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Original Article

Treatment of Neer type-II distal clavicle fracture with a locking plate combined with trans-acromioclavicular tension band

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Abstract: Background: Surgical treatment of Neer type-II distal clavicle fracture is extremely challenging for surgeons. Since we discovered abduction limitations with the conventional hook plate surgical technique, we developed a new surgical procedure that combines trans-acromioclavicular tension bands with locking plates for these fractures. Material and methods: In this retrospective study, 34 patients who had have been treated surgically in Shanghai Jiao Tong University Affiliated Sixth People's Hospital between 2010 and 2014 were included. Outcomes of hook plate (n=16) and the new technique (n=18) interventions for Neer type-II clavicle fractures were compared. The coracoclavicular distance, union time, time of implant removal, shoulder function and complications were determined. For clinical evaluations, the constant score and the Disabilities of the Arm, Shoulder and Hand (DASH) scores were recorded at the last visit with a follow-up time of 17.7 months (12-23). Results: All patients achieved bony union with no delayed union or nonunion being observed. There was no significant difference in the bony union time and radiographic performance after surgery in the two groups. Significantly better clinical manifestations including shoulder abduction, the constant and DASH scores before and after implant removal were observed in fractures fixed with the new technique. Conclusion: The combination of a distal clavicle locking plate and a trans-acromioclavicular tension band is a useful new technique for the treatment of Neer type-II clavicle fractures.

Keywords: Neer type-II distal clavicle fractures, hook plate, locking plate, tension band

Introduction

Distal clavicle fractures account for approximately 15% of clavicle fractures and were subclassified into 3 types by Neer [1]. Type I and Type III fractures are stable fractures by definition, and commonly managed with non-surgical treatments. In type II fractures, the coracoclavicular (CC) ligaments are detached from the medial fracture fragment, caused by interactions of the arm weight, the trapezius muscle and scapular rotation. These fractures are unstable and grossly displaced. Given the relative instability of type II fractures and the high nonunion rate with conservative treatments, surgery has been proposed, especially for younger and more active patients [2, 3].

However, surgical fixation is extremely challenging because of the deforming forceson the proximal clavicle and distal fragment comminution. Several techniques have been introduced, including K-wire [1], Knowles pin [4], tightrope [5], hook plate [6], which yielded variable clinical outcomes, and these techniques were associated with a number of complications such as dangerous wire migration and subacromial impingement [7-9].

The purpose of the present study was to compare conventional hook plate surgery with a new surgical procedure that combines a trans-acromioclavicular tension band and a locking plate together for Neer type II distal clavicle fractures.

Material and methods

The study received Human research ethics approval from the Sixth People's Hospital of

