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Case Report

Close treatment of acute unstable distal clavicle fractures with coracoclavicular fixation by the TightRope® system via two minimal incisions

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Abstract: Distal clavicular unstable fractures (Neer type IIb) with disruption of the coracoclavicular ligament can result in delayed union or non-union such that surgical intervention is required. Various surgical methods have been introduced, but no gold standard has been established. This paper introduces a mini-open technique for the treatment of distal clavicle fractures (Neer type IIb) associated with ruptured coracoclavicular ligament using the TightRope® System. With two minimal incisions, the AC TightRope Constant Guide (ACTRCG) was positioned between the top of the clavicle and the base of the coracoid process. With the help of ACTRCG, the TightRope® System was fixed between the clavicle and the coracoids, achieving coracoclavicular (CC) stabilization. CC stabilization restored the coracoclavicular space to reduce the fracture, which changed the pattern of the fracture from Neer type II to type I. Neer type I only requires conservative treatment. Therefore, repair of the torn coracoclavicular ligament or fixation of the fracture with a plate was unnecessary because the bony union was expected. From April 2014 to January 2016, 12 consecutive patients with acute, closed Neer type IIb distal clavicular fractures were treated operatively at our institution using this mini-open technique. One patient was lost to follow-up and excluded from the study. The mean follow-up time was 14.9 months (range, 8-20 months). All fractures healed without secondary procedures. The mean union time was 14.18 weeks. The mean operation time was 31.5 minutes, and mean blood loss was 5.5 ml. The mean UCLA shoulder rating score was 34.3. Ten patients had excellent results, and 1 had good results. All patients were able to resume their previous levels of activity. This technique provides a simplified way to achieve coracoclavicular stabilization to fix distal clavicle fractures. All patients were satisfied with their functional results and cosmetic appearance. The mini-open treatment is a minimally invasive surgical technique that has been proven effective for the treatment of these lesions. It can be performed quickly, is less invasive and relatively simple, and is characterized by less morbidity, less hospitalization, excellent cosmetic results, and early rehabilitation.

Keywords: Distal clavicle fracture, AC TightRope constant guide, tightrope® system

Introduction

Neer type II distal clavicle fractures account for 10% to 30% of all clavicle fractures and are associated with 30% to 45% delayed or non-union rates [1]. Neer classifies distal clavicular fractures into 3 types according to the location of the coracoclavicular ligament relative to the distal fragment [1]. Type II distal clavicle fractures are classified based on the relationship of the fracture line to the coracoclavicular (CC) ligaments and the AC joint. Type II fractures can be subcategorized into type IIa (i.e., fracture occurs medial to the coracoclavicular ligament) and type IIb (i.e., fracture occurs more laterally with the coracoclavicular ligament disrupted from the proximal section) [1]. Type II fractures are usually unstable. The weight of the arm pulls the distal clavicular fragment downward, while the shoulder girdle and the force of the sternocleidomastoid muscle pull the proximal clavicular fragment upward, and the proximal fragment is displaced superiorly by the lack of CC ligament attachment. Deforming forces cause wide displacement of the fracture site, and reduction is difficult to maintain with conservative treatment. These fractures are responsible for most clavicle non-unions and are challenging to treat because of the small distal bony fragment that is attached only to the

