REVIEW ARTICLE

# TightRope *vs* Clavicular Hook Plate for Rockwood III–V Acromioclavicular Dislocations: A Meta-Analysis

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**Objective:** To assess and compare the clinical outcomes and complications of TightRope® fixation *vs* hook plate fixation for the treatment of Rockwood III-VI Acromioclavicular joint (ACJ) dislocations.

**Methods:** Relevant studies were identified by searching PubMed, Embase, and Web of Science databases, from their inception to 12 April, 2019. The main outcomes of interest included Constant Score, University of California Los Angeles (UCLA) Shoulder Score, Visual Analogue Scale (VAS), coracoclavicular distance (CCD), and complications. Weight mean difference (WMD) with 95% confidence intervals (95% CIs) or risk ratio (RR) with 95% CIs was used to calculate the data.

**Results:** Four studies with a total of 179 patients were included in this study. Compared with hook plate, TightRope® fixation was associated with a significantly less VAS score for pain (WMD = -0.69, 95% CI: −1.10, −0.27; $P = 0.001$). However, there were no significant differences between the two surgical techniques in terms of Constant Score (WMD = 6.12, 95% CI: −3.84, 16.08; $P = 0.229$), UCLA (WMD = 7.96, 95% CI: −5.76, 21.68; $P = 0.256$), CCD (WMD = 0.24, 95% CI: −0.67, 1.15; $P = 0.602$), and complication rate.

**Conclusion:** Both TightRope® and hook plate techniques offered effective outcomes in relieving the pain of dislocation and improving function of ACJ. However, TightRope® fixation showed an advantage over hook plate in terms of postoperative pain. Further larger-scale RCTs are needed to verify our findings.

**Key words:** Acromioclavicular dislocations; Hook plate fixation; Meta-analysis; TightRope® fixation

## Introduction

Acromioclavicular joint (ACJ) dislocation is one of the most common shoulder problems accounting for 50% of all sports-related shoulder injuries[1,2].They often occur in athletic, young patients after blunt force to the shoulder[3]. ACJ injuries are classified by Rockwood classification system into types I-VI based on the radiographic criteria[4]. Treatment of ACJ dislocation is commonly guided by Rockwood's classification[5]. According to the guideline, conservative treatment is usually recommended for type I and II graded lesion, and surgical treatment is advised for IV-VI injuries. However, for type III injuries, the therapeutic schedule still remains controversial[6,7]. Some authors advocate conservative treatments for this type of injury, while some others have reported good clinical outcomes using the operative procedures[7–9].

There are a variety of surgical procedures that are used for ACJ dislocation, including coracoclavicular (CC) fixation, coracoacromial ligament transfer, hook plate, TightRope® fixation, AC or CC reconstruction[10–12]. But none of these techniques can be used as the gold standard for operative ACJ stabilization.

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Received 3 December 2019; accepted 14 May 2020

**Orthopaedic Surgery** 2020;12:1045–1052 • DOI: 10.1111/os.12724

Two commonly used surgical techniques – TightRope® fixation (supplementary file) and hook plate – have been reported of good clinical and radiological outcomes in the management of ACJ dislocations[13,14]. The TightRope® technique is a minimally invasive method used to stabilize the ACJ and augment the CC complex with a high-strength suture[15,16]. The clavicular hook plate method is an open procedure, in which the plate is fixed with screws on the upper surface of the clavicle and the hook is fixed transarticularly at the lower surface of the acromion[17]. This approach could improve the natural healing of ligaments when being used for ACJ dislocations[17].

Currently, there have been several trials that compared the functional and radiological results between TightRope® and hook plate in patients with type III-VI ACJ dislocations. However, there has been no consensus as to which surgical technique is more suitable. Therefore, we conducted this meta-analysis to assess and compare the clinical outcomes of TightRope® fixation *vs* hook plate fixation for the treatment of Rockwood III-VI ACJ dislocations.

## Materials and Methods

Ethical approval and patient consent are not required in this study, because this meta-analysis is performed based on the previously published studies. We carried out this meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and meta-analysis (PRISMA) criteria[18].

