Arthroscopic-assisted stabilization of distal clavicle fractures with coracoclavicular ligament injury: does it restore anatomy and function?

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Background
Fractures of the lateral-third clavicle are less common than the mid-shaft. However, these lateral thirds are associated with disruption of coracoclavicular (CC) ligaments requiring surgical management for optimal fracture healing and functional outcome. Many surgical techniques have been developed to manage these fractures; however, high failure rates and implant-related complications were reported. This study aims to assess the radiological and functional outcomes of arthroscopic-assisted stabilization of the distal end clavicle in terms of union rate, complications, and shoulder function.

Patients and methods
A prospective study of 32 patients with distal displaced clavicle fracture combined with CC ligament injury (Neer type IIB, V) who underwent surgery within the first 2 weeks of injury between January 2017 and February 2020. Clinical evaluation was employed postoperatively using the Constant–Murley score. The stability of the acromioclavicular joint in the horizontal and vertical planes was evaluated by the cross-arm test and manual dislocation. Radiological assessment was reviewed by an independent observer who was not a surgical team member at 1 and 2 months postoperatively.

Results
A series of 32 patients (24 men and eight women) were included. Their mean age was 36 years. Based on the radiological imaging, 20 patients had Neer type-IIB fractures, while 12 showed type-V fractures. Their average union time was 6.12 ± 1.26 weeks (ranged 5–9 weeks), with a mean Constant–Murley score that was 96.1 ± 3.76 (range, 89–100). An average of 6.62 ± 1.82 weeks was needed before returning to prior activities. There were no complications reported.

Conclusions
Arthroscopic-assisted fixation of the distal end clavicle provides excellent fixation results and restores the native anatomy by reconstructing the torn CC ligament without complications or the need for removal of the implant.

Keywords:
arthroscopic-assisted fixation, Constant–Murley score, distal clavicle fracture, functional outcome, radiological outcome

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Introduction

Fracture clavicles represent the most common traumatic injury around the shoulder due to their subcutaneous position. It accounts for ~5–10% of all fractures and up to 44% of injuries to the shoulder girdle. About 70–80% of these fractures are in the middle third of the bone and less often in the distal third (12–15%) and medial third (5–8%). Distal-third clavicle fractures with injury of the coracoclavicular (CC) ligament are potentially unstable [1] and are complicated by a high rate of nonunion (33.3%) when treated conservatively [2].

One of the most commonly used classifications of a lateral-third clavicle fracture is Neer's classification [3] (Table 1). Muscle attachments play a significant role in displacement. The weight of the affected side upper limb and pull of the latissimus dorsi, pectoralis muscles, and scapular rotations pull the distal fragments downward, and the trapezius pulls the proximal fragment superiorly [4–6]. As the distal-third fractures are prone to displacement, they usually result in malunion or nonunion; hence, surgical stabilization is always the best to treat these types of fractures [6].

Also, in distal-third fractures, we should consider the integrity of the CC ligament, which forms a significant part of treatment planning. If the CC ligament

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Table 1 Neer's classification of lateral-third clavicle fracture

Neer's class	Description
Type I	(1) Fracture occurs lateral to coracoclavicular ligaments (trapezoid, conoid) or interligamentous
	(2) Usually minimally displaced
	(3) Stable because conoid and trapezoid ligaments remain intact
Type IIA	(1) Fracture occurs medially to intact conoid and trapezoid ligament
	(2) Medial clavicle unstable
	(3) Up to 56% nonunion rate with nonoperative management
Type IIB	(1) Fracture occurs either between ruptured conoid and intact trapezoid ligament or lateral to both ligaments torn
	(2) Medial clavicle unstable
	(3) Up to 30–45% nonunion rate with nonoperative management
Type III	(1) Intraarticular fracture extending into AC joint
	(2) Conoid and trapezoid intact, therefore stable injury
	(3) Patients may develop post-traumatic AC arthritis
Type IV	(1) A physeal fracture that occurs in the skeletally immature
	(2) Displacement of lateral clavicle occurs superiorly through a tear in the thick periosteum
	(3) Clavicle pulls out of the periosteal sleeve
	(4) Conoid and trapezoid ligaments remain attached to the periosteum, and overall, the fracture pattern is stable
Type V	(1) Comminuted fracture
	(2) Conoid and trapezoid ligaments remain attached to a comminuted fragment
	(3) Medial clavicle unstable

is injured, the displacement is more prominent, necessitating fracture fixation rather than nonoperative treatment.

Internal fixation in these fractures is often difficult because of the inability to attain screw purchase due to inadequate distal fragment size, comminution, and instability caused by torn CC ligament. Numerous techniques, such as CC screws, tension bands, hook, and lock plates, intramedullary screws, transacromial K-wire or Knowles pin fixation, and CC ligament repair [7–10].

Neer's type-I and type-III fractures are stable fractures generally treated nonoperatively [11]. Neer's type-II and type-V fractures are unstable, and treatment remains controversial [11,12]. Various treatment options, including open reduction and internal fixation with hook plate fixation, tension band wiring, screw fixation, and distal locking plates, have been described. Many of these techniques are associated with a high perioperative complication rate. Most of these complications are related to painful or prominent hardware, resulting in reoperation rates as high as 43% [13].

Nowadays, attention shifted toward minimally invasive surgery and arthroscopic fixation of these unstable fractures [14–19]. Midterm arthroscopic flip button fixation results showing favorable results in distal clavicle fractures have recently been published [16,17]. In this study, we describe a novel arthroscopic technique that allows indirect fixation of distal clavicle fractures and reconstruction of the CC ligaments without using prominent hardware. More than 2 years of follow-up clinical results show excellent union rates and functional outcomes while minimizing hardware-related complications.

Patients and methods

Study population

This is a prospective study of 32 patients with distal displaced clavicle fracture combined with CC ligament injury, who received close reduction and arthroscopic-assisted fixation by suspension of the medial part of the clavicle to the coracoid using handmade tight rope (TightRope; Arthrex Inc., Naples, Florida, USA).