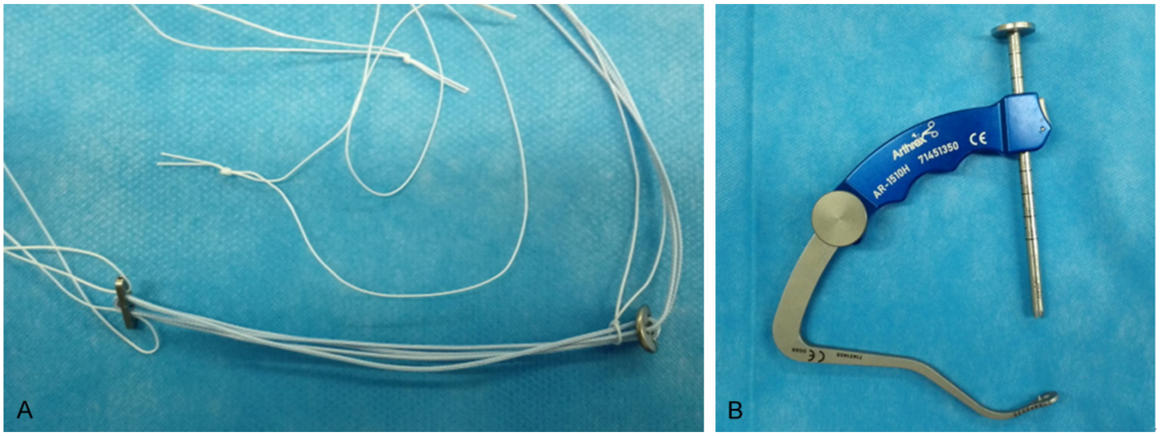

Figure 1. The TightRope System, 4 mm Cannulated Drill and AC TightRope Constant Guide. A. The TightRope System is a device that was originally designed for reduction and stabilization of tibiofibular syndesmosis of the ankle. It consists of two metal buttons, one circular and one oblong, joined by a continuous loop of #5 FiberWire®. B. The 4 mm Cannulated Drill and AC TightRope Constant Guide.

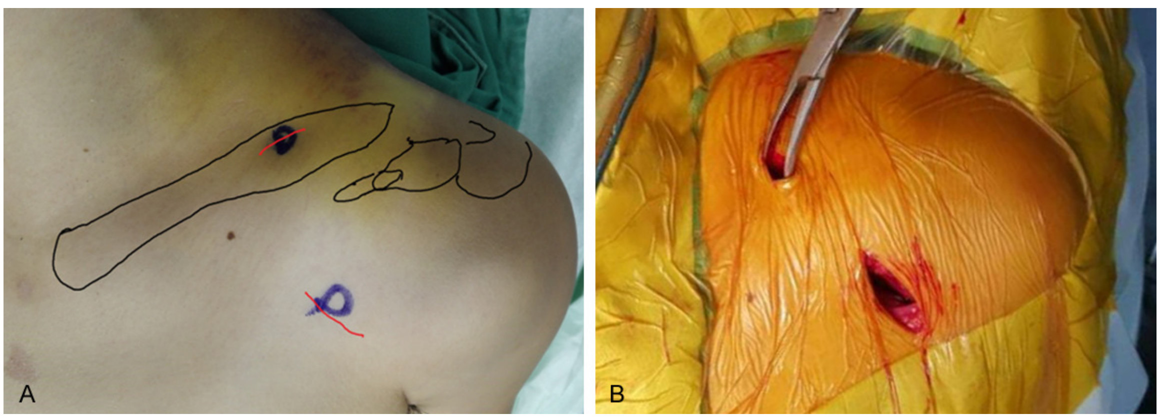

Figure 2. Longitudinal incision at both the distal clavicle and the coracoid process. A. The red marked lines on the skin are the incisions before the operation. B. The incisions during the operation.

trapezoid ligament and the substantial displacement [2]. Several surgical methods have been proposed to treat unstable distal clavicular fractures, including transacromial fixation with Kirschner wires, hook-plate fixation, locking-plate fixation, stabilization of the proximal fragment with CC screws or slings, tension band wiring, and cerclage wiring of the fragments [2-14]. However, the most reliable method has not yet been established.

In this paper, we present a novel technique by which we use AC TightRope Constant Guide (ACTRCG) (**Figure 1**) with only two minimal incisions (**Figure 2**) to fix the acute acromioclavicular joint dislocation with the TightRope® System to reduce and stabilize the distal clavicle fracture. The TightRope® System is a device that is designed to reduce and stabilize Acute Acromioclavicular Joint Dislocation, which originally utilized arthroscopes [15, 16]. It consists of two metal buttons, one circular and one oblong, joined by a continuous loop of #5 FiberWire® [17] (**Figure 1**). It provides a fast, simple, direct, reproducible, minimally invasive technique to stabilize the acute unstable distal clavicle fracture. This technique enables a rapid return to activity for the acute unstable fractures of the distal clavicle.

We hypothesized that this method would maintain the reduction of the fracture, restore the coracoclavicular space, and provide sufficient strength with the TightRope® System to maintain the reduction until union of the fracture site.