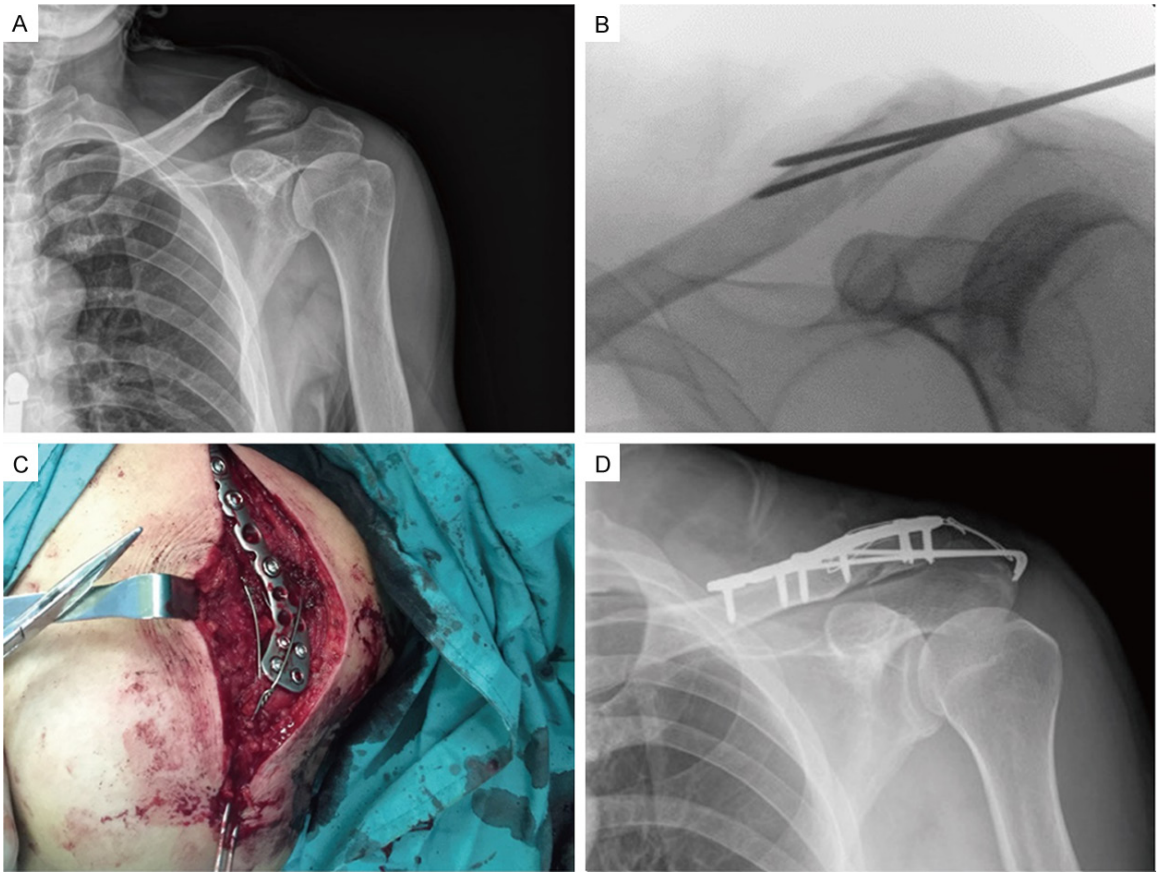

Figure 1. The operation technique: A. Radiograph after injury. B. Radiograph in operation. Two Kirschner wires were inserted in parallel from the outer margin of the acromion, penetrating the acromioclavicular joint and the fracture site to maintain the reset. C. After plate fixation, a steel wire was used in a figure of eight configuration. D. Radiograph after the operation.

Shanghai Jiao Tong University Office of Research Ethics, the office approved that verbal consents obtained by telephone were enough because this study is retrospective and all the radiographs and data needed in this study were recorded in the case system of our hospital, in addition, surgical informed consent had been signed before operation. All patients were diagnosed with Neer type-II distal clavicle fracture by shoulder anteroposterior and lateral radiographs preoperatively, and the fracture types were confirmed again during the operations (**Figure 1A**). Inclusion criteria were operative fractures with a minimum of 1-year follow-up and an age older than 16 years, while exclusion criteria were other types of distal clavicle fractures, concomitant injuries of the affected arm, and open fractures.

Finally, 34 patients with Neer type-II distal clavicle fractures who were treated between 2010 and 2014 were included in this study. The same surgeon, who used hook plates at the beginning of the study period, performed all the operations; these patients represented the control group (n=16). With the discovery of abduction limitation with hook plate treatment, the surgeon developed and applied a new technique to the subsequent group of patients (n=18).

Surgical technique

After successful anesthesia, the patient was placed in the beach chair position. An incision was made from the middle part of the clavicle to the outer margin of the acromion. After detachment of the surrounding soft tissue, the fracture site, the acromioclavicular joint and the acromion were exposed without dissection of the joint capsule. The displaced distal fracture was then reduced using reduction forceps. Forhook plate fixation, an appropriate hook

plate was chosen and applied with the hook positioned under the acromion, posterior to the acromioclavicular joint. If necessary, the hook plate was bent to fit the clavicle and finally the plate was fixed to the clavicle using several screws.

