REVIEW ARTICLE

Comparison of Effectiveness and Safety in Treating Acute Acromioclavicular Joint Dislocation with Five Different Surgical Procedures: A Systematic Review and Network Meta-Analysis

Yuan Yan, MSc[1,2], Mingxin Liao, MD[3], Huahao Lai, MSc[2], Ziyang Xu, MSc[2], Haobin Chen, MSc[2], Wenhan Huang, PhD[2], Hui Yu, PhD[4], Yu Zhang, MD, PhD[1,2]

[1]Guangdong Cardiovascular Institute, Guangdong Provincial People's Hospital, Guangdong Academy of Medical Sciences, Southern Medical University, [2]Department of Orthopaedics, Guangdong Provincial People's Hospital (Guangdong Academy of Medical Sciences), Southern Medical University and [4]Department of Orthopaedics, The Third Affiliated Hospital of Guangzhou Medical University, Guangzhou and [3]Nanping First Hospital Affiliated to Fujian Medical University, Nanping, China

This network meta-analysis aims to evaluate the comparative effectiveness and safety of suture anchors (SA), tendon grafts (TG), hook plates (HP), Tight-Rope (TR), and EndoButton (EB) in the treatment of acute acromioclavicular joint (ACJ) dislocation. The Embase, PubMed, and Web of Science databases were searched from their inception date to June 3, 2022. Studies included all eligible randomized controlled trials (RCTs) and cohort studies with the comparison of five different fixation systems among SA, TG, HP, TR, and EB were identified. All studies were reviewed, performed data extraction, and assessed the risk of bias independently by two reviewers. The primary outcomes are Constant–Murley score (CMS) improvement for assessing clinical efficacy, and complications. The second outcomes are visual analog scale (VAS) for assessing pain relief and the coracoclavicular distance (CCD) for assessing postoperative joint reduction. Version 2 of the revised Cochrane risk of bias tool for randomized trials (RoB 2) and the risk of bias in nonrandomized studies of interventions (ROBINS-I) were used to assess the RCTs and non-randomized trials, respectively. The continuous outcomes were presented as mean differences (MD), and risk ratios (OR) were used for dichotomous outcomes, both with 95% confidence intervals (CI). Surface under the cumulative ranking curves (SUCRA) results were calculated to offer a ranking of each intervention. We identified 31 eligible trials, including 1687 patients in total. HP showed less CMS improvement than TR and EB in both the Network Meta-analysis (NMA) and pairwise meta-analysis. HP also showed less CMS improvement than SA in NMA. For pain relief, HP performed worse than TR both in pairwise meta-analysis and NMA. No significant differences were found for the measured value of CCD. Both TR and EB showed a lower incidence of complications than HP in pairwise meta-analysis. The rank of SUCRA for CMS improvement was as follows: SA, TR, EB, TG, and HP; for pain relief: TR, EB, TG, SA, and HP; for CCD: HP, TR, SA, EB, and TG. For complications, HP showed the highest rank, followed by TG, EB, TR, and SA. SA shows better clinical effectiveness and reliable safety in the treatment of acute ACJ dislocation. Although HP is the most widely used surgical option currently, it should be carefully taken into consideration for its high incidence of complications.

Address for correspondence Yu Zhang, MD, PhD, Room 1042, 10/F, Main Clinical Building, Guangdong Provincial People's Hospital, Guangdong Academy of Medical Sciences, Guangzhou, Guangdong, China Tel: (086) 13602744495; Fax: (086) 020-8382-7812; Email: luck_2001@126.com; Hui Yu, PhD, Department of Orthopaedics, The Third Affiliated Hospital of Guangzhou Medical University, Guangzhou, China Tel: (086) 18175361071; Fax: (086) 020-8382-7812; Email: yuhuijm@outlook.com

Grant sources: This study was supported by the National Key R&D Program of China (Grant No. 2021YFC24007004), the research project outlay of Guangdong Provincial People's Hospital (No. 2021YFC2400704), and the Startup Fund for Scientific Research, Fujian Medical University (No. 2019QH1221).

Disclosures: Our manuscript contains original unpublished work and is not being submitted for publication elsewhere at the same time. All authors have agreed with the submission in its present forms and disclose no potential conflicts of interest. Each of the authors has read and concurs with the content in the final manuscript.

Yuan Yan is the first author; Mingxin Liao and Huahao Lai are co-first authors.

Received 4 September 2022; accepted 16 March 2023

Orthopaedic Surgery 2023;15:1944–1958 • DOI: 10.1111/os.13731

Key words: Acute Acromioclavicular Joint Dislocation; Internal Fixation; Network Meta-Analysis; Rockwood Classification; Surgery

Introduction

Acute acromioclavicular joint (ACJ) dislocation is the most common sports-related injury accounting for more than 50% of cases.[1,2] Rockwood's classification of ACJ is the most commonly used in clinical practice.[3,4] It is based on the degree and direction of clavicle displacement.[4] Rockwood's classification suggests that surgery should be the first choice for some type III and all type IV–VI dislocations.[3,4]

Given that acromioclavicular and coracoclavicular (CC) are the most important structures for holding the stability of the ACJ.[5] The current main surgery strategy for unstable acute ACJ dislocation is to reconstruct acromioclavicular (AC) or coracoclavicular (CC). Due to CC reconstruction being lower in difficulty than that AC reconstruction, CC reconstruction has become the clinically preferred surgical strategy.[6] The main surgical procedures reported for CC reconstruction in the literature so far include suture anchors (SA), tendon grafts (TG), hook plates (HP), Tight-Rope (TR), and EndoButton (EB).[6–12]

Each surgical procedure has its advantages and disadvantages, thus a multitude of evaluation methods from various perspectives was utilized to comprehensively access postoperative efficacy. Clinically Constant–Murley score (CMS) is the most commonly used scale to assess shoulder function.[1] The CMS is a 100-point scale composed of several individual parameters.[2] It is divided into four subscales: pain, activities of daily living, strength, and range of motion.[2] Although CMS includes a pain assessment component, the visual analog scale (VAS) is still widely used to rate patients' postoperative pain. It is one of the pain rating scales used for the first time in 1921 by Hayes and Patterson, which is often used in epidemiologic and clinical research to measure the intensity or frequency of various symptoms.[3] Meanwhile, the radiological assessment is evaluated by coracoclavicular distance (CCD). The CCD is commonly defined as the height as a percentage to the contralateral shoulder between the upper border of the coracoid process and the inferior cortex of the clavicle.[4] Currently, CMS and VAS are the most important indicators for the evaluation of clinical efficacy, while CCD is used to access the radiological results.

Although all surgical procedures have been reported to achieve satisfactory clinical results, there is still debate as to which one is the best choice. The pairwise meta-analyses have only directly compared HP with TR,[13,14] EB,[15] or other CC ligament fixation[16] previously, whereas the refined direct or indirect comparisons between the various surgical procedures are lacking. Therefore, adequate evidence was still insufficient to ensure which one is optimal for treating acute ACJ dislocation. Network meta-analysis (NMA) has been developed to give indirect results of more than two options based on indirect outcomes and a rank of all the options.[17] Hence, we built an NMA to comprehensively analyze and rank the five surgical procedures from the aspects of the Constant–Murley score, visual analog scale, CC distance, and complications.

Methods

Our study complied with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR (Assessing the Methodological Quality of Systematic Reviews) guidelines inclusion and exclusion criteria.

Types of Studies

In our NMA, we identified relevant studies, including all RCTs or non-RCT studies, to compare the efficacy and safety of SA, TR, TG, EB, and HP. For accessing literature quality assessment, papers with abstracts only and RCT protocols were excluded. Additionally, the following were all excluded: review articles, meta-analyses, cadaveric and animal research, case report, conference paper, and incomplete or missing data. The study selection process was showed in detail in Figure 1.

Types of Participants

Participants were adults aged 18 years or older with ACJ dislocation, without distinction in terms of ethnicity, gender, and race.

Types of Interventions

The studies which aimed at any comparison of SA, TR, TG, EB, and HP were included. Each study contained at least two of the five surgical procedures.

Types of Outcomes

The following four main outcomes were obtained: Constant–Murley score (CMS), visual analog score (VAS), coracoclavicular distance (CCD), and complications.

Search Strategy

Embase, PubMed, and Web of Science were searched from their inception date to June 3, 2022. The following keywords were used for searching in an electronic database: acute acromioclavicular dislocation, hook plate, EndoButton, suture anchors, tightrope, Bosworth screws, screw,