'Declaration of Helsinki' guidelines were followed, and patient consent was taken before taking part. All patients underwent surgery within the first 2 weeks of injury between January 2017 and February 2020 in the University Hospital. This technique was used for Neer type-IIB and type-V fractures in patients of more than 18 years. The patients excluded from this study are those presented to us with fractures over 2 weeks, undisplaced lateral end clavicle, and patients with a floating shoulder injury. Patients with other fracture types (I, III, and IV) and those diagnosed with associated injuries of the rotator cuff, labrum, or biceps tendon during the arthroscopic examination were excluded from this study.

Surgical technique

Under general anesthesia with the patient in the beach chair position, under image intensifier guidance. Diagnostic arthroscopy of the glenohumeral joint was performed through the posterior portal to assess any associated injuries. Next, the anterolateral portal is made

~1.5 cm lateral to and in line with the anterior border of the acromion guided by the cannula. The rotator interval is debrided and opened; the scope is pushed anterior of the posterolateral portal into the space under the coracoid. The base of the coracoid is carefully cleaned to detect the medial and lateral border with a radiofrequency device. A 1.5-cm skin incision was made medial to the fracture site along the midline of the distal clavicle. An acromioclavicular TightRope drill guide (Arthrex Inc.) was centered on the undersurface of the base of the coracoid through the anterolateral portal, while its other end (the drill sleeve) was placed 1 cm medial to the fracture in the center of the clavicle.

With the drill guide held in this position and under a clear arthroscopic view, a 2.4-mm guide pin was drilled from the clavicle to the undersurface of the coracoid process. Next, a 4.0-mm tunnel was made using a 4.0-mm cannulated drill pet. The cannulated drill pet was left *in situ*, and the guide pin was removed. A guide wire was inserted through the TightRope reamer, passed out of the hole drilled in the coracoid, then retrieved with a grasper placed through the anterior portal, and the reamer was removed. The flip button device (two metal buttons, one oblong and the other rounded, connected by a loop of #5 FiberWire; Arthrex Inc.) was inserted into the loop and pulled through the clavicle and the base of the coracoid. Using a suture retriever, the button was flipped and positioned horizontally under the coracoid. The medial clavicular fragment was pushed inferiorly with a bone tamp, and superior force was applied on the elbow and arm to reduce the fracture indirectly (Fig. 1). The flip button was tied down over the button on the superior surface of the clavicle after adequate reduction was obtained under an image intensifier. The affected shoulder was immobilized in a shoulder brace in a neutral position for 4 weeks postoperatively. Patients were discharged on the next day of surgery in a shoulder brace for 4 weeks. Immediate elbow and hand movements were started after surgery. Passive pendular shoulder movement started 3 weeks after surgery and increased to full active motion at 6 weeks.

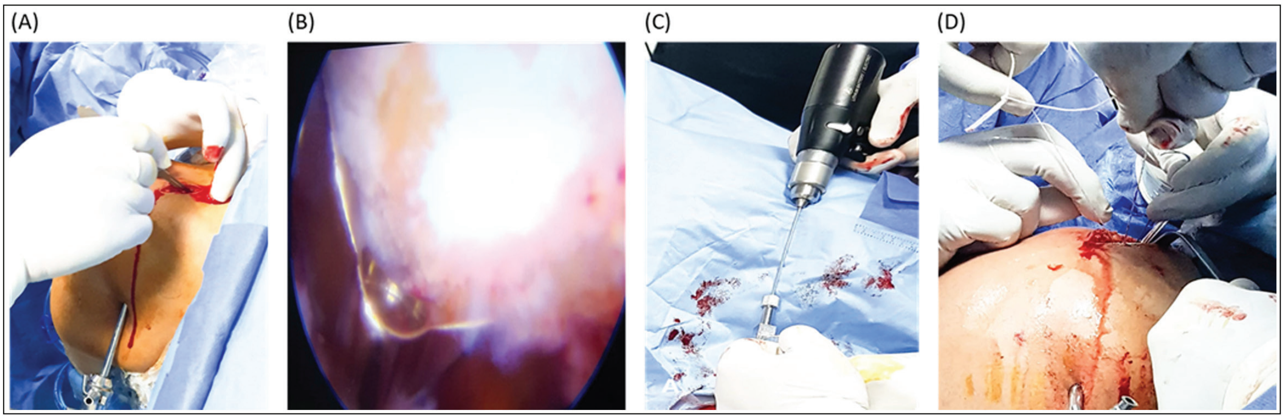
Postoperative clinical and radiological evaluation

Clinical evaluation was done on 2, 6, 12, and 24 months postoperatively using the Constant–Murley score, and stability of the acromioclavicular joint in the horizontal and vertical planes was evaluated by the cross-arm test and manual dislocation [20]. Radiological assessment was evaluated by an independent observer who was not a surgical team member at 1 and 2 months postoperatively. The radiological union was defined as the presence of cortical bridging consolidated callus between the proximal and distal callus in different radiological views. Clinical consolidation was evaluated by the absence of pain on movement of the clavicle and shoulder. All patients had a minimum follow-up period of 2 years (range, 2.0–2.5 years) (Fig. 2).