In the new technique cohort of patients, after reduction, two 2.0 mm Kirschner (K)-wires were inserted in parallel from the outer margin of the acromion, penetrating the acromioclavicular joint and the fracture site and finally to the proximal clavicle (**Figure 1B**). Thereafter, a locking plate of appropriate length was placed onto the superior surface of the distal clavicle to fix the distal clavicle fracture. Following completion of plate fixation, a tension band spanning the acromioclavicular joint and distal fracture adjunctively stabilized the distal clavicle fracture. First, a drill tunnel was made in the proximal part of the fracture vertical to the clavicle axisanteroposteriorly, and then a 1.0-mm diameter stainless steel wire was placed through the tunnel, over the surface of the plate in a figure of eight configuration and by passing the blunt end of the two previous K-wires that were used for fixation. The ends of the K-wires were bent and tap over onto the acromion to increase their stability beneath the skin (**Figure 1C**). After radiographic confirmation of reduction, the incision was closed (**Figure 1D**).

Rehabilitation

Active motion of the shoulder immediately after the operation was encouraged. Asling was used to protect the shoulder for 2 weeks when the patient was resting. Us ualdaily activities were permitted 2 weeks postoperatively within acceptable pain tolerance, except for weight bearing and extreme elevation of the arm of the operated side, which were prohibited until bony union. The implant was removed at least 6 months after surgery.

Follow-up

Standard shoulder anteroposterior and lateral radiographs were taken every 4 weeks after the operation until fracture union was observed. Union was defined as bony bridging between the fracture fragments and confirmed by clinical manifestations; delayed union was defined as lack of any healing on plain radiographs within 3 months and nonunion was defined as lack of any healing on plain radiographs within 6 months. Patients were followed up every 4 weeks before radiographic union and 3 months after union, until the implant was removed. For clinical evaluations, the constant score and the DASH scores were recorded at the last visit.

Data collection

Data was collected by the same surgeon from the medical board, including basic patient information (age, sex), exact cause of injury, the surgical method used, bony union time, major postoperative complications, secondary surgical procedures, as well as pre- and postoperative coracoclavicular (CC) distances [10], DASH [11], and constant scores [12] before and after implant removals.

Statistical analysis

The data including the sex and arm infected was compared using chi-square test, the constant and DASH score of the two groups after implant removal were assessed using the repeated measure ANOVA. Other continuous variables were analyzed using independent sample t test. The statistical analysis was performed with SPSS and significant difference was considered when $P<0.05$.

Results

The mean age of the patients in the hook plate group was 38.4 years (range 18-52 years) and in the new technique group it was 41.7 years (range 15-63 years). 66.7% of patients in the hook plate group had the right arm affected and 68.8% in the new technique cohort. There was no significant difference between periods from injury to surgery (2.19 days vs 2.44 days); a little more time was spent during surgery using the new technique (66.6 minutes vs 58.9 minutes) (**Table 1**).

All patients were followed up for an average of 17.65 months (12-23 months) and all patients had bony union, no delayed union, or nonunion was observed. The mean period until bony union was 12.1 weeks (range 8-16 weeks) for hook plate fixation and 11.6 weeks (range 8-16 weeks) for the new technique fixation ($P>0.05$). In preoperative radiographs, the CC distance before operation in the two groups was not