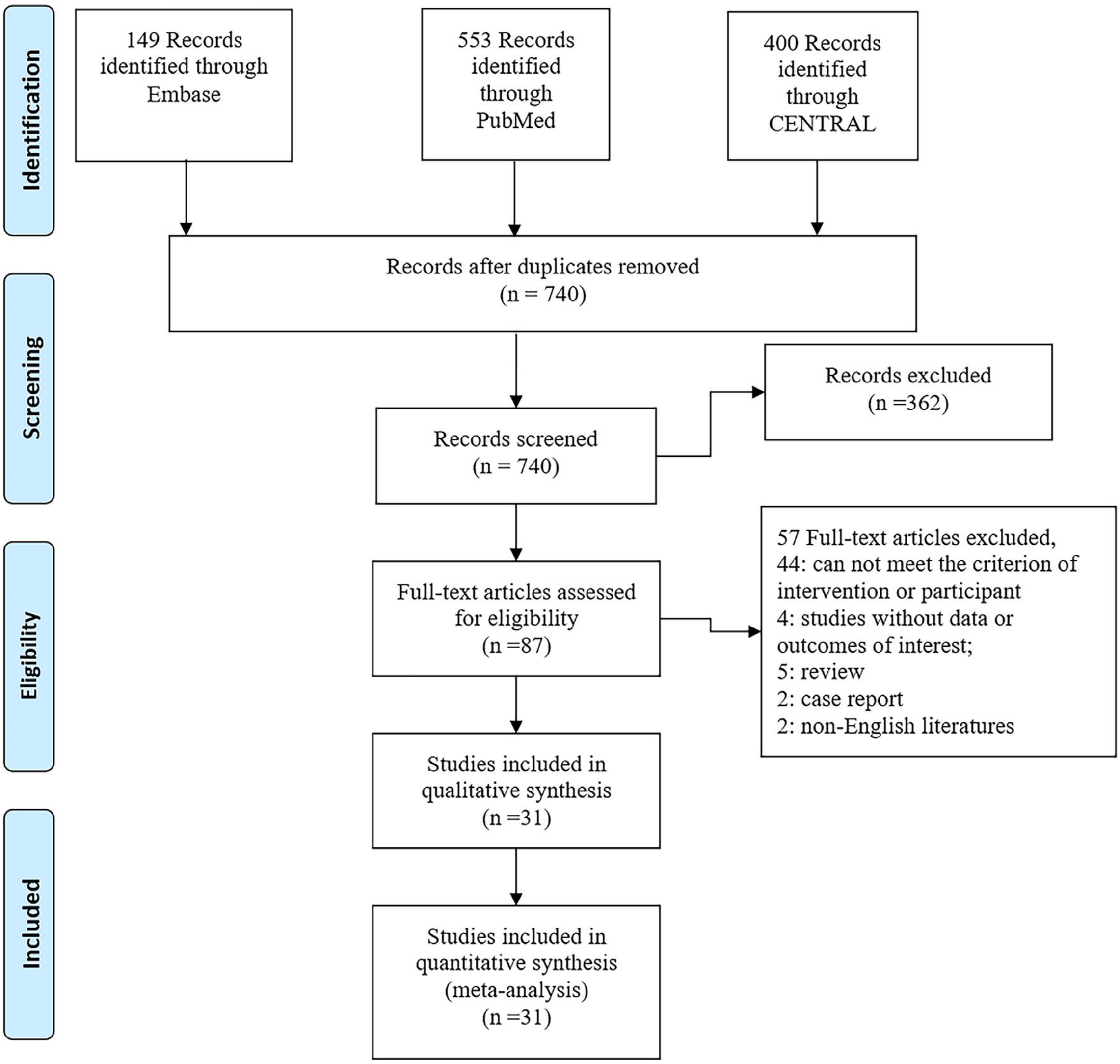

FIGURE 1 Flowchart of the study selection process.

tension band wire, and Kirchner wires. Search strategies were described in detail in "Supplementary files." Previously published systematic reviews and meta-analyses were also screened to search for the relevant trials. Only English-language articles were screened in our meta-analysis.

Study Selection

After the removal of duplicates, two reviewers independently retrieved and reviewed the titles and abstracts of all publications. The full-text papers were obtained to identify the eligibility of studies for inclusion when necessary. Then, the reviewers selected potentially relevant studies according to pre-designed criteria. If discrepancies in judgment arose, a third reviewer was consulted.

Data Extraction and Quality Assessment

The basic information was extracted from each enrolled study using a specifically designed form. The extracted data was as follows: (1) general information: lead author, year of publication, study design, country of study, study period, and follow-up time; (2) demographic information: the number and proportion of male or female patients, age at diagnosis, number of involved patients; (3) surgery information (intervention and comparison); (4) clinical outcome information: VAS, CCD, CMS, and complication. If SD is not available from the publication, we imputed the SD which used the method from the Cochrane Handbook. For the assessment of consistency, the value of the correlation coefficient (0.5 and 1) was also calculated.

The Geometry of the Network

The network of four outcomes was presented summarily as graphs. The size of the circle and the thickness of the edge represented the number of patients included and the number of studies, respectively. A qualitative description of network geometry was provided.

Risk of Bias within Individual Studies

We applied the RoB 2 for randomized trials,[18] and ROBINS-I for non-randomized trials[19] to assess methodological quality. HY and YY were evaluated independently. The ROBINS-I checklist included seven main domains: confounding, selection bias, classification of intervention, reporting bias, deviations from intervention, missing data, and measuring the outcome. According to the general guideline of the ROBINS-I, each domain contains five levels of bias judgment: no information (0), low (1), moderate (2), serious (3), critical (4).The assessment was categorized as high quality if most of the domains were well-described and scored low risk of bias. The strength of evidence of RCTs was evaluated by the five domains (randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, selection of the reported result) using RoB 2 tool. After the discrepancies in grading was discussed, researchers came to consensus on final rating.

Summary Measures

CMS improvement, VAS, and CCD were measured as mean difference (MD) with a 95% confidence interval (CI) individually. And the complications were measured as odds ratio (OR) with 95% CI. Surface under the cumulative ranking curves (SUCRA) values were calculated to offer a ranking of all interventions.

Planned Methods of Analysis

The data with treatments as well as clinical outcomes were extracted. Direct comparisons of the pairwise meta-analysis were performed using a random-effects model. MD with 95% CI for CMS improvement, VAS, and CCD as continuous variables of outcome were provided. And OR with 95% CI for complications as a dichotomous outcome was presented. The statistical heterogeneity across studies was assessed by the χ^2 test and the inconsistency (I^2). All statistical analyses were carried out using STATA with Metan package (Version 15.0; STATA Corporation, College Station, TX). Second, the NMA was built within the Bayesian framework by the Markov Chain Monte Carlo algorithm in WinBUGS 1.4.3[20] using a random effect model. Results presented for each model were simulated on three Markov chains for 100,000 iterations, after a burn-in of 50,000.

The number of thinning intervals was set at 10 iterations. Subsequently, the direct and indirect variances of convergence were obtained through the Brooks–Gelman–Rubin method.[21] The potential scale reduction factor (PSRF) (approaching or equal to 1.0) indicated that convergence has been achieved.[21] The NMA results were also presented as OR or MD with a 95% confidence interval. The results of five fixation methods, which were calculated by WinBUGS, were input by STATA to generate the surface under the cumulative ranking curves (SUCRA).[22] The value of SUCRA was presented as 0% (the worst treatment) to 100% (the best treatment).

Assessment of Inconsistency

Risk of Bias Across Studies

The global inconsistency was measured by the consistency and inconsistency models. Model fit was compared using the deviance information criterion (DIC) and a reduction of larger than 3 in DIC shows the inconsistency existed. The local inconsistency was evaluated by the node-splitting method.[23] If node-splitting analysis showed a *p*-value <0.05, inconsistency would be considered statistically significant.

RESULTS

Documentation Retrieval

A total of 1102 potential titles were screened through the first search strategy, with 362 excluded for duplications. Among the remaining 740 studies, 87 potentially qualified articles were acquired to check eligibility after carefully screening titles and abstracts. With careful full-text reading, 56 studies were excluded for the reasons shown in Figure 1. Finally, 31 articles were included in our study.[24–54]

Network Graphs

All the network of comparisons were shown in Figure 2. The network for CMS included 21 studies, for VAS included 15 studies, for CCD included 13 studies, and for complications included 27 studies. Lines between two nodes indicate direct evidence between two interventions, with the thickness of the line corresponding to the number of studies. The size of the nodes corresponds to the number of treatments included.

Characteristics of the Included Trials

A total of 1687 patients were recorded. The network for CCM included 1252, for VAS included 1000, for CCD included 615, and for complications included 1539. Three studies were RCTs and 28 were retrospective studies. We recorded the characteristics of all included studies in Table 1.

Risk of Bias and Quality Assessment

According to the ROBINS-I tool analysis, Table 2 presented the quantification of the risk of bias assessment of

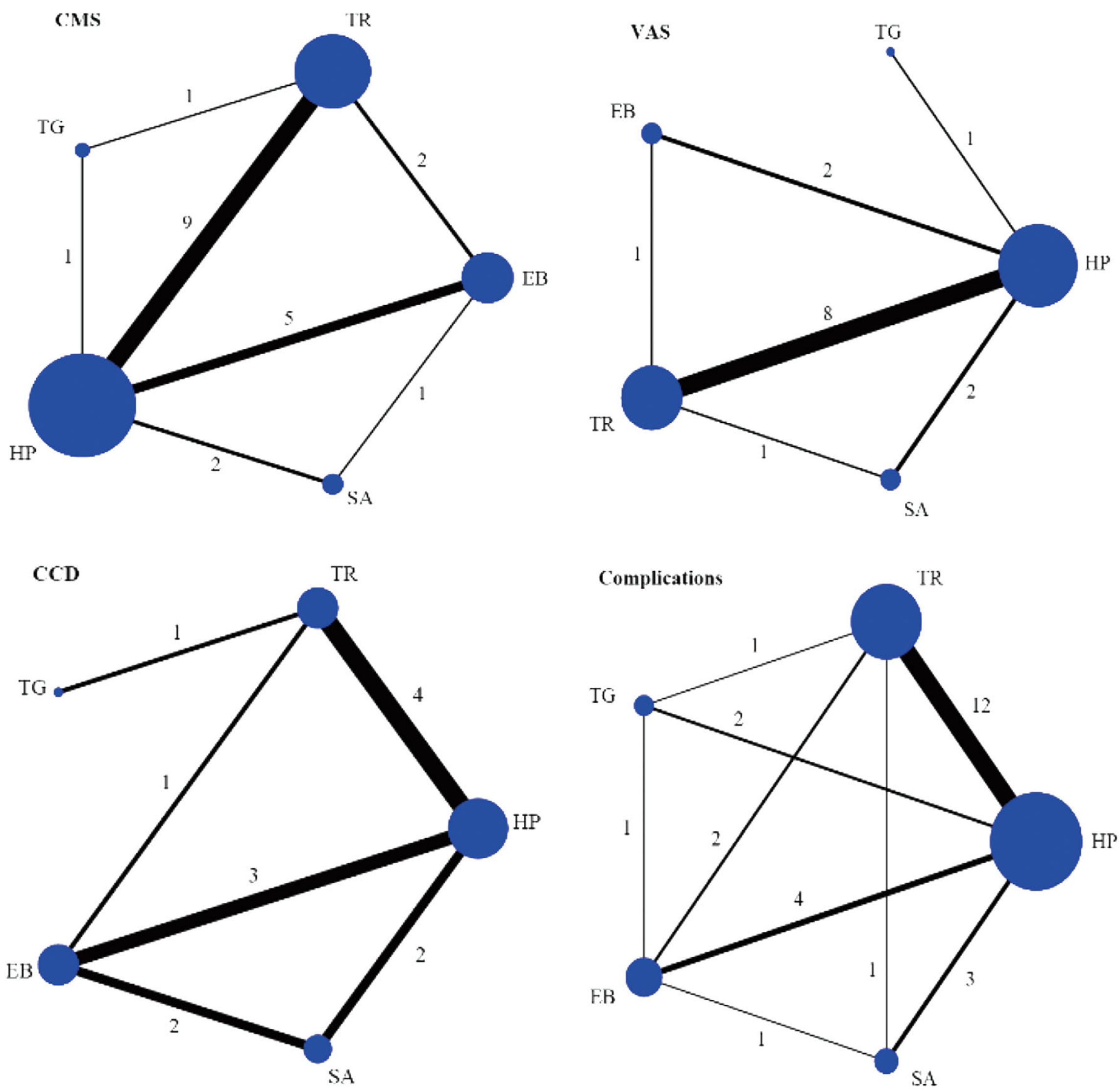

FIGURE 2 Network of comparisons of HP, TR, TG, EB, and Suture for AC dislocation. The circle means the number of patients, and the edge thickness means the number of studies. CCD, coracoclavicular distance; CMS, Constant–Murley score; EB, EndoButton; HP, hook plates; SA, suture anchors; TG, tendon grafts, TR, Tight-Rope; AS, visual analog scale.

retrospective studies. The outcome showed that the overall risk of bias in all eligible studies was moderate, indicating all of the studies were of high quality. However, selection bias was inevitable for none of these studies were randomized studies. The risk of bias analysis of the included three RCTs was evaluated by using RoB 2 tool analysis. The results were listed in Figure 3. Some concerns in the randomization process were mentioned in two studies, and the bias of measurement of the outcome was described in detail in one study. No study reported the deviations from intended interventions, missing outcome data, and selection. Thus, two domains, the randomization process and measurement of the outcome, possibly led to bias.