Statistical analysis

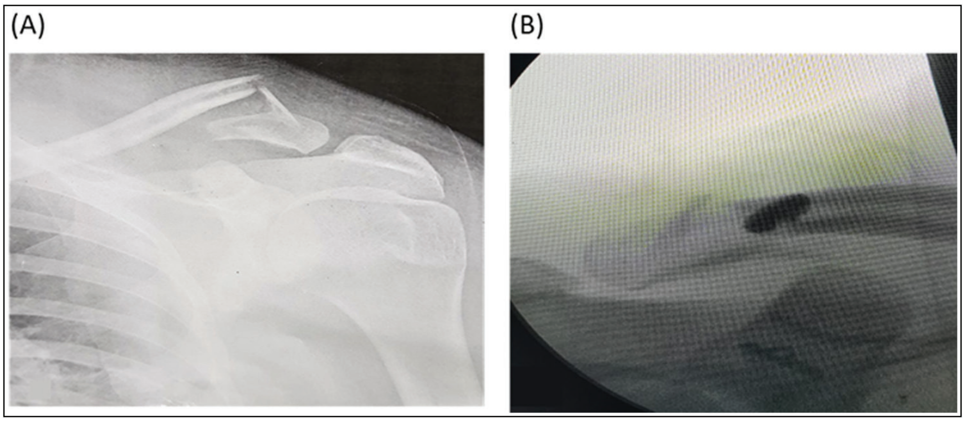
SPSS, v27.0 (Chicago, IL, USA), and R version 3.5.1 (R Studio Version 1.2.1335) were used. Independent Student *t* test and one-way analysis of variance tests were used. Statistical significance was considered at *P* value less than 0.05. Categorization was employed for some quantitative variables as follows: (a) age: less than or equal to 35 and more than 35 years old, (b) Constant–Murley score: more than or equal to 95 and less than 95, (c) time union: less than or equal to 6 and more than 6 weeks, and (d) return to standard activity time: less than 7 and more than 7 weeks. Pearson's correlation test was employed for correlation analysis. Cluster analysis was performed using the 'ape' R package and Euclidean metrics. The R package

Figure 1



Arthroscopic-assisted stabilization of distal clavicle fractures with a coracoclavicular ligament injury. (a) A 1.5-cm skin incision was made medial to the fracture site along the midline of the distal clavicle. (b) An acromioclavicular joint TightRope drill guide (Arthrex Inc.) was centered on the undersurface of the base of the coracoid through the anterolateral portal. (c) A 2.4-mm guide pin was drilled from the clavicle to the undersurface of the coracoid process. (d) The flip button was tied down over the button on the superior surface of the clavicle.

Figure 2



Arthroscopic-assisted stabilization of distal clavicle fractures with a coracoclavicular ligament injury. (a) Twenty-eight male patients with a fracture in the distal end of the clavicle type IIB due to a motor car accident. (b) An intraoperative photo was obtained after adequate reduction and stabilization under an image intensifier. The Constant–Murley score postoperatively was 100. Union was apparent after 5 weeks, and the patient resumed his previous activities at week 5.

'rpart.plot' was used for decision tree analysis to predict the time needed to return to patient activities before the injury. A logistic nomogram was carried out to predict early union times postoperatively using *the* 'regplot' and 'survival' R packages.

Literature review

The keywords 'distal clavicle/clavicular' or 'lateral clavicle/clavicular' and 'fracture' and 'arthroscopy/arthroscopic' were used during the search in PubMed, WOS, and Embase online databases. Hozo's method was used for estimating SD from minimum and maximum values when available in the article. Empirical Bayes estimator and Clopper–Pearson interval with arcsine transformation were employed for a one-arm meta-analysis of proportions. For quantitative variables such as union time and Constant–Murley score, an untransformed mean was reported. Both 'metafor' and 'meta' R packages were used. Random-fixed model was selected if there was significant heterogeneity (I^2>50%).

Table 2 Clinical and radiological features of the study population

Characteristics	Level	Value
Demographics		
Age (years)	Mean±SD	35.9±9.8
	≤35	15 (46.9)
	>35	17 (53.1)
Sex	Male	24 (75)
	Female	8 (25)
Injury characteristics		
Affected injury side	Dominant side	21 (65.5)
	Nondominant side	11 (34.5)
Mechanism of injury	Motor traffic	18 (56.2)
	Falling from a height	7 (21.9)
	Sports injuries	7 (21.9)
Radiological assessment		
Neer's classification	Type IIB	20 (62.5)
	Type V	12 (37.5)
Additional injuries	Fracture humerus	2 (6.4)
	Hip dislocation	1 (3.2)

Data are shown as *n* (%) or mean±SD.

Result

Characteristics of the study population

This study included 32 patients: 24 (75%) men and eight (25%) women, with a mean age of 35.9 ± 9.8 years (range, 18 to 52 years). Twenty-one (65.5%) patients present with a dominant side injury, and 11 (34.5%) with a nondominant side injury. The mechanisms of injuries were motor traffic accidents in 18 (56.2%) patients, falling from a height in seven (21.9%) patients, or sports injuries in seven (21.9%) patients (Table 2).

Radiological assessment of the injury

Radiological imaging using anteroposterior and axillary view demonstrated Neer's type-IIB fractures in 20 (62.5%) patients and type-V fractures in 12 (37.5%) patients. Additional injuries include two (6.4%) patients with fracture humerus on the contralateral side and one (3.2%) patient with ipsilateral fracture hip dislocation and posterior wall acetabulum (Table 2 and Supplementary Table S1).