Table 1. Patient data

Patient No/ Sex/age, (y)	Time from injury to surgery, (d)	Time to bony union, (wk)	Follow-up, (mo)	Operation time (min)	Blood lose (ml)	Return to work	Modified UCLA score	Result
1/M/21	6	12	20	40	5	Yes	35	Excellent
2/M/59	2	18	20	35	5	Yes	34	Excellent
3/F/36	7	12	18	29	10	Yes	35	Excellent
4/F/32	2	12	18	32	5	Yes	32	Good
5/M/65	2	12	16	25	5	Yes	34	Excellent
6/F/46	2	12	16	32	5	Yes	35	Excellent
7/M/42	8	18	15	33	5	Yes	35	Excellent
8/F/69	2	18	12	28	5	Retired before injury	34	Excellent
9/M/21	2	12	12	25	5	Yes	35	Excellent
10/M/29	2	12	9	35	5	Yes	35	Excellent
11/M/51	2	18	8	33	5	Yes	34	Excellent

Materials and methods

From April 2014 to January 2016, 12 consecutive patients with acute, closed Neer type IIb distal clavicular fractures were treated operatively at our institution. One patient was lost to follow-up and excluded from the study. Of the remaining 11 patients, 6 were men and 5 were women. The mean age of the patients was 42.8 years (range, 21-69 years) (**Table 1**). Mechanisms of injury included car accidents (n=8) and falls (n=3). Seven patients without associated injuries were treated operatively within 3 days. Three patients with associated injuries, including 2 with pelvic fracture and 1 with head injuries, underwent surgery within 2 weeks. Two experienced orthopedic trauma surgeons (Tiecheng YU, Yi Zhao) treated all patients using the same technique. A single independent observer (Jinlu Yu) evaluated and reviewed the results for all patients.

Surgical technique

Surgery was performed with the patient under general anesthesia in a semiseated position. One intravenous dose of cefazolin (1000 mg) was administered prophylactically to all patients. A small rolled towel "bump" was placed centrally behind the patient between the scapulae to aid in clavicle reduction. The fluoroscopy unit with a large C-arm was positioned on the contralateral side to ensure appropriate radiographs before preparation. The large C-arm allowed for visualization of the entire clavicle and could be rotated to obtain anteroposterior and apical oblique images. Bringing the C-arm from the opposite side simplifies intraoperative imaging because the surgical team does not need to step away from the surgical field. The entire clavicle and upper extremity were prepared and draped free. The head was gently tilted (roughly 30°) away from the operative side to optimize the working area for the surgeon during superior to inferior placement of a drill bit.

Two small incisions were made in Langer's lines. First, a 10 mm incision was created by splitting the deltotrapezial fascia at the clavicle midline approximately 25 mm from the distal clavicle (at the distal third of the clavicle) and approximately 10 mm from the fracture point. The fracture site is identified by palpation before creating the incision. It was important to ensure that the incision was positioned at the proximal fracture segment and not at the fracture site. Another 2 cm skin incision was generated over the coracoid process, and the base of the coracoid process was exposed.

The AC TightRope Constant Guide (ACTRCG) was fixed into the two incisions. The top of the Guide Pin Sleeve of the ACTRCG was positioned through the incision over the superior clavicle. The Drill Stop tip of the ACTRCG was positioned under the base of the coracoids as close to the scapula as possible. The Centering Device of the ACTRCG helps to center the drill sleeves on the clavicle.

Using a power drill, a 2.4 mm Drill Tip Guide Pin was inserted into the guide pin sleeve and advanced through the clavicle and coracoids (**Figure 3**). The tip of the guide pin was captured by the drill stop of the ACTRCG at the base of the coracoids under direct visualization. The position of the pin in relation to the coracoids