### *Search Strategy*

A comprehensive literature search for articles published between the inception to 12 April 2019 was performed using PubMed, Embase, and Web of Science. The following combination of keywords and MeSH terms were used: ((“acromioclavicular joint” [MeSH Terms] OR (“acromioclavicular” [All Fields] AND “joint” [All Fields]) OR “acromioclavicular joint” [All Fields]) AND (“joint dislocations” [MeSH Terms] OR (“joint” [All Fields] AND “dislocations” [All Fields]) OR “joint dislocations” [All Fields] OR “dislocation”[All Fields])) AND TightRope®[All Fields] AND ((“clavicle” [MeSH Terms] OR “clavicle” [All Fields] OR “clavicular” [All Fields]) AND hook [All Fields] AND (“bone plates” [MeSH Terms] OR (“bone” [All Fields] AND “plates” [All Fields]) OR “bone plates” [All Fields] OR “plate” [All Fields])). In addition, a manual search of references listed in included studies and published reviews were conducted to search for potentially eligible studies.

### *Study Selection*

Studies that met the following inclusion criteria were considered: (i) Patient: adult patients were diagnosed with ACJ dislocations (Rockwood III-IV); (ii) Intervention: surgical fixation with TightRope®; (iii) Comparison: clavicular hook plate; (iv) Outcome: Constant Score, the University of California Los Angeles (UCLA) Shoulder Score, Visual Analogue Scale (VAS), coracoclavicular distance (CCD), and complications; (v) Study design: randomized controlled trial (RCT), case–control study, or cohort study. We excluded studies with the following properties: patients diagnosed with ACJ dislocations (Rockwood I–II); surgical fixation methods were not TightRope® or clavicular hook plate; studies did not provide outcomes of our interest; studies that were case reports, reviews, letters, or non-comparative observational articles. We would also contact the corresponding authors for original data when important information was not provided in the study.

### *Data Extraction*

Two independent investigators performed the data extraction using a standardized Excel file. The following data were extracted from the included studies: first author’s name, year of publication, study design, sample size in each group, patient characteristics, duration of follow-up, and the outcome measures. Any disagreement between the investigators was resolved by discussion and consensus. When several studies that were from the same population or clinical trial were published, we only included the study with longest duration of follow-up, or with the most complete information.

### *Outcome Measures*

#### *Constant Score*

Constant score is one of the most frequently used scoring systems for assessing shoulder outcomes worldwide[19,20]. The Constant score comprised items related to pain (15 points), activities of daily living (20 points), range of motion (40 points), and muscle strength (25 points), amounting to a full score of 100[19,20]. Constant scores of ≥90, ≥80, ≥70, and <70 are regarded as excellent, good, fair, and poor, respectively[19,20].

#### *The University of California Los Angeles Shoulder Score*

The UCLA shoulder score is widely used for the evaluation of functional and quality of life outcome after arthroscopic rotator cuff repair with good reliability and validity[21]. This method assigns a score to patients based on five separate domains: pain (10 points), function (10 points), active forward flexion (5 points), strength of forward flexion (5 points), and overall satisfaction (5 points), with a total score of 35 points[22]. A higher score indicates increased shoulder function[22].

#### *Visual Analogue Scale*

VAS has been in use for the measurement of intangible quantities such as pain, quality of life, and anxiety[23]. It consists of a line usually 100 mm in length, with anchor descriptors such as (in the pain context) “no pain” and “worst pain imaginable”[23]. A higher score indicates a higher level of pain[23].

#### *Coracoclavicular Distance*

The CCD is defined as height in the contralateral shoulder between the upper border of coracoid process and the inferior cortex of the clavicle[24]. Increase in CCD by 50%–100% and higher than 100% with respect to the contralateral side was considered as subluxation and redislocation, respectively[24].

### *Quality Assessment*

The assessment of risk of bias in each RCT was conducted using the method recommended by Cochrane Collaboration[25]. In accordance with the quality domains and scoring system, each RCT was classified as being "high" (seriously weakens confidence in results), "low" (unlikely to seriously alter the results), or "unclear" risk of bias[25].