Surgical outcomes

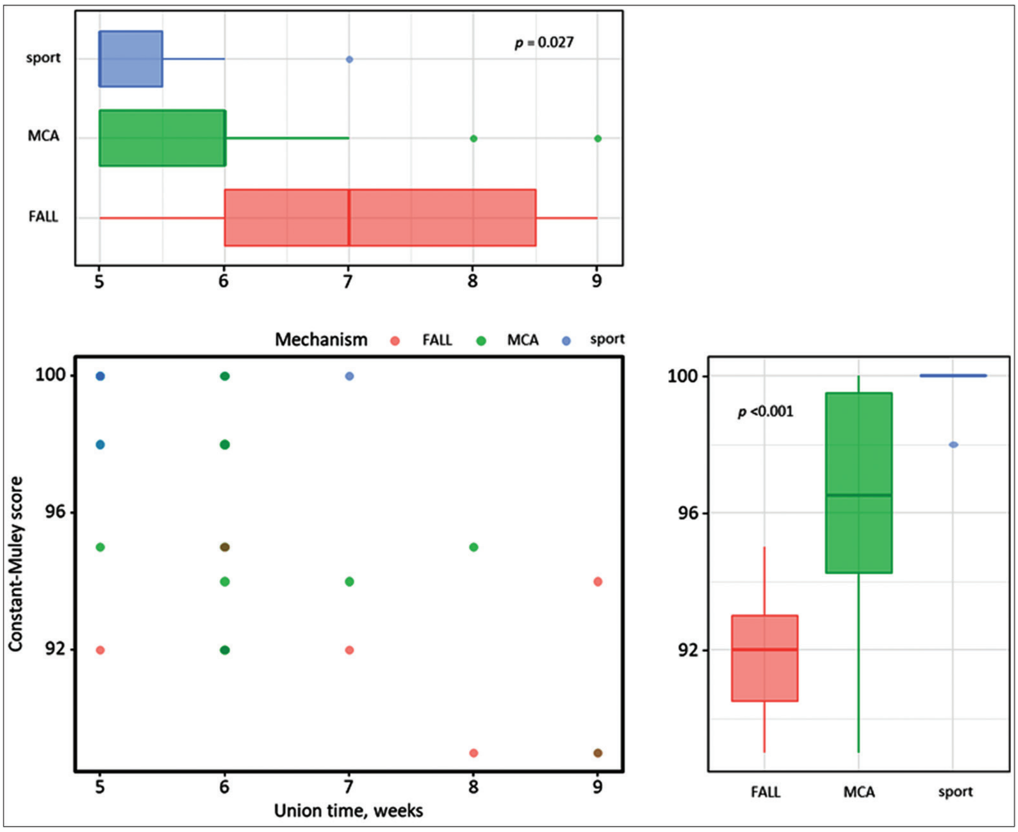
A total of 24 (75%) patients showed early union time (≤6 weeks). The mean union time of the study population was 6.12 ± 1.26 weeks (range, 5–9 weeks). Diagnostic arthroscopies showed no associated glenohumeral injuries. For functional assessment, 21 (65.6%) cases exhibited a high Constant–Murley score (≥95). The mean Constant–Murley score was 96 ± 3.76 (range, 89–100). There were no cases of infection, malunion, nonunion, and symptomatic hardware. None of the patients required reoperation related to their clavicle fracture fixation. Four (12.5%) patients presented with postoperative delay in the range of motion (adhesive capsulitis), managed by intraarticular steroid injection and physiotherapy. After follow-up till recovery, 23 (71.9%) patients returned to their activities within 7 weeks of the surgery. The mean time for the return to previous activities was 6.62±1.82 weeks (range, 5–12 weeks). As depicted in Table 3, younger patients (≤35 years) were more likely to have better functional score (*P*<0.001), earlier union time (*P*=0.010), and earlier recovery (*P*=0.002). Female patients had better Constant–Murley score than males (*P*=0.032). In contrast, patients with Neer's classification type V exhibited unfavorable functional score (*P*<0.001) and delayed activity (*P*=0.019). As shown in Fig. 3, injury due to falling from a height was associated with the worst outcomes in terms of lower Constant–Murley score (*P*<0.001), prolonged union time (*P*=0.027), and delayed recovery to usual activities (*P*=0.001).

Table 3 Association between clinical features and outcomes

Characteristics	Level	*N*	Constant–Murley score	*P* value	Union time (weeks)	*P* value	Return time (weeks)	*P* value
Age (years)	≤35	15	99.1±1.5	<0.001	5.53±0.6	0.010	5.6±0.8	0.002
	>35	17	93.4±2.9		6.64±1.5		7.52±2.0	
Sex	Male	24	95.3±3.8	0.032	6.29±1.4	0.20	6.91±1.9	0.12
	Female	8	98.5±2.3		5.62±0.7		5.75±0.7	
Dominant side	No	11	95.0±4.2	0.26	5.95±1.2	0.29	7.45±2.3	0.06
	Yes	21	96.6±3.5		5.95±1.4		6.19±1.3	
Mechanism of injury	MCA	18	96.3±3.3	<0.001	6.0±1.1	0.027	6.3±1.4	0.001
	Falling	7	91.8±2.3		7.1±1.6		8.6±2.2	
	Sports	7	99.7±0.8		5.4±0.8		5.4±0.5	
Neer's type	IIB	20	98.2±2.5	<0.001	5.9±1.08	0.11	6.05±1.4	0.019
	V	12	92.6±2.8		6.6±1.4		7.58±2.2	

Data are presented as mean and SD.
MCA, motor car accident.
Independent Student *t* test and one-way analysis of variance tests were used. Statistical significance was set at *P* value less than 0.05.

Figure 3



Association between initial Constant–Murley functional score and the expected union time according to the mechanism of injury. Fall, falling from a height; MCA, motor car accident. The one-way analysis of variance test was used. Statistical significance was set at *P* value less than 0.05.