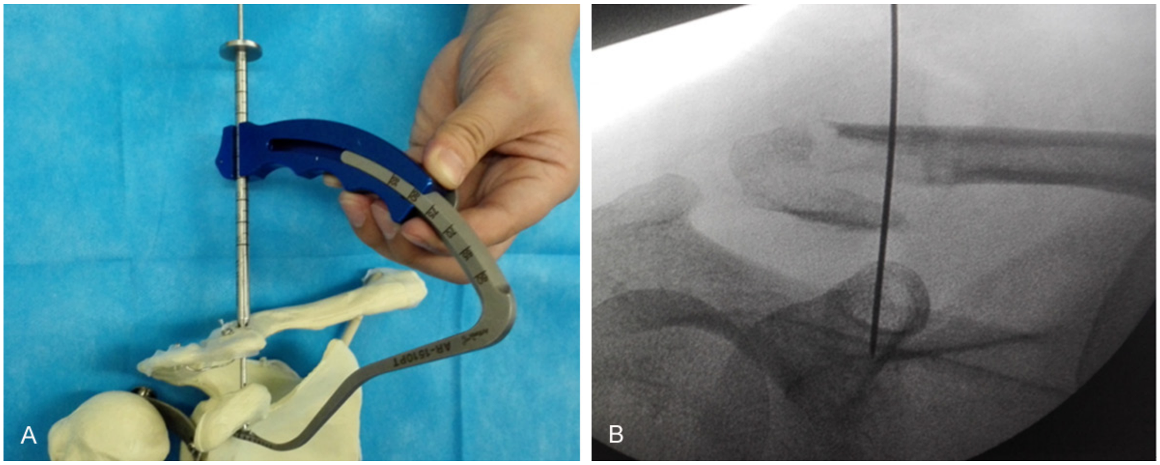

Figure 3. Insertion of the Constant Guide for the AC TightRope with the Coracoid Drill Stop and Graduated Guide Pin Sleeve through the two incisions. Position of the Drill Stop tip under the base of the coracoid as close as possible to the scapula. A. Position of the top of the Guide Pin Sleeve over the superior clavicle at its midline approximately 25 mm from the distal clavicle through a 1.5 cm incision generated in Langers lines by splitting the deltotrapezial fascia. Insertion of a 2.4 mm Drill Tip Guide Pin into the guide pin sleeve and advanced through the clavicle and coracoid using a power drill. The tip of the guide pin is captured by the drill stop at the base of the coracoids under direct visualization. B. The position of the pin in relation to the coracoids should be checked radiographically to ensure that the tip of the guide the pin is centered between the medial and lateral edges of the coracoid.

was evaluated radiographically, and the tip of the guide was checked to ensure that the pin was centered between the medial and lateral edges of the coracoid. If it was incorrectly verified by fluoroscopy, the guide pin was redrilled. The ACTRCG was removed, and the guide pin was left in situ.

Using a power drill, the 4 mm Cannulated Drill was advanced over the pin and through the clavicle and coracoids (**Figure 4A**). Cannulated drilling beyond the coracoids was stopped by the drill stop of the AC TightRope Constant Guide. Additionally, an elevator was positioned under the base of the coracoid process to prevent damage from over-penetration of the drill bit. The guide pin was removed, and the Cannulated Drill was left in situ.

A Nitinol Suture Lasso SD™ Wire Loop was advanced down through the cannulated drill, and the tip was grasped with the hemostatic forceps (**Figure 4B**). The two white traction sutures were inserted from the oblong button of the TightRope® System through the Nitinol SutureLasso SD Wire Loop (**Figure 4C**).

The suture passing wire was pulled to retrieve the two white traction sutures through the coracoid incision (**Figure 4D**). One of the two white traction sutures was pulled to flip the oblong button into a vertical position suitable for advancement through the bone tunnels. The oblong button was advanced through the clavicle and the coracoids under direct visualization until it exited the base of the coracoids. Hemostatic forceps may be used to pull both white traction sutures down until the oblong button emerges from the bone tunnel. Each of the white traction sutures of the oblong button was independently pulled to flip the button onto the underside of the coracoid base.

The distal clavicle fracture was reduced until the position was considered satisfactory by fluoroscopy. Once the fracture was reduced, both of the blue TightRope suture tails were pulled to advance the round button down to the surface of the clavicle. First, the medial TightRope must be tightened (**Figures 4E** and **5**). The sutures were tied over the top of the TightRope to generate a surgeon's knot and four additional half-hitches, reversing posts and throws. This step completed the reduction and stabilization of the acromioclavicular joint. The suture tails can be sewn under the deltotrapezial fascia to minimize the knot stack. Any remaining white traction sutures were removed by cutting and pulling them out of the buttons.