The quality of non-RCT was assessed using modified Newcastle-Ottawa Scale (NOS)[26]. This method evaluated the study quality based on three items, including selection, comparability, and exposure (case–control study) or outcome (cohort study). The total scale of this method was 9 points, and a score of 8–9 points indicated high quality, 6–7 points being moderate quality, and ≤ 5 points being low quality[26].

### *Statistical Analysis*

Meta-analysis was performed using STATA version 12.0 (Stata Corporation, College Station, TX, USA). Continuous variables were presented as weight mean difference (WMD) with 95% confidence intervals (CIs); while dichotomous variables were pooled as risk ratio (RR) with 95% CIs. Heterogeneity across studies was evaluated by Cochrane Q and $I^2$ statistic[27]. The $P$ value less than 0.1 or $I^2$ exceeded 50% indicated significant heterogeneity[27]. Pooled results were calculated with a fixed-effect model[28] when there was no evidence of heterogeneity, or a random-effects model[29] when significant heterogeneity was identified. For clinical heterogeneity, we performed sensitivity analysis by removing one trial at a time to explore the potential sources of heterogeneity. Since the number of included studies was less than 10, assessment of publication bias was not performed. A $P$ value less than 0.05 was judged as statistically significant except where a certain $P$-value had been given.

## Results

### *Study Selection*

The initial search yielded 482 studies, of which 316 were excluded because of duplicate records. After screening by title/abstracts, 157 were excluded because of the following reasons: reviews, editors, letters, or case reports, leaving nine studies for full-text review. Among these studies, five were excluded because three studies[30–32] compared TightRope® with other techniques and two studies[33, 34] were single-arm study design. Finally, four studies[35–38] were included in this meta-analysis for data analysis. A flow diagram of the study selection process is presented in Fig. 1.