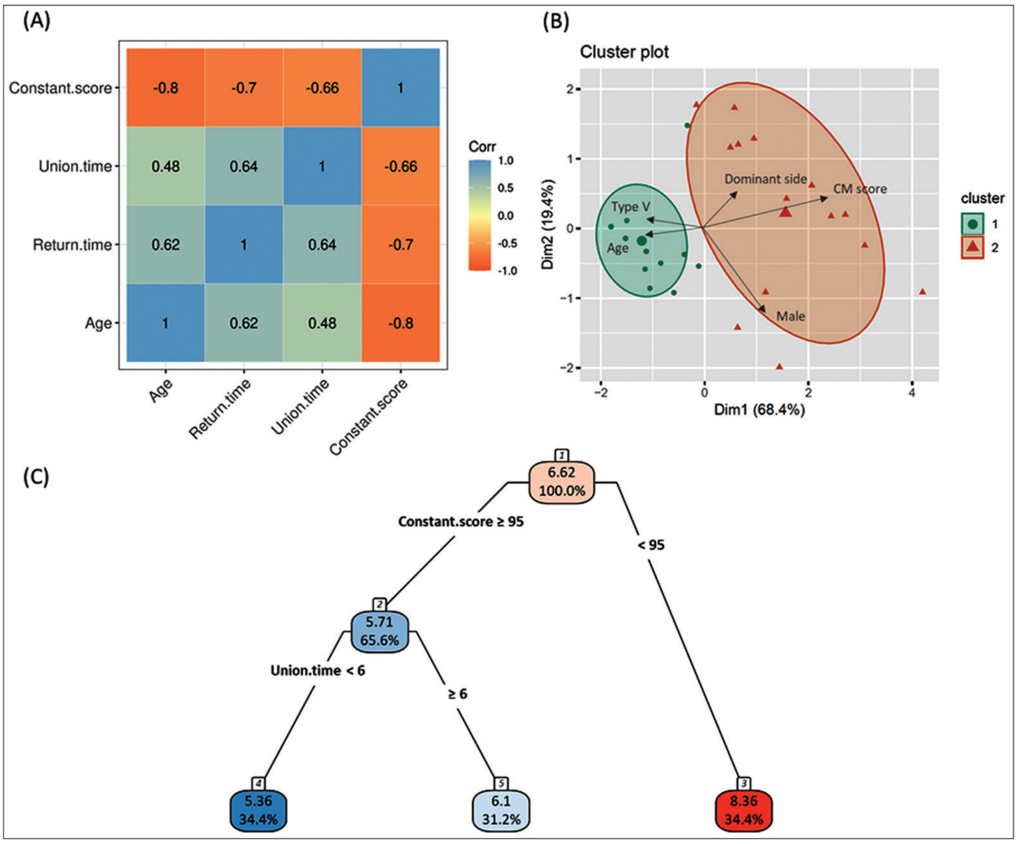
Multivariate analysis

The correlation matrix showed direct correlations between the age of the patient and the surgical outcomes. The correlation coefficients were *r*=0.62 (*P*<0.001) for the recovery time to ordinary activities and *r*=0.48 (*P*<0.001) for the union time needed, while it was negatively correlated with the Constant–Murley score *r*=-0.8 (*P*<0.001), thus highlighting poor outcomes with advanced age (Fig. 4a). Cluster analysis classified patients into two categories: (a) cluster 1 showed delayed union after 6 weeks and was associated with higher age and Neer type V, and (b) cluster 2 had early union 6 weeks or less, and they had higher postoperative Constant–Murley score (Fig. 4b). Decision tree analysis showed that the postoperative Constant–Murley score and the union time detected by radiological assessment could predict the time to return to preinjury activities (Fig. 4c). If the postoperative functional score is less than 95, therefore, the patient will regain his activities after 8 weeks or more. However, if the patient had a good score more than or equal to 95, then looking into the second node of the classifier, the union time of more than or equal to 6 weeks will yield a prolonged recovery time, while a patient with union time visualized prior to 6 weeks that would be a successfully earlier regain of the patient's activities within 2 months. A predictive nomogram was generated using logistic regression analysis to identify the expected union time of the injury 6 weeks postoperatively (Fig. 5).

Comparison of our results with the literature

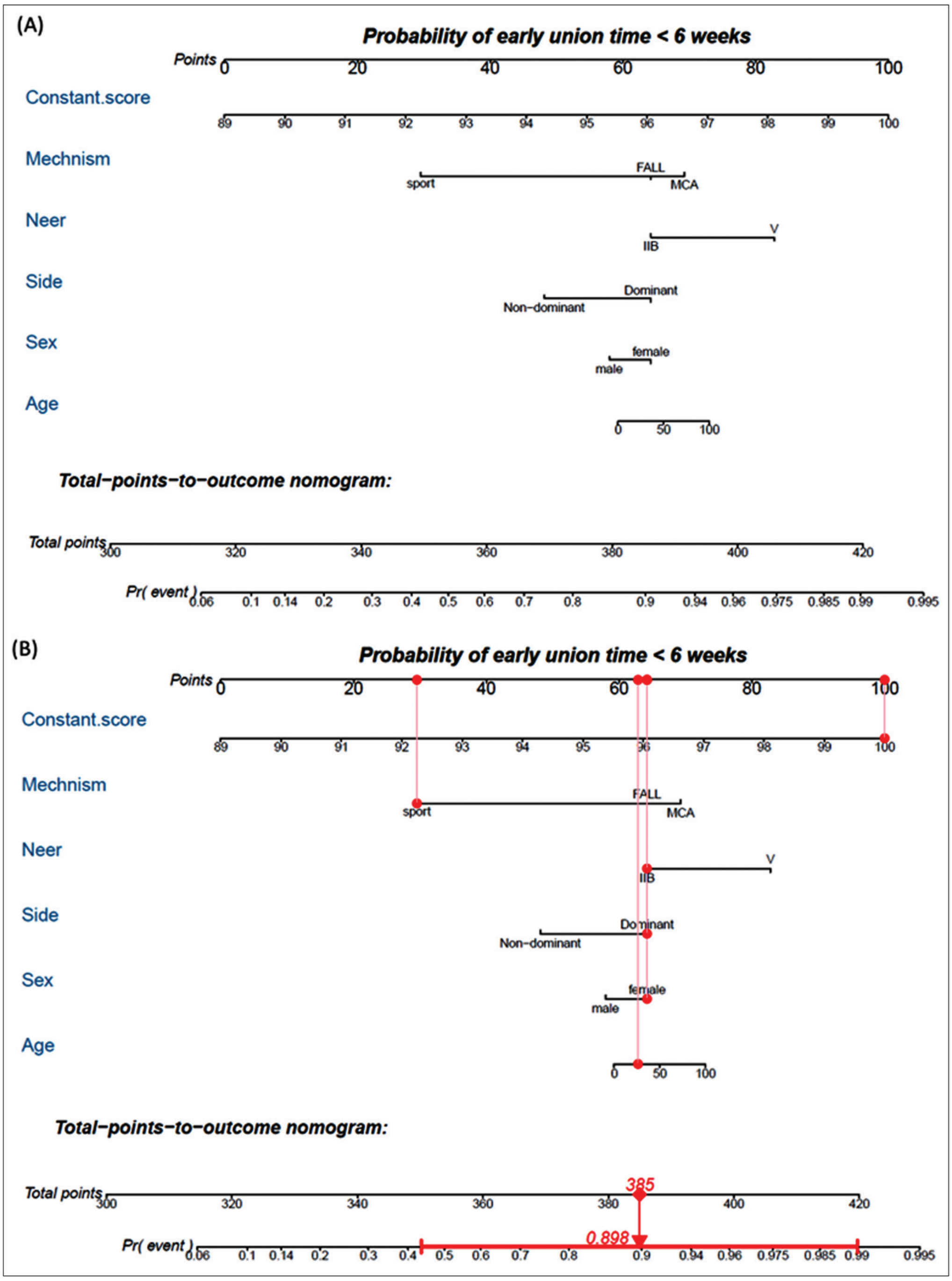
Eleven studies for human participants who had acute distal clavicle fractures with CC ligament injury within 2 weeks and underwent arthroscopic-assisted stabilization were selected according to the inclusion and exclusion criteria (Supplementary Table S2) [15,16,21–29]. Postoperatively, the patient restored their shoulder function as assessed by the Constant–Murley score of 93.7 [95% (confidence interval): 92.1–95.4, I^2=74%] (Fig. 6a). A high union rate was observed, accounting for 99% (95% CI: 96–100%, I^2=27%) within a union time of 7.06 weeks (95% CI: 4.5–9.62, I^2=99%) (Fig. 6b,c). The complication rate was 5% (95% CI: 1–13%) with significant heterogeneity (I^2=74%) (Fig. 6d). Across studies, 17 patients developed complications.