Postoperatively, pendulum exercises for the affected shoulder were encouraged, and the

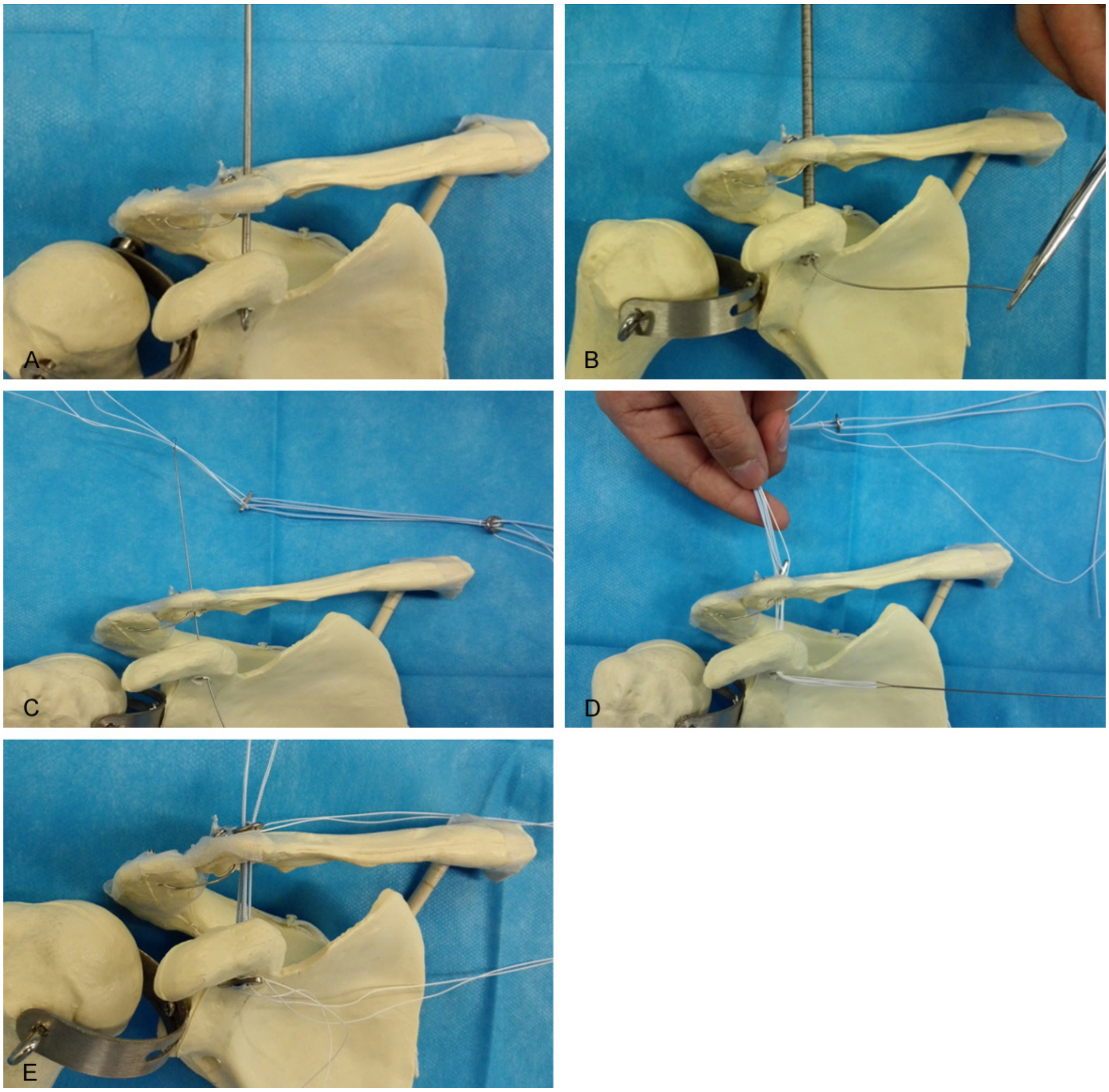

Figure 4. The procedure for coracoclavicular fixation with the TightRope® System. A. Using a power drill, the 4 mm Cannulated Drill is advanced over the pin and through the clavicle and coracoid. Cannulated drilling beyond the coracoids will be stopped by the drill stop of AC TightRope Constant Guide. The guide pin is removed, and the Cannulated Drill is left in situ. B. An 18 Nitinol Suture Passing WireWire Loop is advanced down through the cannulated drill, and the tip is grasped with hemostatic forceps. The drill is removed prior to delivering the wire tip from the coracoid incision, leaving the wire loop in a superior position. C. The two white traction sutures are inserted from the oblong button of the TightRope® system through the Nitinol Suture Lasso SD Wire Loop (AR-4068-05SD). D. The suture passing wire is pulled to retrieve the two white traction sutures from the coracoid incision. One of the two white traction sutures is pulled to flip the oblong button into a vertical position that is suitable for advancement through the bone tunnels. The oblong button is advanced through the clavicle and the coracoid under direct visualization until it exits the coracoid base. Hemostatic forceps can be used to pull both white traction sutures down until the oblong button emerges from the bone tunnel. Each of the white traction sutures of the oblong button is pulled independently to flip the button onto the underside of the coracoid base. E. Both of the blue TightRope suture tails are pulled to advance the round button to the surface of the clavicle to reduce the clavicle until the position is noted to be satisfactory under direct visualization. The TightRope must be tightened. The sutures are tied over the top of the TightRope using a surgeon's knot and four additional half-hitches, reversing posts, and throws. This step completes the reduction and stabilization of the acromioclavicular joint. The suture tails can be sewn under the deltotrapezial fascia to minimize the knot stack.