Figure 4 showed a funnel plot assessing publication bias, and the results indicated that small studies did not affect the primary (CMS and complications) and secondary outcomes (VAS, CCD).

Results of CMS

The results of CMS were shown in Table 3. The lower-left triangle indicated pairwise meta-analysis, and the upper-right triangle indicated NMA. The shadows represented significant differences. HP showed less CMS improvement

TABLE 1 Characteristics of included trials

Author	Year	Region	Design	Intervention	Number of patients (M/F)	Mean age (years)	Follow-up (months)	CMS	VAS	CCD	Complications
Leyi	2017	China	RCT	TR	30(19/11)	42.80 ± 11.88	12	91.97 ± 6.70	0.97 ± 1.03	12.13 ± 1.96	3/30
				HP	39(26/13)	41.79 ± 10.2	12	92.56 ± 6.37	1.92 ± 1.11	11.90 ± 2.51	5/39
Emre	2021	Turkey	R	TR	21(19/2)	39.2(20–60)	12	NR	NR	NR	12/21
				HP	14(13/1)	41.8(18–85)	12	NR	NR	NR	7/14
Frank	2013	Germany	R	EB	13(NR)	43.6(18–71)	28.8(12–68.4)	NR	NR	NR	3/13
				TG	46(NR)	43.6(18–71)	28.8(12–68.4)	NR	NR	NR	13/46
Athar	2017	Germany	RCT	HP	52(0/52)	44.8 ± 9.1	≥12	NR	NR	NR	17/52
				TR	24(1/23)	42.6 ± 11.6	≥12	NR	NR	NR	13/24
P. Vulliet	2017	France	R	TR	22(19/3)	38.8 ± 8.7	27.7 ± 8.3	94.3 ± 4.4	0.5 ± 1.1	NR	6/22
				EB	18(15/3)	37.4 ± 14.8	24.1 ± 5.0	95.0 ± 6.1	1.0 ± 1.9	NR	16/18
Si Nie	2021	China	R	TR	28(11/17)	35.9 ± 7.9	33.1 ± 6.0	89.3 ± 4.2	1.2 ± 0.6	NR	2/28
				HP	84(33/51)	36.0 ± 8.3	32.9 ± 6.4	83.3 ± 8.8	1.8 ± 1.1	NR	12/84
Michele	2021	Italy	R	HP	22(16/6)	48.2(22–70)	40.6 ± 13.7	92.7 ± 5.1	NR	NR	13/22
				TR	22(20/2)	40.5(21–63)	32.0 ± 10.1	96.1 ± 6.2	NR	NR	5/22
Jong Pil	2015	Korea	R	HP	24(19/5)	38.8 ± 14.2	16.0 ± 12.8	90.2 ± 9.9	1.6 ± 1.5	NR	9/24
				TG	18(14/4)	42.2 ± 12.3	17.4 ± 4.3	89.2 ± 3.5	1.3 ± 1.3	NR	6/18
Sandesh	2022	India	R	HP	16(16/0)	44.3 ± 12.82	55.38 ± 10.9	92.38 ± 6.64	NR	7.02 ± 2.36	12/16
				EB	16(13/3)	42.1 ± 11.85	32.88 ± 14.0	94.65 ± 2.38	NR	10.08 ± 4.08	11/16
Pei Yu	2022	China	R	HP	60(35/25)	56.43 ± 9.64	12	91.00 ± 4.82	0.97 ± 0.60	10.10 ± 3.01	2/60
				TR	52(32/20)	50.2 ± 15.39	12	92.08 ± 5.80	0.88 ± 0.58	11.38 ± 2.94	0/52
Song Liu	2022	China	R	TR	32(23/9)	39.6 ± 8.9	12	94.8 ± 3.5	0.3 ± 0.8	12.2 ± 1.6	1/32
				HP	39(29/10)	41.8 ± 10.5	12	94.4 ± 3.2	0.4 ± 0.8	12.6 ± 1.6	3/39
Hasan	2018	Iran	R	HP	8(7/1)	39.6 ± 16.2	19.8 ± 8.8	55 ± 22.9	0.76 ± 0.95	8.6 ± 0.9	NR
				EB	9(8/1)	37.3 ± 12.02	23.8 ± 19.2	91.7 ± 5.9	0.32 ± 0.89	11.6 ± 1.2	NR
Omer	2020	Turkey	R	HP	21(6/15)	30.7 ± 9.65	32.4 (26–42)	NR	NR	NR	8/21
				EB	18(5/13)	31.7 ± 8.17	34.6 (21–45)	NR	NR	NR	7/18
Anica	2011	Germany	R	HP	27(NR)	42.3(23–73)	>9	91.2 ± 2.2	0.77 ± 0.2	16.7 ± 0.77	10/27
				SA	25(NR)	42.3(23–73)	>9	94.6 ± 1.0	0.80 ± 0.2	23.9 ± 1.2	3/25
Yon-Sik	2020	Korea	R	SA	12(8/4)	42.8 ± 5.4	30.1 ± 5.5	NR	1.02 ± 1.32	7.96 ± 2.52	2/12
				HP	10(7/3)	44.4 ± 6.5	33.8 ± 7.6	NR	1.14 ± 1.45	11.27 ± 2.59	4/10
L. Natera	2015	Spain	R	TR	20(17/3)	36(25–52)	38.40 ± 4.34	95.30 ± 2.45	0.40 ± 0.50	NR	3/20
				HP	11(11/0)	41(19–55)	32.5 ± 11.64	91.36 ± 6.84	1.45 ± 1.51	NR	2/11
Alexandre	2016	Brazil	R	SA	12(11/1)	35.4 ± 16.1	>6	NR	1.2 ± 1.3	NR	0
				TR	11(11/1)	32.4 ± 11.05	>6	NR	1.2 ± 2.0	NR	1/11
Murat	2020	Turkey.	R	SA	9(9/0)	39(24–56)	13.7 ± 2.7	93.6 ± 3.7	NR	15.2 ± 3.9	0/9
				EB	11(11/0)	37(22–50)	12.9 ± 1.4	89.6 ± 13.6	NR	16.0 ± 4.4	1/11
Ruchu	2019	Poland	R	SA	11(NR)	39(18–63)	21.2 ± 13.1	95.22 ± 10.3	NR	NR	NR
				HP	4(NR)	39(18–63)	10.8 ± 3.2	78.97 ± 12.1	NR	NR	NR
Gunnar	2012	Germany	R	HP	30(28/2)	39(16–68)	48(7–77)	NR	1.7 ± 2.3	NR	8/30
				TR	26(23/3)	39(18–54)	17(7–29)	NR	1.3 ± 1.8	NR	5/26
Hamid	2017	Singapore	R	TR	16(15/1)	41.4 ± 12.3	23(14–35)	87.6 ± 11.7	1.0 ± 1.7	11.8 ± 1.7	0/16
				HP	10(9/1)	49.2 ± 16.9	23(14–35)	77.5 ± 12.3	1.0 ± 0.7	13.6 ± 4.8	3/10
Yu-chen	2020	China	R	TR	30(18/12)	39.4 ± 15.3	27.67 ± 2.48	93.70 ± 1.78	NR	11.40 ± 1.13	0/30
				EB	30(12/18)	42.20 ± 13.5	28.30 ± 2.51	93.27 ± 1.59	NR	11.47 ± 1.19	1/30
You-Shui	2015	China	R	HP	24(19/5)	36.0 ± 6.7	18.3 ± 8.0	86.1 ± 5.7	NR	NR	16/24
				TR	24(18/6)	35.4 ± 8.6	18.8 ± 7.5	97.5 ± 2.7	NR	NR	6/24
Cheng	2018	China	R	SA	25(15/20)	43.7 ± 15.6	26.2(24–35)	NR	NR	NR	10/25
				HP	24(19/5)	42.0 ± 14.9	26.2(24–35)	NR	NR	NR	9/21
Guheng	2018	China	R	TG	8(6/2)	49.0 ± 17.8	29.8 ± 6.0	NR	NR	NR	0/8
				HP	8(5/3)	41.3 ± 13.4	30.9 ± 7.8	NR	NR	NR	0/8
Guangsi	2021	China	R	TR	16(11/5)	44.9 ± 11	27	95.7 ± 7.3	0.4 ± 0.6	NR	1/16