Figure 4



Multivariate association between the study variables and the outcomes. (a) Correlogram showing the correlation analysis between quantitative variables. Pearson's correlation test was employed. All *P* values were less than 0.001. A positive correlation is in blue, and an inverse correlation is in orange. (b) Cluster analysis split the patients into two distinct clusters with clear demarcation: cluster 1 (green) showed delayed union after 6 weeks and was associated with higher age and Neer type V, and cluster 2 (orange) had early union 6 weeks or less, and they had higher postoperative Constant–Murley score. (c) Decision tree analysis. rpart R package was used. Inputs were age, sex, mechanism of injury, side of injury, Neer's classification, union time, and Constant–Murley score. The outcome variable for prediction was the time to return to preinjury activities.

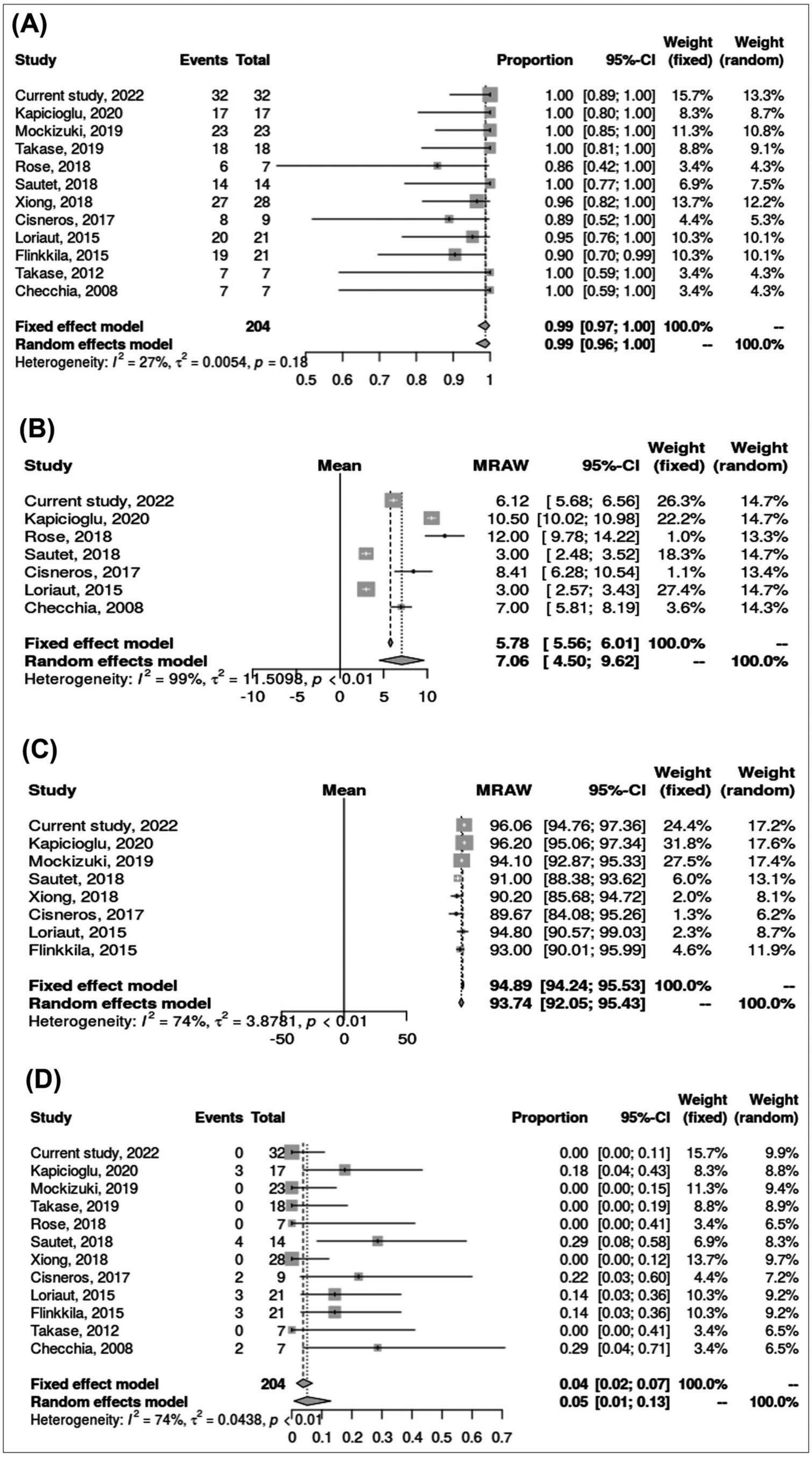
Figure 5



The prognostic nomogram predicts the union time following arthroscopic-assisted stabilization of distal clavicle fractures with a coracoclavicular ligament injury. (a) Predictive nomogram. The input variables are shown as horizontal lines with labeled levels. These include age, sex, the affected side of injury, Neer's classification of injury, the mechanism of injury, and the Constant–Murley score. MCA, motor car accidents; Neer, Neer's classification type IIB or type V, side, affected side of injury. Based on a particular level per variable, perpendicular lines are drawn to reach the Points' horizontal line. Based on the sum of each point, the total points are estimated and used to define the probability of early union time before 6 weeks. (b) Nomogram with points showing an example of a case. Assume that the injured case is a 30-year-old female patient who showed an injury at the dominant side during practicing sports and is presented with type-IIB Neer's classification of fracture. Postoperatively, she had an excellent Constant–Murley score of 100. Therefore, summing the scores of all these points: 63 + 64 + 64 + 64 + 30 + 100=385, which corresponds to the probability of 89.8% for early union time less than 6 weeks postoperatively.