arm was protected in an arm sling for 4 weeks. Active range-of-motion exercises were then initiated. The patients were clinically and radiographically followed up at 6-week intervals until

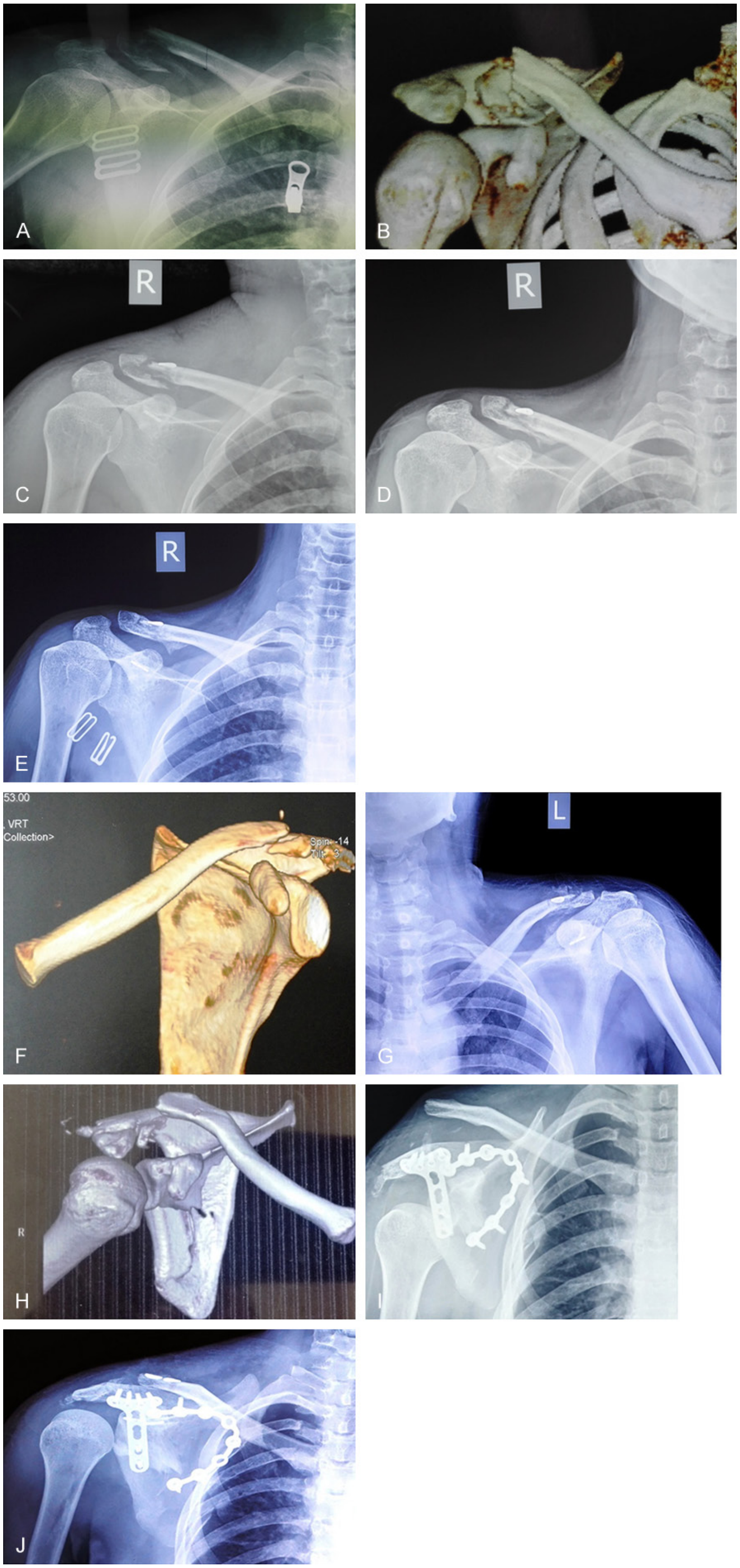

Figure 5. Images showing 3 cases with acute unstable distal clavicle fracture. A 36 year old woman with acute unstable distal clavicle fracture before (A, B) and after (C) single coracoclavicular fixation with the TightRope® System with bony union 6 weeks (D) and 12 weeks (E) after surgery. A 42 year old man with acute unstable distal clavicle fracture before (F) and after (G) single coracoclavicular fixation with the TightRope® System. A 32 year old woman with acute unstable distal clavicle fracture and ipsilateral scapula comminuted fracture before (H) and after (I) the fixation of ipsilateral scapula comminuted fracture and after (J) single coracoclavicular fixation with the two TightRope® Systems.

bony union. Bilateral anteroposterior clavicle radiographs in a standing view without stress were obtained. Bony union was clinically defined as the patient's ability to move the shoulder without pain, and radiographically defined as a solid, bridging callus or as obliteration of the fracture site (**Figure 5E**). The coracoclavicular difference was recorded after measurement of the distance between the highest point of the coracoid and the inferior border of the clavicle on both sides according to the radiographs.

The functional results were evaluated using the modified University of California Los Angeles (UCLA) shoulder rating scale, which assesses pain (maximum 10 points), function (maximum 10 points), active forward flexion (maximum 5 points), strength of forward flexion (maximum 5 points), and patient satisfaction (maximum 5 points) [7, 16]. Based on the UCLA score, the clinical results were stratified as excellent (34-35 points), good (28-33 points), fair (21-27 points), or poor (< 21 points).

Results

The mean follow-up was 14.9 months (range, 8-20 months). All fractures healed without secondary procedures. No wound infections, loss of reduction, bone erosion, or postoperative arthrosis of the acromioclavicular joint occurred. **Table 1** summarizes the data for all 11 patients. The mean union time was 14.18 weeks (range, 12-18 weeks). The mean operation time was 31.5 minutes (range, 28-40 min), and the mean blood loss was 5.5 ml (range, 5-10 ml). The mean UCLA shoulder rating score was 34.3 (range, 32-35). Ten patients had excellent results, and 1 had good results. All patients were able to resume their previous levels of activity. There was no major morbidity. One patient experienced a frozen shoulder on the treated side postoperatively. After adequate rehabilitation, the symptom resolved without complications at the final follow-up.