TABLE 1 Continued

Author	Year	Region	Design	Intervention	Number of patients (M/F)	Mean age (years)	Follow-up (months)	CMS	VAS	CCD	Complications
Thomas	2018	Germany	RCT	HP	19(10/9)	40.2 ± 8.7	30	93.7 ± 6.6	0.7 ± 0.6	NR	1/19
				HP	27(26/1)	37.65 ± 9.66	40.1 ± 23.64	90.19 ± 7.79	NR	19.38 ± 6.42	NR
Jun Zhang	2017	China	R	EB	29(28/1)	34.24 ± 9.68	30.75 ± 1.41	95.31 ± 4.42	NR	16.92 ± 4.16	NR
				EB	30(NR)	40.83 ± 10.2	24	91.2 ± 7.0	NR	NR	0/30
				HP	30(NR)	37.80 ± 13.9	24	89.6 ± 4.0	NR	NR	5/30
Yingliang	2021	China	R	SA	32(28/4)	34	39.69 ± 7.42	NR	NR	11.62 ± 2.54	NR
				EB	28(26/2)	32	37.86 ± 8.23	NR	NR	16.78 ± 5.53	NR
Sujie	2021	China	R	HP	146(45/101)	40.2	3	87.4 ± 5.2	0.9 ± 0.7	NR	96/146
				EB	146(47/99)	38.7	3	88.4 ± 3.9	0.5 ± 0.5	NR	77/146
Alberto	2015	Italy	R	TR	10(9/1)	43.3 ± 12.9	43.3 ± 12.8	96.5 ± 4.9	NR	12.51 ± 3.48	6/10
				TG	8(7/1)	50.9 ± 10.4	62.7 ± 18.78	93.3 ± 7.0	NR	16.5 ± 4.4	5/8

Abbreviations: CCD, coracoclavicular distance; CMS, Constant–Murley score; EB, EndoButton; HP, hook plates; NR, not record; R, retrospective study; RCT, randomized controlled study; SA, suture anchors; TG, tendon grafts; TR, Tight-Rope; VAS, visual analog scale.

than TR and EB in both pairwise meta-analyses [TR vs. HP, MD = 3.83, 95% CI: (0.99, 6.67); EB vs. HP, MD = 3.66, 95% CI: (0.30, 7.02)], and NMA [TR vs. HP, MD = 3.66, 95% CI: (1.47, 5.85); EB vs. HP, MD = 3.57, 95% CI: (0.71, 6.43)]. HP also showed less CMS improvement than SA in pairwise meta-analysis [SA vs. HP, MD = 5.91, 95% CI: (0.58, 11.24)]. While other than that, no significant differences were found both in pairwise meta-analysis and NMA. Based on the results obtained from SUCRA, close to 100% represents better CMS. Among them, SA ranked best (88.1%), followed by TR (66.0%), EB (63.7%), TG (18.2%), and HP (13.9%) (Figure 5).

Results of VAS

The results of VAS were shown in Table 4. HP showed less pain relief than TR both in pairwise meta-analysis [TR vs. HP, MD = −0.39, 95% CI: (−0.65, −0.14)] and NMA [TR vs. HP, MD = −0.39, 95% CI: (−0.63, −0.16)]. HP did not differ significantly from EB in the NMA but showed less pain relief than EB in pairwise meta-analysis [EB vs. HP, MD = −0.40, 95% CI: (−0.54, −0.26)]. Other than that, no other significant differences were found. Based on the results obtained from SUCRA, close to 100% represents better pain relief. Among them, TR ranked best (77.2%), followed by EB (69.4%), TG (58.6%), SA (25.4%), and HP (19.4%) (Figure 5).

Results of CCD

The results of the CCD were shown in Table 5. TG showed larger CCD than TR in pairwise meta-analysis [TG vs. TR, MD = 3.99, 95% CI: (0.26, 7.72)]. But given that there is only one set of direct comparisons, this result is not credible. No other significant differences were found between each other. For the results of SUCRA, close to 100% means better reduction. Among them, HP ranked best (73.7%), followed by TR (64.4%), SA (59.2%), EB (32.8%), and TG (19.4%) (Figure 5).

Results of Complications

The results of complications are shown in Table 6. TR showed a lower incidence of complications than HP both in pairwise meta-analysis [TR vs. HP, MD = 0.56, 95% CI: (0.30, 1.00)] and NMA [TR vs. HP, MD = 0.52, 95% CI: (0.31, 0.88)]. EB showed a higher incidence of complications than TR [EB vs. TR, MD = 0.56, 95% CI: (0.30, 1.00)] but lower than that of HP [EB vs. HP, MD = 0.58, 95% CI: (0.38, 0.88)] in pairwise meta-analysis. Meanwhile, no significant differences were found between each other. For the results of SUCRA, close to 100% means a lower incidence of complications. Among them, SA ranked lowest (81.5%), followed by TR (75.3%), EB (38.7%), TG (36.9%), and HP being the highest incidence of complications (17.7%) (Figure 5).

TABLE 2 Evaluation of the quality of studies with the ROBINS-I

Bias Domain	Bias due to confounding	Selection of participants	Classification of interventions	Deviations from intended interventions	Bias due to missing data	Measurement of outcomes	Selection of the reported result	Overall risk of bias
Song 2022	Low	Low	Low	Low	Low	Low	Moderate	Moderate
Sandesh 2022	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate
Pei Yu 2022	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Yingliang 2021	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate
Sujie 2021	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate
Si Nie 2021	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Michele 2021	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate
Guangsi 2021	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Emre 2021	Moderate	Low	Low	Moderate	Low	Moderate	Low	Moderate
Yon-Sik 2020	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Omer 2020	Low	Low	Low	Moderate	Low	Moderate	Low	Moderate
Murat 2020	Moderate	Moderate	Low	Low	Low	Moderate	Low	Moderate
Yu-chen 2020	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Klinika 2019	Serious	Moderate	Low	Moderate	Low	Moderate	Moderate	Moderate
Ying-Cheng 2018	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Hasan 2018	Moderate	Moderate	Low	Low	Low	Moderate	Low	Moderate
Guheng 2018	Moderate	Moderate	Low	Moderate	Low	Moderate	Low	Moderate
P. Vulliet 2017	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
Jun Zhang 2017	Moderate	Moderate	Low	Moderate	Low	Moderate	Moderate	Moderate
Hamid 2017	Low	Low	Low	Moderate	Low	Low	Low	Moderate
Alexandre 2016	Moderate	Low	Low	Moderate	Low	Moderate	Moderate	Moderate
You-Shui 2015	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
L. Natera 2015	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Jong Pil 2015	Moderate	Low	Low	Moderate	Moderate	Low	Low	Moderate
Alberto 2015	Moderate	Low	Low	Moderate	Moderate	Moderate	Low	Moderate
Frank 2013	Low	Low	Moderate	Moderate	Low	Moderate	Low	Moderate
Nasser 2012	Low	Low	Low	Moderate	Low	Low	Low	Moderate
Anica 2011	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate

We ranked the surgical procedures according to the two dimensions of clinical efficacy and complication rate (Figure 6). In general, SA showed the best clinical efficacy with the lowest complication rate. Additionally, the high loss of reduction rates should be paid more attention to the groups of EB (21.94%), HP (10.85%),

FIGURE 3 Results of Cochrane Risk of Bias tool (ROB 2) visualized in traffic light plots for each individual domain.

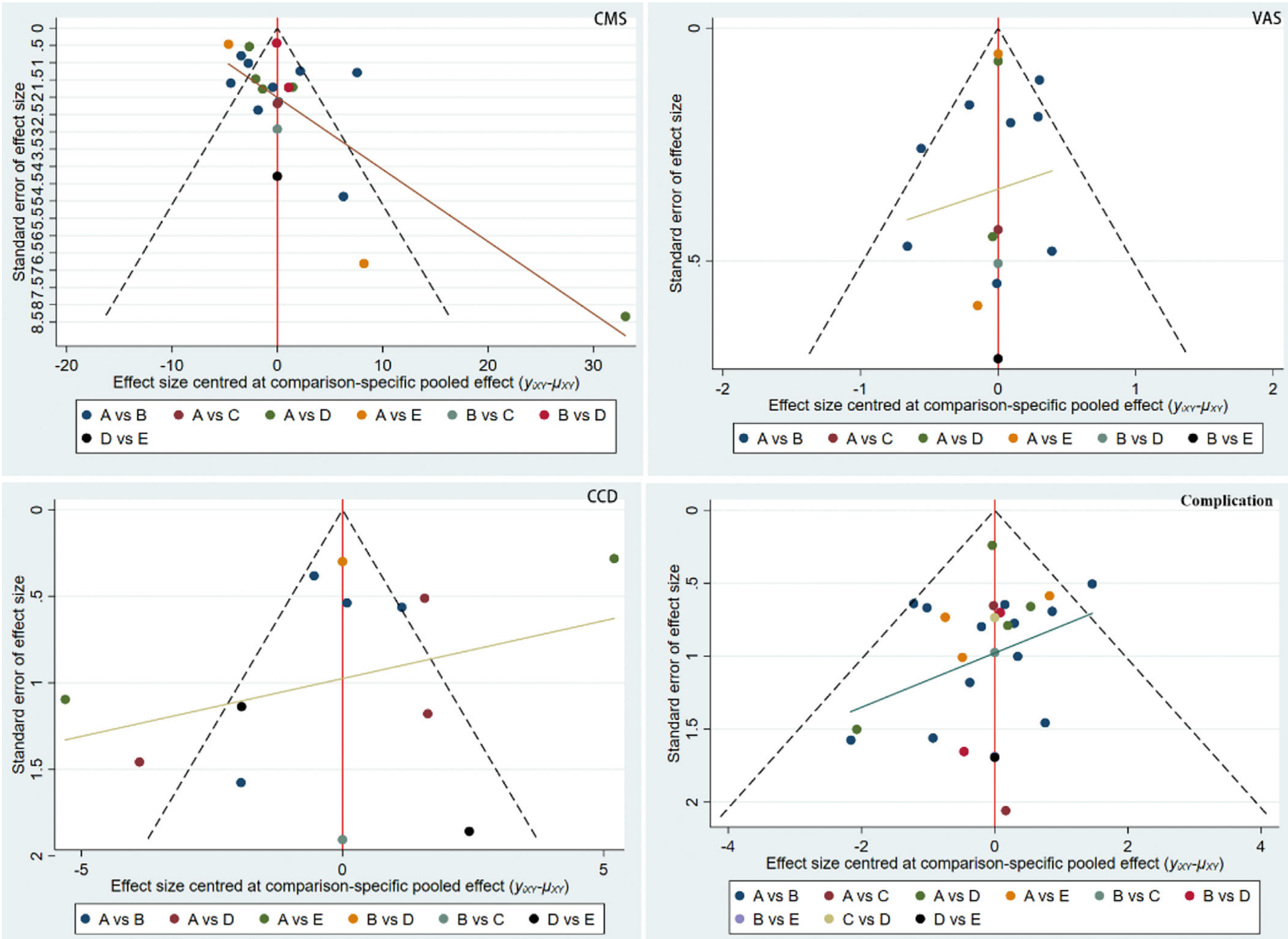

FIGURE 4 Comparison-adjusted funnel plot. The red full line represents the null hypothesis that the study-specific effect sizes do not differ from the respective comparison-specific pooled effect estimates. The two black dashed lines represent a 95% CI for the difference between study specific effect sizes and comparison-specific summary estimates. yixy is the noted effect size in study i that compares x with y. lxy is the comparison-specific summary estimate for x versus y. A, HP; B, TR; C, TG; D, EB; E, SA.

and SA (9.57%). It should also be noted that the HP group was related to a higher ratio of erosion of the acromion and stiffness. The total complication incidence of HP (34.8%), TG (37.5%), and TR (35.8%) are similar, both more than double that of TR (14.8%) and SA (13.0%) (Table 7).