These included wound problems (*N*=3), hardware-related issues (*N*=6), fractures (*N*=3), implant failure (*N*=1), shoulder stiffness (*N*=3), and osteoarthritis (*N*=1) (Supplementary Table S3). Subgroup analysis by the method of intervention is demonstrated in Supplementary Table S4. Comparison between studies with different intervention methods did not show significant differences regarding regaining shoulder function (*P*=0.16), union rate (*P*=0.96), or prevalence of complications (*P*=0.36). However, fixation by TightRope demonstrated the fastest union time of 5.7 weeks (95% CI: 2.7–8.7), while cortical button and

Figure 6



Pooled one-arm meta-analysis for the impact of arthroscopic-assisted stabilization following distal clavicle fractures. (a) Shoulder function assessed by the Constant–Murley score. (b) Union rate. (c) Union time in weeks. (d) Rate of complications.

sutures showed the most prolonged time (10.5 weeks, 95% CI: 10.0–10.9) (P<0.001).

Discussion

The clavicle is the most common site of traumatic fracture. Most clavicular fractures can be managed conservatively without surgical intervention. However, displaced distal clavicle fractures, especially Neer type-IIB and type-V fractures, need surgical stabilization due to disruption of the CC ligaments and the resultant instability with the displacement of the medial fragment caused by the pull of the attached muscles [30].

Many surgical techniques have been developed to manage these injuries, such as K-wire fixation from the acromion to the proximal fragment, tension band wiring fixation, small fragment plating, distal radius plate fixation, and hook plate fixation [2,3,6,10]. However, many complications are reported with these techniques, such as migration loss of the K-wire, pin tract, deep infection, and nonunion. The hook plate is known to cause undersurface acromion osteolysis and impingement in the majority of the cases (68%). Also, it led to fracture, rotator cuff injury, and migration of the hook into the acromion that needs the removal of the plate after the complete union is achieved [2,3,6,10]. In a study by Tan *et al.* [31] on using a hook plate for fixation of the lateral end clavicle, they reported that 74% of the patients had persisting mild-to-severe shoulder pain relieved by plate removal. Moreover, using a lateral clavicle locking plate is very difficult in the comminuted distal fragment (Neer type V) due to the limitation of finding appropriately sized screws.

Regarding indirect flexible osteosynthesis fixation, CC stabilization and the use of a suspensory loop fixation system are the two principal fracture stabilization techniques. Neer [32] published a technique of surgical fixation of unstable shoulder girdle fractures using braided polyethylene sutures. Largo *et al.* [33] use CC augmentation for the reduction of minor and/or comminuted distal clavicle bone fracture with unstable proximal fragments for prevention of the high shearing forces. The TightRope device was initially designed to stabilize syndesmotic ankle injury and then applied for acromioclavicular joint disruption. A biomechanical study was done on fresh frozen cadavers to compare the locking plate and TightRope for managing unstable, comminuted distal-third clavicle fractures. A TightRope device can effectively reduce the unstable Neer type-II fracture pattern into a stable pattern without massive soft tissue dissection required for direct osteosynthesis and allow fracture healing, especially in osteoporotic patients. This may reduce the risk of microfracture, bone resorption, and fixation failure [34]. Nourissat *et al.* [18] first explained the technique of arthroscopic stabilization of displaced fracture of the distal part of the clavicle, but clinical and radiological results were not reported. Pujol *et al.* [35] reported encouraging radiological and clinical results with no complications in four patients when using the same technique of arthroscopically assisted fixation of the distal clavicle fractures.

The main advantages of our technique were that we attain reduction and stabilization of the unstable displaced and comminuted Neer type-IIB and type-V distal clavicular fractures by arthroscopic CC reconstruction as it provides good stability in the vertical direction, which resists the upward pulling of the muscle, without opening of the fracture site and disturbance of fracture hematoma. We have found that there is no need for additional fixation by plates. The fracture heals in 5–9 weeks with a mean of 6.12 weeks with no need for implant removal and returns to their preinjury function results. Our technique achieved satisfactory outcomes at a mean follow-up of 2.65 years (range, 2.5–3 years). Four patients were delayed in the return range of motion as they had adhesive capsulitis, which was managed by local steroid injection in the rotator interval followed by physiotherapy. Otherwise, there were no complications related to the fracture union, such as a nonunion or delayed union. The results were superior to the other conventional open techniques, such as locking plate, hook plate, intramedullary K-wire, and CC screw fixation.

Sautet *et al.* [25] concluded that arthroscopic fixation of Neer IIB fracture of the distal part of the clavicle provided satisfactory clinical and radiological results with minimal complications. The reported complications of this technique are coracoid fracture, nonunion with implant failure, or retractile capsulitis [18,25,35].

The strength of this study is that all patients were followed for up to 30 months until the radiographic union became evident and patients returned to their daily activities. Also, the cases included in this series represent various injury mechanisms. However, due to the relatively low frequency of type-IIB and type-V fractures and lack of randomization, we recommend additional clinical studies for further validation and generalization.

