)	37.3 ± 7.7 (26-49)	M: 12 F: 0	Acute: 0 Chronic: 12 12.5 ± 5.4 weeks (7-22)	III: 0 IV: 0 V: 12 VI: 0	Sports: 4 Traffic accidents: 5 Falls, unspecified: 3	31.2 ± 9.5 (24-51)
Bostrom et al., 2010[51]	III	23 (18 re-examined, 5 phone)	Re-examined: 37 (23-53) years Phone: 42 (23-56) years	N/R	Acute: 0 Chronic: 23 Re-examined: 35 (7-108) months Phone: 13 (6-26) months	III: 6 IV: 1 V: 16 VI:0	N/R	Re-examined: 99 (51-155) months Phone: 114 (69-156) months
Kocaoglu et al., 2017[30]	III	16 (16)	37.9 (22-60)	M: 14 F: 2	Acute: 0 Chronic: 16 N/R	III: 13 IV: 2 V: 1 VI: 0	Sport: 9 Fall, unspecified: 7	47.8 (33-60)
Tauber et al., 2009[24]	II	12 (12)	42.6 (26-59)	M: 8 F: 4	Acute: 0 Chronic: 12 16.6 months (6-36)	III: 7 IV: 2 V: 3 VI: 0	Sport: 7 Motorcycle accident: 1 Fall, unspecified: 4	39.8 (24-58)
Bezer et al., 2009[52]	IV	29 (29)	29.8 ± 8.3 (19-47)	M: 21 F: 8	Acute: 0 Chronic: 29 25.6 ± 15.7 months (2-63)	III: 29 IV: 0 V: 0 VI: 0	N/R	69.5 ± 35.4 (25-143)
Hegazy et al., 2016[22]	IV	10 (10)	40.3 (21-60)	M: 9 F: 1	Acute: Chronic: 10 18.2 (9-28)	III: 10 IV: 0 V: 0 VI: 0	Traffic accident: 8 Fall, unspecified: 2	27.9 (24-32)
Total		149 (149)	37.0	M: 104 F: 22 N/R: 23	Acute: 29 Chronic: 120 ±	III: 70 IV: 7 V: 72 VI: 0	Sports: 33 Traffic accidents: 19 Motor vehicle accidents: 7 Fall from height: 8 Fall, unspecified: 23 Motorcycle accident: 1 Bicycle accident: 6 N/R: 52	51.7

F, female; M, male; N/R, not reported.

Appendix Table 5. Patient Demographic Data Summary for the Included Studies Using Osteosynthesis

Author, Year	Level of Evidence	Number of Patients (Shoulders)	Mean Age, Years ± SD (Range)	Sex	Acute/Chronic, Mean Time to Surgery ± SD (Range)	Rockwood Grade	Mechanism of Injury	Mean Follow-up in Months ± SD (Range)	Technique
Canadian Orthopedic Trauma Society, 2015[54]	I	40 (40)	37.9	M: 36 F: 4	Acute: 40 Chronic: 0 All <28 days	N/R	Sports: 17 Motor vehicle accident: 4 Fall from height: 5 Bicycle accident: 7 Other/unknown: 7	24	Operative repair with hook plate left in place for minimum 6 months (mean = 8.2 months)
Joukainen, 2014[53]	II	16 (16)	53 ± 7.8	M: 15 F: 1	Acute: 16 Chronic: 0 N/R	III: 7 IV: 0 V: 9 VI: 0	Traffic accident: 1 Fall, unspecified: 5 Collision: 2 Bicycle accident: 7 Other: 1	224.4 ± 8.7	Two transarticular K-wires and ACJ ligament suturing with K-wire removal after 6 weeks
Metzlaff et al., 2016[45]	III	20 (20)	N/R for individual group	N/R for individual group	Acute: 20 Chronic: 0 All <2 weeks	III: 4 IV: 6 V: 10 VI: 0	N/R for individual group	>24	Hook plates removed after a median 11.9 weeks
Total		76 (76)	42.2	M: 51 F: 5 N/R: 20	Acute: 76 Chronic: 0	III: 11 IV: 6 V: 19 VI: 0	Sports: 17 Motor vehicle accident: 4 Traffic accident: 1 Bicycle accident:14 Fall: 10 Collision: 2 Other/unknown: 8 N/R: 20	24-224	

ACJ, acromioclavicular joint; F, female; M, male; N/R, not reported.