TABLE 3 Results of the pairwise and network meta-analysis of CMS (MD, 95% CI)

SA	2.34 (−3.21, 7.88)	6.26 (−1.52, 14.04)	2.25 (−3.38, 7.88)	5.91 (0.58, 11.24)
N = 1, 4.00 (−4.39, 12.39)	**EB**	3.92 (−2.36, 10.20)	−0.09 (−3.18, 3.00)	**3.57 (0.71, 6.43)**
		TG	−4.01 (−9.79, 1.76)	−0.35 (−6.08, 5.38)
	N = 2, −0.36 (−1.19, 0.47)	N = 1, −3.20 (−8.92, 2.52)	**TR**	**3.66 (1.47, 5.85)**
N = 2, 8.03 (−4.06, 20.12)	**N = 5, 3.66 (0.30, 7.02)**	N = 1, −1.00 (−5.28, 3.28)	**N = 9, 3.83 (0.99, 6.67)**	**HP**

Note: Upper-right triangle shows the results of the network meta-analysis. Lower-left triangle shows the results of the pairwise meta-analyses. The N represents the numbers of studies which compared the two interventions directly. For MD with 95%CI, a negative MD favor the lower-right intervention. For OR with 95%CI, a OR >1 favor the lower-right intervention. Statistically significant findings are shaded.; Abbreviations: CCD, coracoclavicular distance; CI, confidence interval; CMS, Constant–Murley Score; EB, EndoButton; HP, hook plates; MD, mean difference; OR, odd ratio; SA, suture anchors; TG, tendon grafts; TR, Tight-Rope; VAS, visual analog scale.

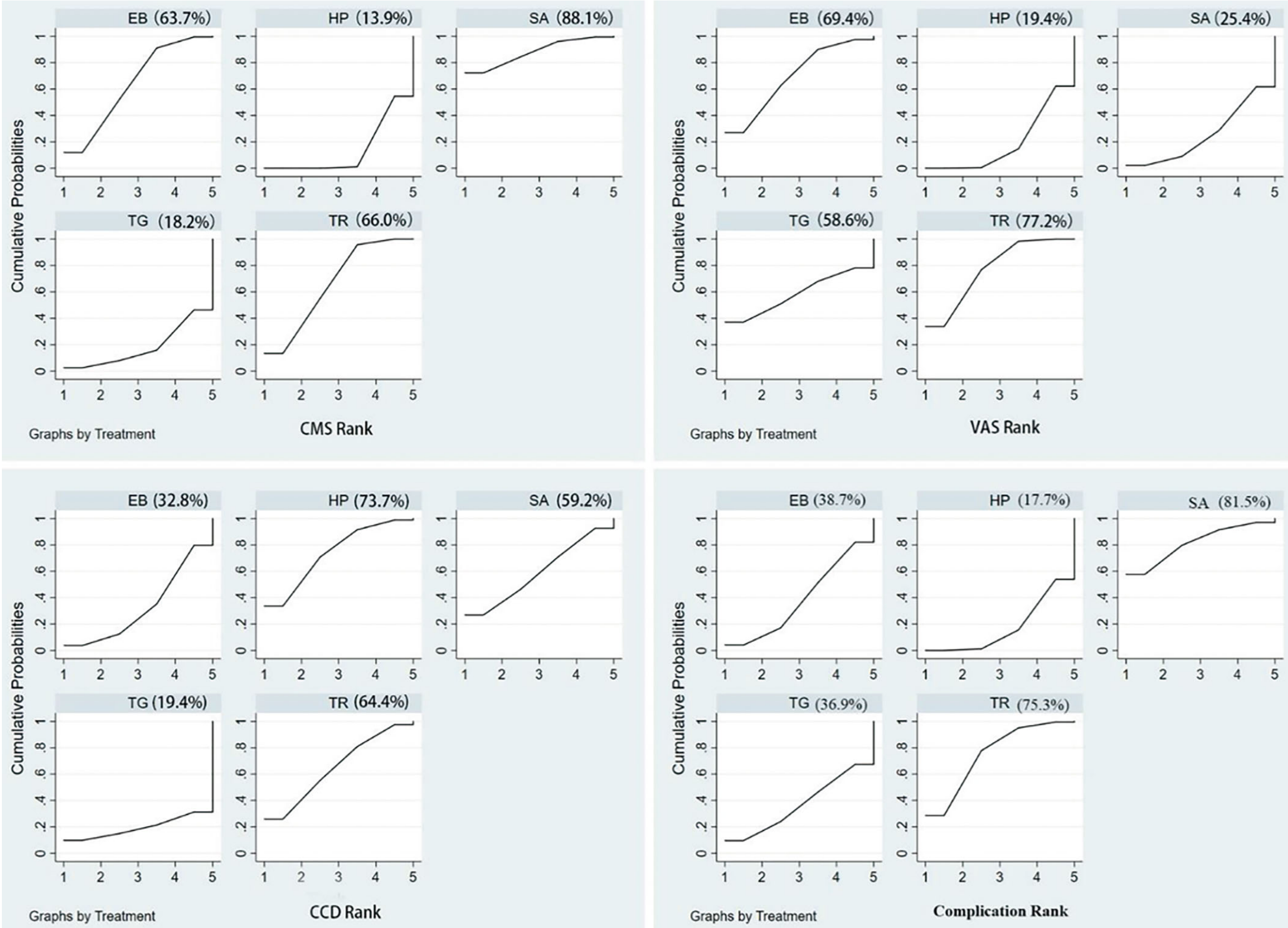

FIGURE 5 SUCRA of HP, TR, TG, EB, and Suture for AC dislocation. CCD, coracoclavicular distance; CMS, Constant–Murley Score; EB, EndoButton; HP, hook plates; SA, suture anchors; TG, tendon grafts, TR, Tight-Rope; VAS, visual analog scale.

TABLE 4 Results of the pairwise and network meta-analysis of VAS (MD, 95% CI)

SA	0.32 (−0.26, 0.90)	0.28 (−0.76, 1.32)	0.37 (−0.09, 0.83)	−0.02 (−0.43, 0.40)
	EB	−0.04 (−1.08, 0.99)	0.05 (−0.40, 0.50)	−0.34 (−0.74, 0.05)
		TG	0.09 (−0.89, 1.08)	−0.30 (−1.26,0.66)
N = 1, 0.00 (−1.39, 1.39)	N = 1, 0.50 (−0.49, 1.49)		**TR**	**−0.39 (−0.63, −0.16)**
N = 2, 0.03 (−0.08, 0.14)	**N = 2, −0.40 (−0.54, −0.26)**	N = 1, −0.30 (−6.33, 5.73)	**N = 8, −0.39 (−0.65, −0.14)**	**HP**

Note: Upper-right triangle shows the results of the network meta-analysis. Lower-left triangle shows the results of the pairwise meta-analyses. The N represents the numbers of studies which compared the two interventions directly. For MD with 95%CI, a negative MD favor the lower-right intervention. For OR with 95%CI, a OR >1 favor the lower-right intervention. Statistically significant findings are shaded.; Abbreviations: CCD, coracoclavicular distance; CI, confidence interval; CMS, Constant–Murley Score; EB, EndoButton; HP, hook plates; MD, mean difference; OR, odd ratio; SA, suture anchors; TG, tendon grafts; TR, Tight-Rope; VAS, visual analog scale.

Inconsistency Analysis

The results of inconsistency were listed in Table 8. For all outcomes, no local inconsistencies were detected (p values >0.05).

Discussion

To the best of our knowledge, this is the first comprehensive and integrated NMA to pool data focusing on CMS, VAS, CCD, and complications of five widely applied surgical

TABLE 5 Results of the pairwise and network meta-analysis of CCD (MD, 95% CI)

SA	−1.31 (−5.12, 2.50)	−3.70 (−12.47, 5.07)	0.29 (−4.32, 4.90)	0.59 (−3.14, 4.32)
N = 2, −3.23 (−7.47, 1.02)	**EB**	−2.39 (−10.79, 6.01)	1.60 (−2.25, 5.44)	1.90 (−1.20, 4.99)
		TG	3.99 (−3.47, 11.45)	4.29 (−3.77, 12.35)
	N = 1, 0.07 (−0.52, 0.66)	**N = 1, 3.99 (0.26, 7.72)**	**TR**	0.30 (−2.74, 3.34)
N = 2, 2.00 (−8.30, 12.30)	N = 3, 1.43 (−1.50, 4.35)		N = 4, 0.14 (−1.09, 0.80)	**HP**

Note: Upper-right triangle shows the results of the network meta-analysis. Lower-left triangle shows the results of the pairwise meta-analyses. The N represents the numbers of studies which compared the two interventions directly. For MD with 95%CI, a negative MD favor the lower-right intervention. For OR with 95%CI, a OR >1 favor the lower-right intervention. Statistically significant findings are shaded.; Abbreviations: CCD, coracoclavicular distance; CI, confidence interval; CMS, Constant–Murley Score; EB, EndoButton; HP, hook plates; MD, mean difference; OR, odd ratio; SA, suture anchors; TG, tendon grafts; TR, Tight-Rope; VAS, visual analog scale.

procedures including HP, TR, TG, EB, and SA in the surgical treatment of ACJ; this information can be used to help surgeons choosing the optimal surgical procedure for their actual situations. The key findings of this systematic review and NMA here show that: (1) HP have a worse effect on the CMS improvement than TR, EB, and SA; (2) TR shows better pain relief than HP; (3) all of them have a significant effect in the CCD reduction with no significant difference between each other; (4) HP has a higher incidence of complications than TR, meanwhile no significant difference is observed among the others; (5) the SA has the best clinical efficacy with the lowest complication rate according to our primary outcomes.