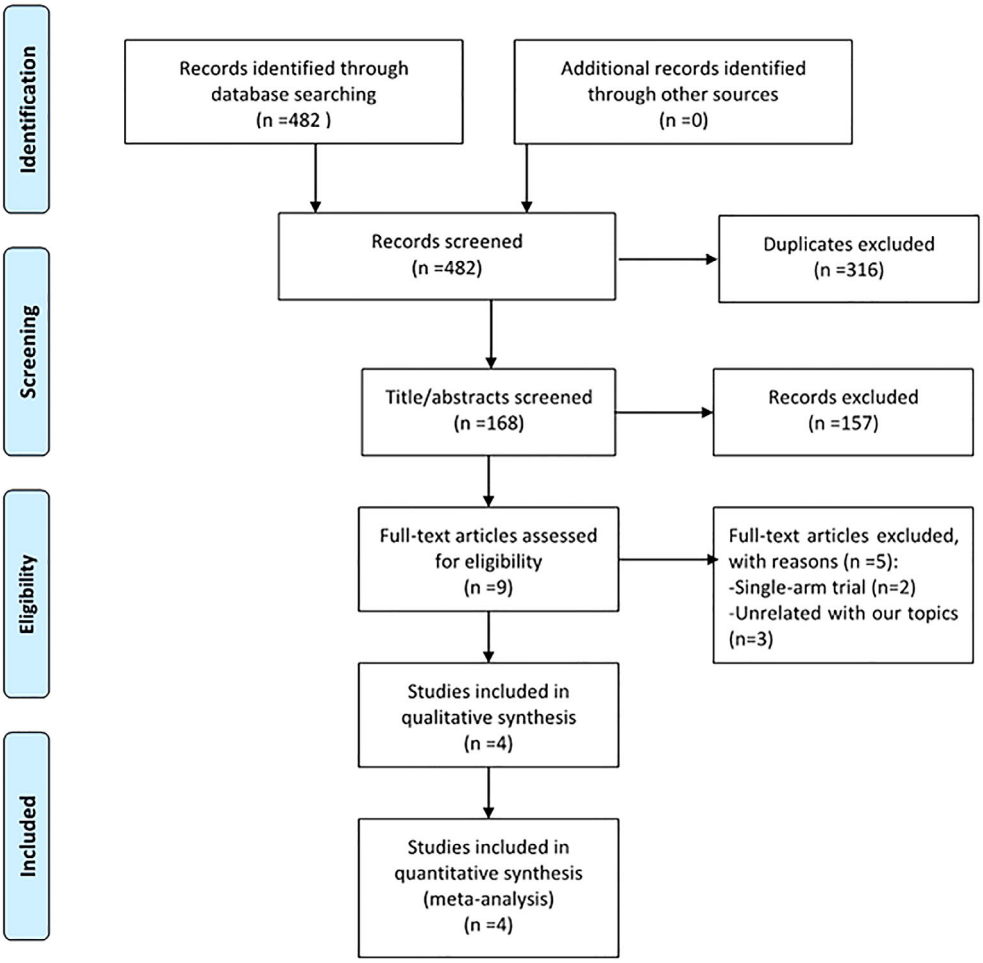


**Fig. 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart displaying the search and selection process performed.

### *Study Characteristics*

The baseline characteristics of included studies are presented in Table 1. These studies were published between 2014 and 2018. Two of the studies were prospective/retrospective case–control studies[35,36], one was a prospective cohort[38], and one was an RCT[37]. All the patients were diagnosed with Rockwood type III-VI ACJ dislocations, and patients in two studies[37,38] were type III injury. The mean age and percentages of male gender varied from 18 years to 68 years, and 63.33% to 93.75%, respectively. The mean duration of follow-up in these studies ranged from 12 to 48 months. TightRope® fixation was carried out in these studies, but only one study [38] reported that it was performed with double technique and the other three [35–37] did not. In the hook plate group, two studies[35,38] reported the time of plate removal, which were within 3 and 6 months of the initial surgery, respectively. Whereas, in the TightRope® group, no implant removal was implemented. Three of the included studies[35, 36, 38] performed the TightRope® with arthroscopic-assisted techniques.

The quality assessment of three non-RCTs showed that, the NOS scores were greater than 6, which indicated that they were of moderate or high quality. The risk of bias for the only RCT showed that it was classified as being at high risk bias. The reason for this was that it was difficult to perform the blinding for the surgeon or outcome assessors.

### *Constant Score*

Data on Constant Score was available in all of the included studies[35–38]. Significant heterogeneity was found among these studies ($I^2$ = 93.0%, $P$ < 0.001). Thus, a random-effect model was used to pool the data. The results showed that TightRope® had similar effect with hook plate in Constant Score (WMD = 6.12, 95% CI: −3.84, 16.08; $P$ = 0.229) (Fig. 2). We

**TABLE 1 Baseline characteristics of patients in the trials included in the meta-analysis**

| Study | Country | Study design | Treatment regimen | No. of patients | No. of patients with III/IV/V/VI grade | Male/female | Age (mean ± SD, y) | Duration of follow-up (m) |
|---|---|---|---|---|---|---|---|---|
| Bin Abd Razak35 | Singapore | Case-control | Arthroscopic TR | 16 | NR | 15/1 | 41.4 ± 12.3 | 23 (14–35) |
| | | | Hook plate | 10 | NR | 9/1 | 49.2 ± 16.9 | 23 (14–35) |
| Andreani36 | Italy | Case-control | TR | 19 | NR | NR | 32.3 (19–60) | 24 (48–60) |
| | | | Hook plate | 9 | NR | NR | 32.3 (19–60) | 24 (48–60) |
| Cai37 | China | RCT | TR | 30 | 30/0/0 | 19/11 | 42.8 ± 11.88 | 12 |
| | | | Hook plate | 39 | 39/0/0 | 26/13 | 41.79 ± 10.21 | 12 |
| Jensen38 | Germany | Cohort | Double TR | 26 | 26/0/0 | 23/3 | 39 (18–54) | 17 (7–29) |
| | | | Hook plate | 30 | 30/0/0 | 28/2 | 39 (18–68) | 48 (7–77) |

SD, standard deviation; RCT, randomized controlled trial; NR, not reported; TR, TightRop.