Discussion

Neer type IIb distal clavicular fractures have high non-union rates of up to 33-44% if treated with nonsurgical methods [1]. Many methods have been proposed for the treatment of these fractures, which includes K-wire fixation, clavicular hook-plate fixation, coracoclavicular screw fixation, modified tension-band fixation, and Bosworth-type screw fixation [2-7, 9, 11, 13, 18-25]. However, each of these methods has its own set of disadvantages [13], because the distal segment of the fracture is too small to be fixed, and fixation of the fracture must span the AC joint, which limits the natural micromotion of the AC joint [26, 27]. Currently, there is no gold standard. Although K-wire fixation is simple, it is associated with numerous complications such as pin migration, pin tract infection, and loss of reduction, which limits its application [11]. The threaded Knowles pin is more secure than a smooth pin, but the transacromial fixation can lead to acromioclavicular joint arthrosis [12, 13]. Despite the extra-articular Knowles pin fixation, which offers an indirect reduction method, the high rate of complications is its limitation (32%) [12, 13].

Clavicular hook-plate fixation has become popular in China because it is effective and simple. However, its associated complications of subacromial impingement and rotator cuff tears make it necessary to remove the hardware as soon as the fracture heals [5, 6, 25]. Additionally, the risk of acromial fracture and hook cut-out in patients with osteoporosis always accompany clavicular hook-plate fixation [5, 25]. Locking distal radius plates require more big distal fragments to fix the fracture, but the distal fragments are usually small, preventing its application [28]. Either the hook plate or the locking plate requires wide open methods to expose the clavicle fracture and a second operation to remove the hardware [7, 28]. Coracoclavicular screw fixation is a kind of rigid fixation of the coracoclavicular ligament to stabilize the distal clavicle fracture, which requires a second operation to remove the hardware [8]. The associated high failure rate (32%) makes its application more difficult [8]. It is challenging to adequately fix comminuted distal fragments with a tension band wiring [3].