Ligament Reconstruction for ACJ Dislocation

The CC ligament is one of the most important stabilizing structures of the ACJ.[5] CC fracture is a major factor in clavicle displacement; therefore, CC reconstruction is important for ACJ reduction and maintaining stability.[6] Since Rockwood's classification of ACJ is based on the degree and direction of clavicle displacement, reconstruction of the CC ligament is the most commonly applied clinical surgical strategy.[3,4] Although Bosworth screws have been reported in the literature in addition to the five surgical procedures included in this study, after a careful review of the literature we found that few studies met the criteria and no valid data were available.[55–57] Notably, in addition to CC reconstruction, AC reconstruction (tension band wires, Kirschner wires, or sutures),[8,58] AC and CC reconstruction (Weaver–Dunn procedures)[59] are also options for surgical treatment. However, the literature on AC reconstruction is scarce and valid data are not available. And Weaver–Dunn procedures were used to treat chronic ACJ dislocation.[60] Therefore, our study only includes TR, HP, EB, SA, and TG of CC reconstruction.

Results of Clinical Outcome

Regarding the clinical outcome measurements, the CMS is an effective indicator to evaluate the patient's functional recovery. Previous studies have proved that all of them have a significant improvement in CMS, indicating that all techniques could have sufficient functional recovery.[61–63] Although there is no difference in direct comparisons of SA and HP, the results of NMA are more plausible considering that there are only two studies for direct comparisons. Our results here show that the functional recovery of HP is worse than TR, EB, and SA. This is consistent with the results of the published literature head-to-head meta-analyses. Pan et al.[13] and Qi et al.[14] both reported that TR showed an advantage over HP in terms of improving the function of ACJ. Arirachakaran et al.[64] performed a meta-analysis and concluded that SA showed better effects in shoulder

TABLE 6 Results of the pairwise and network meta-analysis of complications (OR, 95% CI)

SA	0.53 (0.17, 1.70)	0.51 (0.12, 2.14)	0.82 (0.28, 2.43)	0.43 (0.16, 1.14)
N = 1, 0.37 (0.01, 10.18)	**EB**	0.96 (0.31, 2.99)	1.55 (0.70, 3.45)	0.81 (0.40, 1.62)
	N = 1, 0.76 (0.18, 3.22)	**TG**	1.62 (0.53, 4.98)	0.84 (0.29, 2.46)
N = 1, 0.28 (0.01, 7.62)	**N = 2, 4.92 (1.39, 17.44)**	N = 1, 1.11 (0.16, 7.51)	**TR**	**0.52 (0.31, 0.88)**
N = 3, 0.52 (0.24, 1.14)	**N = 4, 0.58 (0.38, 0.88)**	N = 2, 0.83 (0.23, 3.00)	**N = 12, 0.56 (0.30, 1.00)**	**HP**

Note: Upper-right triangle shows the results of the network meta-analysis. Lower-left triangle shows the results of the pairwise meta-analyses. The N represents the numbers of studies which compared the two interventions directly. For MD with 95%CI, a negative MD favor the lower-right intervention. For OR with 95%CI, a OR >1 favor the lower-right intervention. Statistically significant findings are shaded.; Abbreviations: CCD, coracoclavicular distance; CI, confidence interval; CMS, Constant–Murley Score; EB, EndoButton; HP, hook plates; MD, mean difference; OR, odd ratio; SA, suture anchors; TG, tendon grafts; TR, Tight-Rope; VAS, visual analog scale.

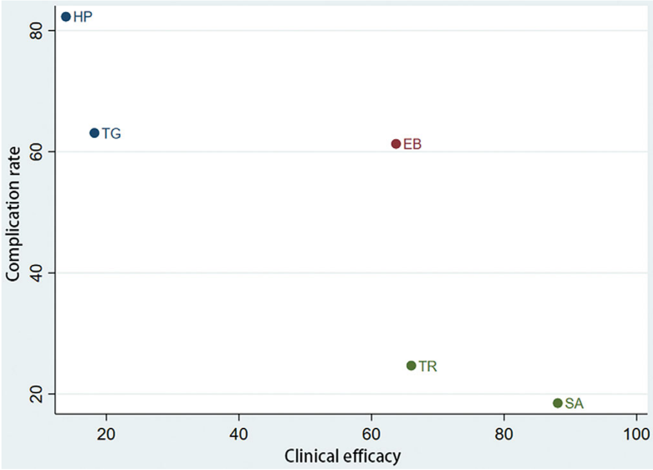

FIGURE 6 Ranking of the surgical procedures according to primary outcomes: clinical efficacy and complication rate. X axis represents clinical efficacy that close to 100% means better clinical efficacy. Y axis represents complication rate that close to 100% means higher incidence of complication.

functional recovery than HP. Wang et al.[15] proved that EB resulted in better functional outcomes than HP. Our study subdivides the surgical procedures of CC reconstruction and ranks them systematically via our NMA.

Efficacy in Relieving Pain

As for the postoperative shoulder pain, our results show that TR had a slightly lower VAS than HP. This conclusion has already been proved by previous head-to-head meta-analyses.[13,14] It may be due to more soft tissue destruction during HP surgery, as well as a postoperative high-stress concentration between the hook and the acromion.[65] All of the mean VAS reported in the included literature are below 2. Therefore, these differences in pain relief outcomes are not very significant. Nevertheless, the subtle ranking among them is still distinguished via our comprehensive analysis.

Results of Postoperative Reduction

The CCD is the main imaging indicator for postoperative confirmation of reduction. Though the direct comparison of TG and TR shows that TR had a better CCD than TG, the results of MNA are more plausible for only one direct comparison was available. Our results show that there is no difference in the effect of these five surgical procedures on repositioning, which is also consistent with previous pairwise meta-analyses.[13–15,64] Maintaining anatomic reduction does not appear to be a prerequisite for regaining proper shoulder function, and a small increase in CCD does not appear to affect overall outcomes.[66] Interestingly, even elongated reconstructed ligaments can improve clavicular stability enough to relieve symptoms and improve shoulder function.[53,66,67] Thus, complete anatomic healing may be important only for cosmetic outcomes. Overreduction, on the other hand, maybe the cause of brachial plexus compression and should not be the first goal of surgery.[68]

Incidence of Complications

The risk of surgery-related complications is considered to be an important disadvantage of all surgical procedures. Our pooled data suggest that HP has a higher rate of complications than TR. This conclusion is consistent with the findings of previous pairwise meta-analyses.[13–15,64] Compared to previous studies, our study here further ranks the five surgical procedures and indicates that SA had the lowest complication rate while HP had the highest complication rate. Our systematic review data (Table 7) indicate that the high loss

TABLE 7 Number and percentage of complications among the five different fixation systems [No. (%)]

Complication	HP (N = 710)	TR (N = 384)	TG (N = 80)	EB (N = 310)	SA (N = 115)
Loss of reduction	77(10.85%)	16(4.17%)	6(7.5%)	68(21.94%)	11(9.57%)
Impaired wound healing	9(1.27%)	5(1.30%)	—	—	1(0.87%)
Impingement syndrome	9(1.27%)	—	—	—	—
Plate/screw breakage or loosening	21(2.96%)	7(1.82%)	7(8.75%)	7(2.26%)	—
Neural injury	1(0.14%)	—	1(1.25%)	—	—
Bone fracture	6(0.85%)	2(0.52%)	3(3.75%)	7(2.26%)	—
Deep infection	1(0.14%)	1(0.26%)	—	1(0.32%)	—
Erosion of the acromion	36(5.07%)	1(0.26%)	—	—	—
Internal fixation reaction	1(0.14%)	2(0.52%)	8(10%)	1(0.32%)	—
Osteolysis of distal clavicle	—	—	—	—	1(0.87%)
AC joint osteoarthritis	19(2.68%)	17(4.43%)	2(2.5%)	1(0.32%)	2(1.74%)
Stiffness	44(6.2%)	4(1.04%)	—	—	—
Ligament ossification	21(2.96%)	2(0.52%)	3(3.75%)	22(7.1%)	—
Skin numbness	2(0.28%)	—	—	1(0.32%)	—
Muscle tear and fraying	—	—	—	3(0.97%)	—
Total	34.79%	14.84%	37.50%	35.81%	13.04%

TABLE 8 The result of inconsistency analysis

	CMS		VAS		CCD		Complications	
Local Inconsistency	Comparison	*p* value	Comparison	*p* value	Comparison	*p* value	Comparison	*p* value
	HP versus TR	0.86	HP versus TR	0.59	HP versus TR	0.71	HP versus TR	0.39
	HP versus TG	0.80	HP versus TG	NA	HP versus TG	NA	HP versus TG	0.98
	HP versus EB	0.91	HP versus EB	0.66	HP versus EB	0.38	HP versus EB	0.20
	HP versus SA	0.72	HP versus SA	0.26	HP versus SA	0.60	HP versus SA	0.53
	TR versus TG	0.80	TR versus TG	0.99	TR versus TG	NA	TR versus TG	0.70
	TR versus EB	0.96	TR versus EB	0.58	TR versus EB	0.38	TR versus EB	0.08
	TR versus SA	NA	TR versus SA	NA	TR versus SA	0.60	TR versus SA	0.52
	TG versus EB	NA	TG versus EB	NA	TG versus EB	NA	TG versus EB	0.75
	EB versus SA	0.72	EB versus SA	0.26	EB versus SA	NA	EB versus SA	0.83
Global inconsistency	Comparison	*p* value	Comparison	*p* value	Comparison	*p* value	Comparison	*p* value
	HP versus TR	0.001	HP versus TR	0.85	HP versus TR	0.001	HP versus TR	0.015
	HP versus TG	0.90	HP versus TG	0.30	HP versus TG	0.54	HP versus TG	0.75
	HP versus EB	0.01	HP versus EB	0.23	HP versus EB	0.09	HP versus EB	0.55
	HP versus SA	0.03	HP versus SA	0.76	HP versus SA	0.93	HP versus SA	0.09

of reduction rates should be paid more attention to the groups of EB (21.94%). It should also be noted that the HP group was related to a higher ratio of erosion of the acromion and stiffness. In general, our study is more comprehensive for synthesizing all existing evidence to provide simultaneous evidence and indicates that SA showed the best clinical efficacy with the lowest complication rate (Figure 6).