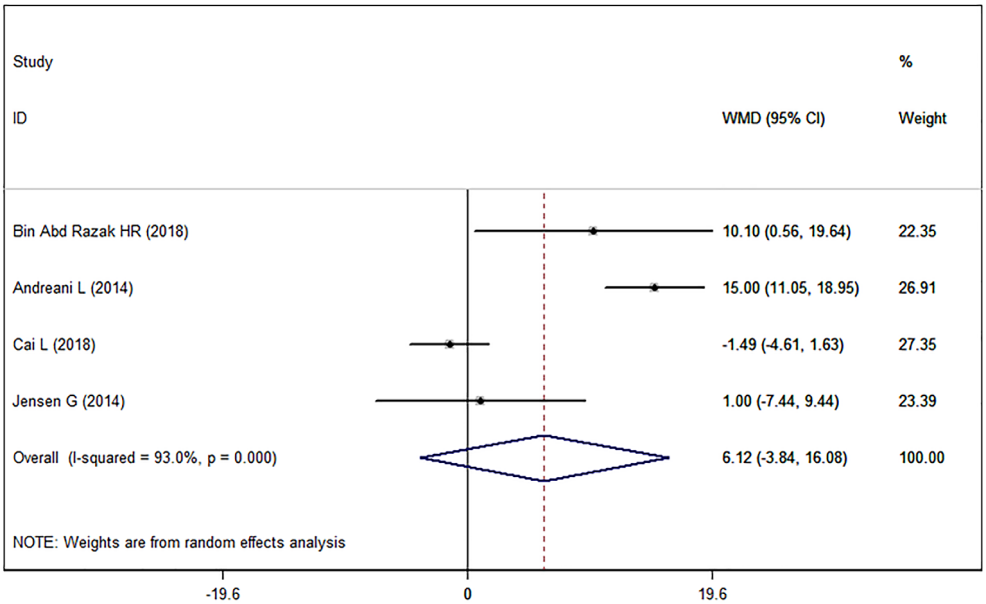


**Fig. 2** Forest plot showing the comparison between TightRope® and hook plate in Constant Score.

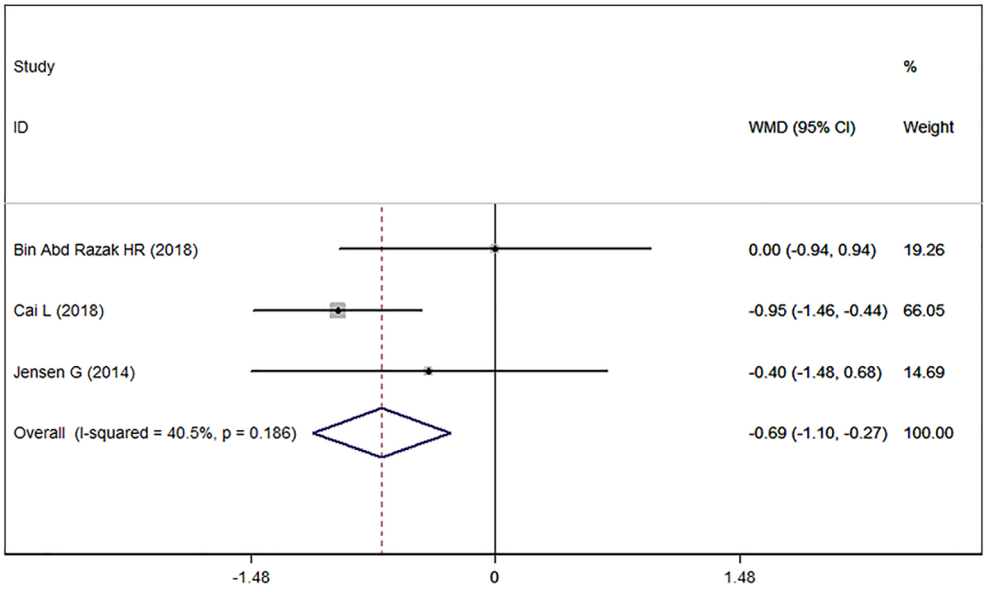


**Fig. 3** Forest plot showing the comparison between TightRope® and hook plate in VAS score.

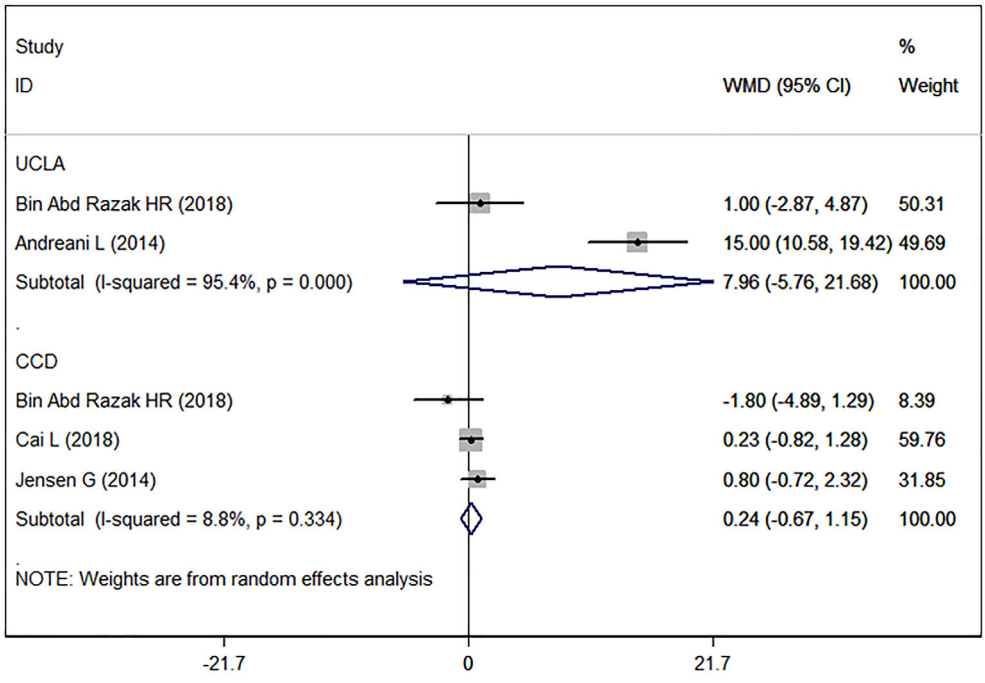


**Fig. 4** Forest plot showing the comparison between TightRope® and hook plate in UCLA Shoulder Score and CCD.

conducted sensitivity analysis by excluding the trial with outlier[37], and results changed substantially (WMD = 12.19, 95% CI: 8.84, 15.54; $P < 0.001$), but significant heterogeneity was still present ($I^2 = 77.5\%$, $P = 0.012$). Further excluding any single study did not change the overall estimate, but the evidence of heterogeneity did not disappear.

### *Visual Analogue Scale Score*

Data on VAS was reported in three studies[35,37,38]. No significant heterogeneity was identified among these studies. Thus, a fixed-effect model was used to summarize the data. Results showed that TightRope® was associated with a significantly less VAS score for pain than hook plate (WMD = -0.69, 95% CI: −1.10, −0.27; $P = 0.001$) (Fig. 3).

### *University of California Los Angeles Shoulder Score*

Data on UCLA Shoulder Score was reported in two studies[35,36]. Since there was significant heterogeneity across the studies, a random-effect model was applied to pool the results. Compared with hook plate, TightRope® was

associated with a similar effect than hook plate in UCLA Shoulder Score (WMD = 7.96, 95% CI: −5.76, 21.68; $P = 0.256$) (Fig. 4).