Coracoclavicular stabilization with suture anchors, supplementary buttons or Mersilene tape is a reliable technique for restoring the stability of the distal clavicle fracture [3]. Clavicular erosion (11%) had been found after using anchors [5]. Unnecessary procedures may increase the extent of soft tissue stripping and devascularization. Mersilene tape stabilization is a promising method [14]; however, it is a wide open technique by which a Mersilene tape is fixed via a 5 cm incision from the distal clavicle to the coracoid process, and the anterior deltoid muscle is detached from the medial segment of the clavicle to access the base of the coracoid process [14]. Although the incision is 5 cm, it is still relatively larger than our incision. Hanflik A. et al describe an open reduction internal fixation technique that achieves both plate and coracoclavicular stabilization using a button device [29, 30]. This technique provides a simplified way to achieve coracoclavicular stabilization when using a plate for fixation of distal clavicle fractures. However, we felt that coracoclavicular stabilization with a button device was sufficient to stabilize the distal clavicle fracture, and fixation of the fracture segments with a plate was unnecessary because a solid bony union was expected. In fact, the distal clavicle fracture has only been treated by coracoclavicular stabilization with a double button using an arthroscopic technique [31, 32]. Arthroscopic surgery causes less injury to the soft tissue envelope, but there is a steeper learning curve for its application in comparison to open reconstructive procedures [33, 34]. The arthroscopic techniques requires at least four incisions: the posterior portal, two anterolateral portals and one mini open incision on top of the clavicula [33]. Although the arthroscopic portals are small, they are usually relatively deep [33].

In our series, we opened only two minimal incisions to stabilize the coracoclavicular ligaments. Single coracoclavicular fixation was used with the TightRope® system via two minimal incisions, which was effective in all patients with acute Neer type IIb distal clavicular fractures, even in those with comminuted distal fragments or osteoporosis. CC fixation with the TightRope® system restored the coracoclavicular space to reduce the fracture, and it changed the pattern of the fracture from Neer type II to type I. In the Neer classification scheme, type I provides intact restraint of the coracoclavicular ligament, and conservative treatment is indicated. Therefore, repair of the torn coracoclavicular ligament or fixation of the fracture with a plate is unnecessary because a bony union is expected. The TightRope® system is strong enough to provide restraint until bony union occurs. No hardware removal is required with this method, and the acromioclavicular joint is not damaged.

The mini-open approach produces a good cosmetic result. The Centering Device of the ACTRCG helps to center the guide pin accurately across the indicated point of both the clavicle and the coracoids, and the Drill Stop of the ACTRCG concurrently helps to prevent advancement of the guide pin too deep with the tip holder of the ACTRCG. Therefore, the ACTRCG is effective for avoiding the risk of damage to the brachial plexus, axillary artery and vein. With the help of the ACTRCG, the TightRope® system can be safely and accurately fixed to both the clavicle and the coracoids. This technique provides a simple, safe, effective, reproducible, minimally invasive technique for acute Neer type IIb distal clavicular fractures that enables a rapid return to activity, results in minimal scarring, and does not require metalwork removal. This procedure may be associated with a risk of clavicle or coracoid erosion, or even fracture of the coracoid tip. Nevertheless, such complications did not occur in our series during the mean 12 months of follow-up.

The limitations of our study include the mid-term follow-up and small number of patients. In general, the incidence of unstable distal clavicle fractures is low, and large numbers of patients are difficult to obtain. Our study is a large case series in comparison to the majority of studies in the literature. However, larger study populations are required to confirm the present results. Long-term follow-up may be necessary to assess the incidence of acromioclavicular arthritis and clavicular erosion by suture materials.

Conclusion

Unstable distal clavicle fractures are associated with a high risk of non-union, and therefore operative treatment is favored. Various surgical methods can be found in the literature, but no gold standard has been established. Based on the results of the present study, this simple, fast, mini-open technique with coracoclavicular fixation by the TightRope® system can stabilize the acute unstable distal clavicular fractures and offer a satisfactory outcome at a mid-term follow-up.

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Disclosure of conflict of interest

None.

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