Limitation and Strengths

The strength of this study was the inclusion of a large number of articles. Including 31 articles and combining the results from 1102 patients allows for an adequate assessment of the five surgical procedures to compare the clinical efficacy, imaging findings, and safety. Meanwhile, a major limitation of this systematic review is that a small proportion of the included studies are RCTs. Moreover, the complications such as the loss of reduction are not uniformly reported across all studies. Nevertheless, given the high quality of the included studies, the results of our comparison are sufficiently convincing.

Conclusion

In conclusion, considering all the criteria evaluated, SA shows better clinical effectiveness and reliable safety in the treatment of acute ACJ dislocation. Although HP is the most widely used surgical option currently, it should be carefully considered for its high incidence of complications.

Author Contributions

Yuan Yan: data curation, formal analysis, writing—original draft preparation; Mingxin Liao: writing—reviewing, formal analysis; Huahao Lai: data curation, writing—original draft preparation; Ziyang Xu: data curation; Haobin Chen: data curation; Wenhan Huang: writing—reviewing; Hui Yu: writing—reviewing and editing, project administration; Yu Zhang: writing—reviewing, supervision, funding acquisition.

Acknowledgments

This study was supported by the National Key R&D Program of China (Grant No. 2021YFC24007004), research project outlay of Guangdong Provincial People's Hospital (2021YFC2400704) and Startup Fund for Scientific Research, Fujian Medical University (2019QH1221). No other relationships or activities appear to have influenced the submitted work.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Ethics Statement

Not applicable.

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

References

1. Willimon SC, Gaskill TR, Millett PJ. Acromioclavicular joint injuries: anatomy, diagnosis, and treatment. Phys Sportsmed. 2011;39:116–22. https://doi.org/10.3810/psm.2011.02.1869
2. Balcik BJ, Monseau AJ, Krantz W. Evaluation and treatment of sternoclavicular, clavicular, and acromioclavicular injuries. Prim Care. 2013;40:911–23, viii-ix. https://doi.org/10.1016/j.pop.2013.08.008
3. Lau ETC, Hong CC, Poh KS, Manohara R, Ng DZ, Lim JL, et al. A relook at the reliability of Rockwood classification for acromioclavicular joint injuries. J Shoulder Elbow Surg. 2021;30:2191–6. https://doi.org/10.1016/j.jse.2021.01.016
4. Gorbaty JD, Hsu JE, Gee AO. Classifications in brief: Rockwood classification of acromioclavicular joint separations. Clin Orthop Relat Res. 2017;475:283–7. https://doi.org/10.1007/s11999-016-5079-6
5. Monica J, Vredenburgh Z, Korsh J, Gatt C. Acute shoulder injuries in adults. Am Fam Physician. 2016;94:119–27.
6. Stucken C, Cohen SB. Management of acromioclavicular joint injuries. Orthop Clin North Am. 2015;46:57–66. https://doi.org/10.1016/j.ocl.2014.09.003
7. Cetinkaya E, Arıkan Y, Beng K, Mutlu H, Yalçınkaya M, Üzümcügil O. Bosworth and modified Phemister techniques revisited. A comparison of intraarticular vs extraarticular fixation methods in the treatment of acute Rockwood type III

acromioclavicular dislocations. Acta Orthop Traumatol Turc. 2017;51:455–8. https://doi.org/10.1016/j.aott.2017.09.002
8. Liu T, Bao FL, Jiang T, Ji GW, Li JM, Jerosch J. Acromioclavicular joint separation: repair through suture anchors for Coracoclavicular ligament and nonabsorbable suture fixation for acromioclavicular joint. Orthop Surg. 2020;12: 1362–71. https://doi.org/10.1111/os.12771
9. Hessmann M, Gotzen L, Gehling H. Acromioclavicular reconstruction augmented with polydioxanonsulphate bands. Surgical technique and results. Am J Sports Med. 1995;23:552–6. https://doi.org/10.1177/036354659502300506
10. Morrison DS, Lemos MJ, Acromioclavicular separation. Reconstruction using synthetic loop augmentation. Am J Sports Med. 1995;23:105–10. https://doi.org/10.1177/036354659502300118
11. Sim E, Schwarz N, Höcker K, Berzlanovich A. Repair of complete acromioclavicular separations using the acromioclavicular-hook plate. Clin Orthop Relat Res. 1995;134–42.
12. Breslow MJ, Jazrawi LM, Bernstein AD, Kummer FJ, Rokito AS. Treatment of acromioclavicular joint separation: suture or suture anchors? J Shoulder Elbow Surg. 2002;11:225–9. https://doi.org/10.1067/mse.2002.123904
13. Pan X, Lv RY, Lv MG, Zhang DG. TightRope vs clavicular hook plate for Rockwood III-V acromioclavicular dislocations: a meta-analysis. Orthop Surg. 2020;12:1045–52. https://doi.org/10.1111/os.12724
14. Qi W, Xu Y, Yan Z, Zhan J, Lin J, Pan X, et al. The tight-rope technique versus clavicular hook plate for treatment of acute acromioclavicular joint dislocation: a systematic review and meta-analysis. J Investig Surg. 2021;34:20–9. https://doi.org/10.1080/08941939.2019.1593558
15. Wang C, Meng JH, Zhang YW, Shi MM. Suture button versus hook plate for acute unstable acromioclavicular joint dislocation: a meta-analysis. Am J Sports Med. 2020;48:1023–30. https://doi.org/10.1177/0363546519858745
16. Arirachakaran A, Boonard M, Piyapittayanun P, Phiphobmongkol V, Chaijenkij K, Kongtharvonskul J. Comparison of surgical outcomes between fixation with hook plate and loop suspensory fixation for acute unstable acromioclavicular joint dislocation: a systematic review and meta-analysis. Eur J Orthop Surg Traumatol. 2016;26:565–74. https://doi.org/10.1007/s00590-016-1797-4
17. Jansen JP, Crawford B, Bergman G, Stam W. Bayesian meta-analysis of multiple treatment comparisons: an introduction to mixed treatment comparisons. Value Health. 2008;11:956–64. https://doi.org/10.1111/j.1524-4733.2008.00347.x
18. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928–8. https://doi.org/10.1136/bmj.d5928
19. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis of observational studies in epidemiology (MOOSE) group. Jama. 2000;283:2008–12. https://doi.org/10.1001/jama.283.15.2008
20. Jonas DE, Wilkins TM, Bangdiwala S, Bann CM, Morgan LC, Thaler KJ, et al. AHRQ methods for effective health care. Findings of Bayesian mixed treatment comparison meta-analyses: comparison and exploration using real-world trial data and simulation. Rockville (MD): Agency for Healthcare Research and Quality (US); 2013.
21. Brooks PS, Andrew G. General methods for monitoring convergence of iterative simulations. J Comput Graphical Stat. 1998;7:131–7.
22. Chaimani A, Higgins JP, Mavridis D, Spyridonos P, Salanti G. Graphical tools for network meta-analysis in STATA. PloS One. 2013;8:e76654. https://doi.org/10.1371/journal.pone.0076654
23. Dias S, Welton NJ, Caldwell DM, Ades AE. Checking consistency in mixed treatment comparison meta-analysis. Stat Med. 2010;29:932–44. https://doi.org/10.1002/sim.3767
24. Athar MS, Ashwood N, Arealis G, Hamlet M, Salt E. Acromioclavicular joint disruptions: a comparison of two surgical approaches 'hook' and 'rope'. J Orthop Surg (Hong Kong). 2018;26:2309499017749984. https://doi.org/10.1177/2309499017749984
25. Bin Abd Razak HR, Yeo EN, Yeo W, Lie TD. Short-term outcomes of arthroscopic TightRope(I) fixation are better than hook plate fixation in acute unstable acromioclavicular joint dislocations. Eur J Orthop Surg Traumatol. 2018; 28:869–75. https://doi.org/10.1007/s00590-017-2095-5
26. Cai L, Wang T, Lu D, Hu W, Hong J, Chen H. Comparison of the tight rope technique and clavicular hook plate for the treatment of Rockwood type III acromioclavicular joint dislocation. J Invest Surg. 2018;31:226–33. https://doi.org/10.1080/08941939.2017.1305022
27. Eschler A, Gradl G, Gierer P, Mittlmeier T, Beck M. Hook plate fixation for acromioclavicular joint separations restores coracoclavicular distance more accurately than PDS augmentation, however presents with a high rate of acromial osteolysis. Arch Orthop Trauma Surg. 2012;132:33–9. https://doi.org/10.1007/s00402-011-1399-x
28. Fosser M, Camporese A. Operative treatment of acute acromioclavicular joint dislocations graded Rockwood III–V: a retrospective and comparative study between three different surgical techniques. Acta Biomed. 2021;92:e2021325. https://doi.org/10.23750/abm.v92i5.10678
29. Gao YS, Zhang YL, Ai ZS, Sun YQ, Zhang CQ, Zhang W. Transarticular fixation by hook plate versus coracoclavicular stabilization by single multistrand titanium cable for acute Rockwood grade-V acromioclavicular joint dislocation: a case-control study. BMC Musculoskelet Disord. 2015;16:360. https://doi.org/10.1186/s12891-015-0820-y
30. Gultac E, Can FI, Kilinc CY, Aydogmus H, Topsakal FE, Acan AE, et al. Comparison of the radiological and functional results of tight rope and clavicular hook plate technique in the treatment of acute acromioclavicular joint dislocation. J Invest Surg. 2022;35:693–6. https://doi.org/10.1080/08941939.2021.1897196
31. Huang YC, Yang SW, Chen CY, Lin KC, Renn JH. Single coracoclavicular suture fixation with Mersilene tape versus hook plate in the treatment of acute type V acromioclavicular dislocation: a retrospective analysis. J Orthop Surg Res. 2018;13:110. https://doi.org/10.1186/s13018-018-0831-0
32. Jensen G, Katthagen JC, Alvarado LE, Lill H, Voigt C. Has the arthroscopically assisted reduction of acute AC joint separations with the double tight-rope technique advantages over the clavicular hook plate fixation? Knee Surg Sports Traumatol Arthrosc. 2014;22:422–30. https://doi.org/10.1007/s00167-012-2270-5
33. Lazarski A, Sarzynska S, Struzik S, Jedral T, Legosz P, Maldyk P. Results of treatment of type 3 acromioclavicular joint dislocation with three methods. Ortop Traumatol Rehabil. 2019;21:167–79. https://doi.org/10.5604/01.3001.0013.2921
34. Liu S, Li C, Song Z, Bai X, Wu H. Comparison of open reduction and fixation with hook plate and modified closed reduction and fixation with tightrope loop plate for treatment of Rockwood type III acromioclavicular joint dislocation. BMC Musculoskelet Disord. 2022;23:301. https://doi.org/10.1186/s12891-022-05261-5
35. Liu Y, Zhang X, Yu Y, Ding W, Gao Y, Wang Y, et al. Suture augmentation of acromioclavicular and coracoclavicular ligament reconstruction for acute acromioclavicular dislocation. Medicine (Baltimore). 2021;100:e27007. https://doi.org/10.1097/MD.0000000000027007
36. Madi S, Pandey V, Murali S, Acharya K. Clinical and radiological outcome of acute high-grade acromioclavicular joint dislocation: a retrospective cohort study on hook plate versus arthroscopic assisted single coracoclavicular tunnel with DogBone button dual FiberTl(R) construct. J Clin Orthop Trauma. 2022;27: 101825. https://doi.org/10.1016/j.jcot.2022.101825
37. Martetschlager F, Horan MP, Warth RJ, Millett PJ. Complications after anatomic fixation and reconstruction of the coracoclavicular ligaments. Am J Sports Med. 2013;41:2896–903. https://doi.org/10.1177/0363546513502459
38. Nascimento AT, Claudio GK. Functional and radiological evaluation of acute acromioclavicular dislocation treated with anchors without eyelet: comparison with other techniques. Rev Bras Ortop. 2016;51:561–8. https://doi.org/10.1016/j.rboe.2016.08.015
39. Natera-Cisneros L, Sarasquete-Reiriz J, Escola-Benet A, Rodriguez-Miralles J. Acute high-grade acromioclavicular joint injuries treatment: arthroscopic non-rigid coracoclavicular fixation provides better quality of life outcomes than hook plate ORIF. Orthop Traumatol Surg Res. 2016;102:31–9. https://doi.org/10.1016/j.otsr.2015.10.007
40. Nie S, Lan M. Comparison of clinical efficacy between arthroscopically assisted tight-rope technique and clavicular hook plate fixation in treating acute high-grade acromioclavicular joint separations. J Orthop Surg (Hong Kong). 2021; 29:23094990211010562. https://doi.org/10.1177/23094990211010562
41. Shen G, Sun S, Tang C, Xie Y, Li L, Xu W, et al. Comparison of the TightRope system versus hook plate in acute acromioclavicular joint dislocations: a retrospective analysis. Sci Rep. 2021;11:11397. https://doi.org/10.1038/s41598-021-90989-8
42. Stein T, Muller D, Blank M, Reinig Y, Saier T, Hoffmann R, et al. Stabilization of acute high-grade acromioclavicular joint separation: a prospective assessment of the clavicular hook plate versus the double double-button suture procedure. Am J Sports Med. 2018;46:2725–34. https://doi.org/10.1177/0363546518788355
43. Taleb H, Afshar A, Shariyate MJ, Tabrizi A. Comparison of short-term clinical outcomes of hook plate and continuous loop double Endobutton fixations in acute acromioclavicular joint dislocation. Arch Bone Joint Surg. 2019;7:545–50.
44. Topal M, Kose A. Surgical management of Rockwood type 3 acromioclavicular joint injuries: a retrospective comparison of outcomes of suture anchor fixation and double-button fixation techniques. Medicine (Baltimore). 2020;99:e20312. https://doi.org/10.1097/MD.0000000000020312
45. Unal OK, Dagtas MZ. Comparison of the results of hook plate and Endo-button used in the surgical treatment of acromioclavicular joint separation. Cureus. 2020;12:e11987. https://doi.org/10.7759/cureus.11987
46. Vulliet P, Le Hanneur M, Cladiere V, Loriaut P, Boyer P. A comparison between two double-button endoscopically assisted surgical techniques for the treatment acute acromioclavicular dislocations. Musculoskelet Surg. 2018;102: 73–9. https://doi.org/10.1007/s12306-017-0501-0
47. Wang G, Xie R, Mao T, Xing S. Treatment of AC dislocation by reconstructing CC and AC ligaments with allogenic tendons compared with hook plates. J Orthop Surg Res. 2018;13:175. https://doi.org/10.1186/s13018-018-0879-x