### *Coracoclavicular Distance*

Data on CCD was presented in three studies[35,37,38]. No significant heterogeneity was tested among the studies. Results from a fixed-effect model suggested that there was no significant difference in CCD between TightRope® and hook plate (WMD = 0.24, 95% CI: −0.67, 1.15; $P = 0.602$) (Fig. 4).

### *Complication*

All the included studies reported the data of complications[35–38]. Pooled estimates demonstrated that there were no significant differences in complications between the two techniques, including plate/screw breakage or loosening (RR = 0.42, 95% CI: 0.11, 1.66; $P = 0.217$), wound infection (RR = 0.18, 95% CI: 0.01, 3.44; $P = 0.257$), neural injury (RR = 0.43, 95% CI: 0.02, 10.20; $P = 0.601$), and redislocation (RR = 1.72, 95% CI: 0.55, 5.36; $P = 0.346$).

## Discussion

The purpose of this meta-analysis is to assess and compare the clinical outcomes of TightRope® fixation *vs* hook plate fixation for the treatment of Rockwood III-VI ACJ dislocations. The main findings of our study were that there was no significant difference in Constant Score, UCLA Score, CCD, and complication rate between the two surgical treatments. However, TightRope® fixation showed a lower shoulder pain reported by VAS score. Our results indicated that both techniques could provide good clinical and radiological outcomes in relieving the pain of dislocation, and improving function of ACJ. However, TightRope® fixation showed an advantage over hook plate in terms of postoperative pain.

There is a variety of techniques that have been performed for the treatment of ACJ dislocations, however, none of them is considered as the gold standard operative ACJ stabilization. In the past years, several studies[31,34,39,40] that have been performed to explore the best operative technique for ACJ dislocation have had controversial conclusions. TightRope® fixation and hook plate fixation are the two most frequently used treatments for ACJ dislocation because they can reduce the dislocation of ACJ[37]. These two techniques have their own advantages, but also can cause treatment-related complications. Compared with hook plate, TightRope® can lead to less damage to the surrounding soft tissue, which could decrease the blood loss of surgery and reduce the length of incision. Moreover, the TightRope® technique is more stable than hook plate in the anatomic reconstruction of ACJ[41,42]. Furthermore, there is no need for a second surgical procedure for implant removal when using the TightRope® technique. Whereas, hook plate fixation also has its own advantage in that it can reduce both the vertical and horizontal planes[43]. In the study conducted by Balke *et al.*[44], the authors concluded that hook plate seemed to become the "standard therapy" in acute ACJ dislocations, in which 44% of surveyed surgeons regarded it as the favored surgical technique.

To the best of our knowledge, the present study is the first meta-analysis that compares the functional, radiological, and complication outcomes of TightRope® fixation with that of hook plate fixation in patients with Rockwood III-VI ACJ dislocations. Reviewing the literature, there were several systematic review and meta-analysis that had been published to assess the effect and safety of different surgical techniques for acute ACJ dislocation[45–47]. Arirachakaran *et al.*[45] performed a systematic review and meta-analysis to compare the postoperative outcomes and complications of hook plate *vs* suspensory loop fixation (LSF) in acute unstable ACJ. In that study, 16 and 25 studies were included for the analysis of hook plate fixation and LSF, respectively[45]. By pooling these data, they reported that LSF had less VAS score [unstandardized mean differences (UMD) = −1.19, 95% CI: −2.03, −0.35] but similar Constant-Murley score (UMD = 2.13, 95% CI: −1.43, 5.69) than hook plate[45]. Moreover, the complication rate was significantly higher in LSF group than in hook plate group (RR = 1.69, 95% CI: 1.07, 2.60)[45]. The authors concluded that LSF showed better effects in shoulder function scores and postoperative pain than hook plate; however, it also produced higher complication rates than hook plate[45].