Conclusion

Arthroscopic-assisted fixation of the distal end clavicle provides excellent fixation and restores the native anatomy by reconstructing the torn CC ligament using a nonrigid suspension device that allows close reduction of the fracture and approximation of the torn ligament ends for better healing without complications or needs for removal of the implant.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Supplementary Table S1 Basic characteristics of the study population

Serial	Age	Sex	Side	Neer's	Mechanism	Time to return	Union time	Constant score
1	26	Female	D	IIB	Sport	6	5	100
2	36	Male	D	V	MCA	6	5	98
3	42	Male	D	V	FALL	6	5	92
4	38	Female	D	IIB	MCA	7	6	95
5	50	Male	ND	V	FALL	10	6	92
6	42	Male	D	IIB	MCA	5	5	100
7	48	Male	D	IIB	MCA	10	6	92
8	33	Female	D	IIB	Sport	6	6	100
9	43	Male	ND	IIB	MCA	7	8	95
10	39	Male	D	IIB	FALL	8	9	94
11	45	Male	D	V	MCA	6	6	92
12	50	Male	ND	V	MCA	5	5	95
13	20	Female	D	IIB	Sport	5	5	98
14	21	Female	D	IIB	MCA	5	5	100
15	32	Male	D	IIB	MCA	6	6	98
16	23	Male	ND	IIB	MCA	6	5	100
17	18	Female	D	IIB	Sport	6	5	100
18	28	Male	ND	IIB	MCA	5	5	100
19	30	Male	D	IIB	MCA	6	6	95
20	38	Female	ND	V	FALL	6	6	95
21	40	Male	D	V	MCA	8	7	94
22	43	Male	ND	V	FALL	8	8	89
23	27	Female	D	IIB	Sport	5	7	100
24	33	Male	ND	IIB	MCA	5	6	98
25	44	Male	D	V	MCA	8	9	89
26	52	Male	ND	V	FALL	12	9	89
27	35	Male	D	IIB	Sport	5	5	100
28	26	Male	ND	IIB	MCA	8	6	100
29	44	Male	D	V	MAC	6	6	94
30	51	Male	ND	V	FALL	10	7	92
31	30	Male	D	IIB	MCA	5	6	98
32	24	Male	D	IIB	Sport	5	5	100

D, dominant; ND, nondominant.

Supplementary Table S2 Characteristics of the reviewed studies for arthroscopic-assisted stabilization of distal clavicle fractures with coracoclavicular ligament injury

References	Country	Design	Sample size	Male	Age (years)	Time from injury (days)	Intervention	Follow-up, months
Kapicioglu *et al*. [21]		CS	17	3	31 ± 9.5	2 ± 0.8	Cortical button/ sutures	25.9 ± 12.5
Mochizuki *et al*. [22]		CS	23	NA	34.3 ± 9.5		Cortical button/ sutures	18.6 ± 3.6
Takase and Yamamoto [23]		CS	18	16	43.5 ± 7	4.1 ± 1.25	EndoButton	29 ± 9.5
Rose *et al*. [24]		CS	7	3	31.9 ± 12.5	7.7 ± 2.8	DogBone	12.7 ± 1.5
Sautet *et al*. [25]		CS	14	10	346.6 ± 89.5		DogBone	20 ± 14.5
Xiong *et al*. [26]		R	28	NA	41.9 ± 13.5	3.5 ± 1.5	Cortical button/ sutures	35.6 ± 13.9
Cisneros and Reiriz [27]		CS	9	5	36 ± 7.8	6 ± 1	TightRope	49 ± 1.73
Loriaut *et al*. [16]		CS	21	14	33 ± 12.25	3 ± 1.5	TightRope	35 ± 8.9
Flinkkilä *et al*. [28]		R	21	20	39 ± 14		TightRope	32 ± 16
Takase *et al*. [29]		CS	7	7	41.9 ± 6.4	2.7 ± 0.3	EndoButton	29 ± 5.6
Checchia *et al*. [15]		CS	7	4	42 ± 11.1	4 ± 3	Sutures only	15 ± 3.5

Eligibility criteria: studies for human participants who had acute distal clavicle fractures with coracoclavicular ligament injury within 2 weeks and underwent arthroscopic-assisted stabilization.
CS, case series; R, retrospective.

Supplementary Table S3 Complications following for arthroscopic-assisted stabilization of distal clavicle fractures

References	Intervention	Description of complications
Kapicioglu *et al*. [21]	Cortical button/sutures	2 Coracoid fractures, 1 skin irritation requiring removal
Sautet *et al*. [25]	DogBone	4 Button irritation
Cisneros and Reiriz [27]	TightRope	1 Skin irritation, 1 shoulder stiffness
Loriaut *et al*. [16]	TightRope	1 Implant failure, 1 transient-adhesive capsulitis, symptomatic acromioclavicular joint osteoarthritis
Flinkkilä *et al*. [28]	TightRope	1 Deep infection, 1 sinus formation, 1 fracture of clavicular drill hole requiring fixation
Checchia *et al*. [15]	Sutures only	1 Bleeding and superficial infection, 1 shoulder stiffness

Supplementary Table S4 Subgroup analysis according to the method of intervention

Outcome	Procedure	No studies	Estimate (95% CI)	I^2	*P* value
Shoulder function	TightRope	4	94.2 (91.7–96.6)	60%	0.16
	Cortical button and sutures	3	94.2 (91.3–96.9)	81%	
	DogBone	1	91.0 (88.3–93.6)	NA	
Union rate	TightRope	4	93 (84–97)	0%	0.96
	Cortical button and sutures	3	97 (89–99)	0%	
	EndoButton	2	96 (76–99)	0%	
	DogBone	2	91 (66–98)	0%	
	Sutures only	1	100 (59–100)	NA	
Union time	TightRope	3	5.7 (2.7–8.7)	98%	<0.001
	Cortical button and sutures	1	10.5 (10.0–10.9)	NA	
	DogBone	2	7.4 (1.4–16.3)	98%	
	Sutures only	1	7.0 (5.8–8.2)	NA	
Complications	TightRope	4	14 (7–25)	7%	0.36
	Cortical button and sutures	3	6 (1–28)	51%	
	EndoButton	2	4 (1–24)	0%	
	DogBone	2	21 (6–54)	23%	
	Sutures only	1	29 (4–71)	NA	

P value testing for the subgroup difference. I^2 test is for testing heterogeneity. The current study is included. One-arm meta-analysis was performed. Untransformed mean was pooled for shoulder function (Constant–Murley Score) and union time (weeks), while arcsine-transformed proportion was pooled for union rate (%) and complication rate (%).