48. Wang YC, Yong MA, Wei-zhong YU, Wang H. Surgical treatment of acute Rockwood III acromioclavicular dislocations-comparative study between two flip-button techniques. Sci Rep. 2020;10:4447. https://doi.org/10.1038/s41598-020-61488-z
49. Yoo YS, Khil EK, Im W, Jeong JY. Comparison of hook plate fixation versus arthroscopic Coracoclavicular fixation using multiple soft anchor knots for the treatment of acute high-grade acromioclavicular joint dislocations. Art Ther. 2021;37:1414–23. https://doi.org/10.1016/j.arthro.2020.12.189
50. Yoon JP, Lee BJ, Nam SJ, Chung SW, Jeong WJ, Min WK, et al. Comparison of results between hook plate fixation and ligament reconstruction for acute unstable acromioclavicular joint dislocation. Clin Orthop Surg. 2015;7:97–103. https://doi.org/10.4055/cios.2015.7.1.97
51. Yu P, Zhang Y, Ye T, Liu J, Zhuang C, Wang L. Clinical and radiological outcomes of acute Rookwood type IIIB acromioclavicular joint dislocation: mini-open tightrope technique versus hook plate. Injury. 2023;54:S63–9. https://doi.org/10.1016/j.injury.2022.02.019
52. Zhang S, Zhang H, Wang J, Ma X, Gu S. Triple-Endobutton and clavicular hook: a propensity score matching analysis. Open Med (Wars). 2021;16:1328–35. https://doi.org/10.1515/med-2021-0339
53. Vascellari A, Schiavetti S, Battistella G, Rebuzzi E, Coletti N. Clinical and radiological results after coracoclavicular ligament reconstruction for type III acromioclavicular joint dislocation using three different techniques. A retrospective study. Joints. 2015;3:54–61. https://doi.org/10.11138/jts/2015.3.2.054
54. Zhang J, Ying Z, Wang Y. Surgery for acromioclavicular dislocation: factors affecting functional recovery. Am Surg. 2017;83:1427–32. https://doi.org/10.1177/000313481708301231
55. Tavakoli Darestani R, Ghaffari A, Hosseinpour M. Acromioclavicular joint fixation using an acroplate combined with a coracoclavicular screw. Arch Trauma Res. 2013;2:36–9. https://doi.org/10.5812/atr.10338
56. Zheng J, Chen J, Chen L, Ni Y, Lin Z. A novel hybrid fixation (coracoclavicular screw supplemented with K-wire) for the treatment of acute acromioclavicular joint dislocation: a prospective study. Int J Surg. 2018;59:61–6. https://doi.org/10.1016/j.ijsu.2018.09.019
57. Chen YT, Wu KT, Jhan SW, Hsu SL, Liu HC, Wang CJ, et al. Is coracoclavicular reconstruction necessary in hook plate fixation for acute unstable acromioclavicular dislocation? BMC Musculoskelet Disord. 2021;22:127. https://doi.org/10.1186/s12891-021-03978-3
58. Biz C, Berizzi A, Cappellari A, Crimì A, Tamburin S, Iacobellis C. The treatment of acute Rockwood type III acromio-clavicular joint dislocations by two different surgical techniques. Acta Bio-Med: Atenei Parmensis. 2015;86:251–9.
59. Costic RS, Labriola JE, Rodosky MW, Debski RE. Biomechanical rationale for development of anatomical reconstructions of coracoclavicular ligaments after complete acromioclavicular joint dislocations. Am J Sports Med. 2004;32:1929–36. https://doi.org/10.1177/0363546504264637
60. Chang HM, Wang CH, Hsu KL, Kuan FC, Chen Y, Su WR, et al. Does weaver-Dunn procedure have a role in chronic acromioclavicular dislocations? A meta-analysis. J Orthop Surg Res. 2022;17:95. https://doi.org/10.1186/s13018-022-02995-9
61. Nolte PC, Lacheta L, Dekker TJ, Elrick BP, Millett PJ. Optimal Management of Acromioclavicular Dislocation: current perspectives. Orthop Res Rev. 2020;12:27–44. https://doi.org/10.2147/orr.S218991
62. Bontempo NA, Mazzocca AD. Biomechanics and treatment of acromioclavicular and sternoclavicular joint injuries. Br J Sports Med. 2010;44:361–9. https://doi.org/10.1136/bjsm.2009.059295
63. Cisneros LN, Reiriz JS. Management of acute unstable acromioclavicular joint injuries. Eur J Orthop Surg Traumatol. 2016;26:817–30. https://doi.org/10.1007/s00590-016-1836-1
64. Arirachakaran A, Boonard M, Piyapittayanun P, Kanchanatawan W, Chaijenkij K, Prommahachai A, et al. Post-operative outcomes and complications of suspensory loop fixation device versus hook plate in acute unstable acromioclavicular joint dislocation: a systematic review and meta-analysis. J Orthop Traumatol. 2017;18:293–304. https://doi.org/10.1007/s10195-017-0451-1
65. Struhl S, Wolfson TS. Continuous loop double Endobutton reconstruction for acromioclavicular joint dislocation. Am J Sports Med. 2015;43:2437–44. https://doi.org/10.1177/0363546515596409
66. Boström Windhamre HA, von Heideken JP, Une-Larsson VE, Ekelund AL. Surgical treatment of chronic acromioclavicular dislocations: a comparative study of weaver-Dunn augmented with PDS-braid or hook plate. J Shoulder Elbow Surg. 2010;19:1040–8. https://doi.org/10.1016/j.jse.2010.02.006
67. Frank RM, Cotter EJ, Leroux TS, Romeo AA. Acromioclavicular joint injuries: evidence-based treatment. J Am Acad Orthop Surg. 2019;27:e775–88. https://doi.org/10.5435/jaaos-d-17-00105
68. Beitzel K, Cote MP, Apostolakos J, Solovyova O, Judson CH, Ziegler CG, et al. Current concepts in the treatment of acromioclavicular joint dislocations. Arthrosc: J Arthrosc Relat Surg. 2013;29:387–97. https://doi.org/10.1016/j.arthro.2012.11.023