In another meta-analysis, Gowd *et al.*[46] reviewed 58 articles with 1704 patients to compare the outcomes and complications of different techniques of ACJ reconstruction. Their results demonstrated that there were no significant differences between arthroscopic and open techniques in terms of loss of reduction ($P = 0.858$), overall complication rate ($P = 0.774$), and revision rate ($P = 0.390$)[46]. Moreover, open surgery was associated with a higher rate of clavicular/coracoid fractures than arthroscopic surgery ($P = 0.048$)[46]. The authors concluded that open and arthroscopic techniques showed similar effect and complication in the reconstruction of ACJ. The two meta-analyses support the current point that which surgical technique should be used as the ideal method for ACJ dislocation still remains inconclusive.

In the present meta-analysis, we found similar results with that of the previous two meta-analyses. TightRope® was associated with higher shoulder function reported by Constant Score and UCLA Shoulder Score when compared with hook plate, but the differences between them were not significant. Our results were in accordance with the previously published studies, but in contradiction to the study reported by Bin Abd Razak *et al.*[35]. In that study, the authors performed a prospective case–control study of 26 patients with acute ACJ dislocation to compare the short-term outcomes of arthroscopic TightRope® fixation with that of hook plate. At 1 year follow-up, TightRope® had a significantly better Constant Score than hook plate (87.6 ± 11.7 *vs* 77.5 ± 12.3, $P = 0.046$)[35]. Moreover, they also found a significantly better shoulder abduction of TightRope® than hook plate fixation at 6 months. The authors thought that the superior effect of

TightRope® over hook plate might be explained by the secondary surgery for removal of implant required by the hook plate technique[35].

As for the postoperative shoulder pain, recent studies reported that patients treated with TightRope® had a significantly lower VAS score than those with hook plate. Cai *et al.*[37] performed a prospective, randomized study to compare the clinical outcomes of TightRope® and clavicular hook plate for Rockwood type IIIACJ dislocation in adults. Sixty-nine patients were enrolled in that study, with 30 and 39 patients randomly assigned into the two groups. At the 3 and 12 months of follow-up, there were significant differences between the two groups in terms of VAS scores.[37] The VAS score was significantly less in TightRope® group than in hook plate group (postoperative VAS score at 3 months: $1.20 \pm 0.92$ *vs* $2.21 \pm 1.22$; postoperative VAS score at one year: $0.97 \pm 1.03$ *vs* $1.92 \pm 1.11$)[37]. This is because TightRope® technique is a minimally invasive procedure, and it does not cause too much damage to the surrounding soft tissue[37].

In this study, the incidence of complications regarding plate/screw breakage or loosening, wound infection, neural injury, and redislocation was comparable between the two surgical techniques. When hook plate fixation is used as the surgical regimen, subacromial impingement is the main concern. Lin *et al.*[48] has reported that hook plate might induce shoulder impingement or even rotator cuff damage. In their study, 15 out of 40 ACJ dislocation patients (37.5%) who underwent clavicular hook plate developed subacromial impingement syndrome, and six of them had rotator cuff lesion[48]. They advocated that the only solution for this was to remove the implant as soon as bony union and/or ligamentous healing was achieved. It should be noticed that there were no complications of shoulder impingement among the included studies in this meta-analysis.

There are several potential limitations in this study. First, the number of included studies was only four and the sample size was not too large, which would weaken the statistical power of the final results. Moreover, compared with larger trials, studies with small sample sizes were more likely to overestimate the treatment effect. Second, some of the included studies were retrospectively performed, which would result in selection bias. Third, there was significant heterogeneity among the included studies in Constant Score, which might be explained by the differences in patients' characteristics, study design, type of ACJ injury, or timing of plate removal. These factors might have an impact on the data analysis.

In conclusion, the present study demonstrated that both techniques offered good clinical outcomes in relieving the pain of dislocation and improving function of ACJ. However, TightRope® fixation showed an advantage over hook plate in terms of postoperative pain. Therefore, in patients with ACJ dislocations, the surgical method should be chosen based on their status. Further larger-scale RCTs are needed to verify our findings.

## Competing Interests

All the authors declare that they have no conflict of interest.

## Funding

This work was supported by the Project of "13th five - year" Science and Technology Department of Jilin Province, grant number 20190201064JC.

## Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

**Video S1**. Supporting Information

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