Appendix Table 6. The Minors Study Quality Assessment of All the Included Studies

Author, Year	Level of Evidence/ Study Design	Clearly Stated Aim	Inclusion of Consecutive Patients	Prospective Data Collection	End Points Appropriate to Study Aim	Unbiased Assessment of Study Endpoint	Follow-up Period Appropriate to Study Aim	<5% Lost to Follow-up	Prospective Calculation of Study Size	Adequate Control Group	Contemporary Groups	Baseline Equivalence of Groups	Adequate Statistical Analyses	Total
Bezer et al., 2009[52]	IV Case series	2	1	0	2	1	2	0	0	NA	NA	NA	NA	8/16
Bostrom et al., 2010[51]	III Retrospective case control	2	2	1	2	2	2	0	0	1	0	2	1	15/24
Canadian Orthopedic Trauma Society, 2015[54]	I Randomized Clinical Trial	2	2	2	2	2	2	1	2	2	2	2	2	23/24
Choi et al., 2016[34]	IV Case series	1	1	1	2	1	2	1	0	1	1	1	2	14/24
Cisneros and Reiriz, 2017[35]	IV Case series	2	2	1	2	0	2	2	0	1	1	1	1	15/24
El Shewy and El Azizi, 2011[36]	IV Case series	1	1	1	2	1	2	1	0	NA	NA	NA	NA	9/16
Fauci et al., 2013[26]	I Randomized clinical trial	2	2	2	2	1	2	2	2	2	2	2	2	23/24
Greiner et al., 2009[41]	IV Case series	2	2	1	2	1	2	1	0	NA	NA	NA	NA	11/16
Hegazy et al., 2016[22]	IV Case series	2	1	1	2	1	2	1	0	1	0	0	1	12/24
Jeon et al., 2007[40]	IV Case series	1	1	1	2	1	2	1	0	NA	NA	NA	NA	9/16
Joukainen, 2014[53]	II Randomized clinical trial	2	2	2	2	1	2	1	1	1	1	2	1	18/24
Katsenis et al., 2015[42]	IV Case series	2	2	1	2	1	2	2	0	NA	NA	NA	NA	12/16
Kim et al., 2012[50]	IV Case series	2	1	1	2	0	2	2	0	NA	NA	NA	NA	10/16
Kocaoglu et al., 2017[30]	III Retrospective case control	2	1	2	2	0	2	2	0	1	1	1	1	15/24
Kraus et al., 2013[39]	II Prospective	2	1	2	2	2	2	2	0	1	0	0	1	15/24
Laudermann et al., 2011[37]	IV Case series	2	1	1	2	2	2	1	0	NA	NA	NA	NA	11/16
Lee et al., 2015[48]	IV Case series	2	2	1	2	1	2	1	0	NA	NA	NA	NA	11/16
Li et al., 2013[44]	IV Case series	2	2	2	2	1	2	2	0	NA	NA	NA	NA	13/16
Marcheggiani et al., 2016[46]	II Prospective	2	2	2	2	2	2	2	2	2	1	1	2	22/24
Metzlaff et al., 2016[45]	III Retrospective case-control	2	2	1	2	1	2	2	1	2	1	1	2	19/24
Millett et al., 2015[25]	IV Case series	2	2	2	2	1	2	2	0	NA	NA	NA	NA	13/16
Motta et al., 2012[47]	IV Case series	2	2	2	2	1	2	1	0	NA	NA	NA	NA	12/16
Parnes et al., 2015[23]	IV Case series	2	2	2	2	1	2	2	0	NA	NA	NA	NA	13/16
Saccomanno et al., 2014[27]	IV Case series	2	2	2	2	0	2	2	0	NA	NA	NA	NA	12/16
Saier et al., 2016[43]	IV Case series	1	2	1	2	1	2	1	0	NA	NA	NA	NA	10/16
Salzmann et al., 2010[38]	IV Case series	2	2	2	2	1	2	1	0	NA	NA	NA	NA	12/16
Shin and Kim, 2015[31]	IV Case series	2	2	2	2	1	2	1	0	NA	NA	NA	NA	12/16
Shin et al., 2009[49]	IV Case series	2	2	2	2	1	2	1	0	NA	NA	NA	NA	12/16
Sobhy, 2012[33]	IV Case series	2	2	2	2	1	2	1	0	NA	NA	NA	NA	12/16
Struhl and Wolfson, 2015[32]	IV Case series	2	2	2	2	2	2	1	0	NA	NA	NA	NA	13/16
Takase and Yamamoto, 2016[29]	IV Case series	1	2	1	2	1	2	1	0	NA	NA	NA	NA	10/16
Tauber et al., 2009[24]	II Prospective	2	2	2	2	2	2	2	0	1	1	1	2	19/24
Tauber et al., 2016[21]	II Prospective	2	2	2	2	2	2	2	0	1	1	1	2	19/24
Tauber et al., 2007[28]	IV Case series	2	2	2	2	1	2	1	0	NA	NA	NA	NA	12/16