Table 1. Patient demographics and clinical characteristics

	Hook plate group	New technique group	T or χ^2	P
Number of patients	16	18		
Gender, M/F	12/4	12/6	χ^2 = 0.283	0.595[b]
Age (years)	38.44±10.82 (18-52)	41.67±13.42 (16-63)	t = 0.766	0.449[a]
Arm (R/L)	11/5	12/6	χ^2 = 0.017	0.897[b]
Time from injury to surgery (days)	2.19±0.83 (1-4)	2.44±0.70 (1-4)	t = 0.974	0.338[a]
Surgery time (minutes)	58.94±6.90 (47-75)	62.61±7.63 (52-75)	t = 1.465	0.153[a]
Time of follow up (months)	17.56±3.03 (13-23)	17.72±3.25 (12-23)	t = 0.148	0.884[a]
Time for implant removal (months)	8.5±2.37 (3-12)	13.28±1.53 (10-16)	t = 7.075	<0.001[a]

Data are expressed as mean (range) unless stated otherwise; [a]independent samplet test; [b]chi-square test.

Table 2. Efficacy of treatment with the two technique and complications

	Hook plate group	New technique group	T	P
Bony union time (weeks)	11.63±22.28 (8-16)	12.11±2.40 (8-16)	0.604	0.550[a]
*ΔCC_1 (mm)	12.23±4.19 (1.87-23.54)	12.67±4.49 (1.9-20.9)	0.296	0.769[a]
*ΔCC_2 (mm)	0.73±0.47 (0-1.5)	0.79±0.53 (0-1.97)	0.332	0.742[a]
Constant score before implant removal	71.19±13.67 (54-100)	94.33±4.01 (88-100)	6.868	<0.001[a]
Constant score after implant removal	90.12±6.39 (80-100)	988.72±1.87 (95-100)		<0.001[b]
DASH score before implant removal (range)	24.83±10.21 (0-43.3)	8.21±5.76 (0-21)	-5.935	<0.001[a]
DASH score after implant removal (range)	10.04±7.36 (0-23.3)	4.64±4.26 (0-15.8)		<0.001[b]
Complications	1 patient with midshaft clavicle fracture	1 patient with pin withdrawal		

*ΔCC_1 the d-value between CC distance of the injured shoulder before operation and CC distance of the unaffected shoulder; *ΔCC_2 the d-value between CC distance of the injured shoulder after operation and CC distance of the unaffected shoulder; [a]independent samplet test; [b]repeated measure ANOVA.

obviously different and decreased significantly, becoming nearly equal to the unaffected shoulder after the operation. No significant increase in CC distance was observed both in the hook plate and new technique group at the last visit (**Table 2**).

Patients in the hook plate group had implant removal at a mean time of 8.5 months postoperatively (range 3-12 months), which is significantly earlier than the new technique group (13.28 months, range 12-16 months) and was attributed to lower constant (71.19 vs 94.33) and higher DASH scores before implant removals (24.83 vs 8.21). Sixteen patients had shoulder abduction of more than 90 degrees in the new technique group but only 3 patients in the hook plate group. At the last visit, patients in both groups had improved shoulder function, however, more satisfactory clinical performance was observed in the new technique compared to the hook plate group (Constant score 98.7 vs 90.1 and DASH scores 10 vs 4.6) (**Table 2**). The statistical analysis with repeated measure ANOVA further showed that implant removal of the hook plate improved the shoulder function more obviously than the new technique (P<0.001). No incision infection was observed in the present study. One patient with hookplate fixation suffered a midshaft clavicle fracture 3 months postoperatively, due to heavy loading (**Figure 2A**) and finally experienced hook plate removal and internal fixation with a reconstruction plate. No fixation failure was observed in the new technique group; only 1 patient had pin irritation 8 weeks postoperatively and the pins were removed in the outpatient room under regional anesthesia (**Figure 2B**).

Discussion

Neer divided distal clavicle fracture into 3 types according to the fracture site and the integrity of the CC ligaments, which consist of the trapezoid ligament and conoidligament medial to the trapezoid ligament. The importance of the CC ligaments has been well illustrated [13, 14]. In type I and type III fractures, the fracture site is located lateral to both the CC ligaments and the CC ligaments remain intact to bind the medial clavicle fragment to the coracoid, to prevent significant displacement. They are inherently stable and need no special surgical treat-

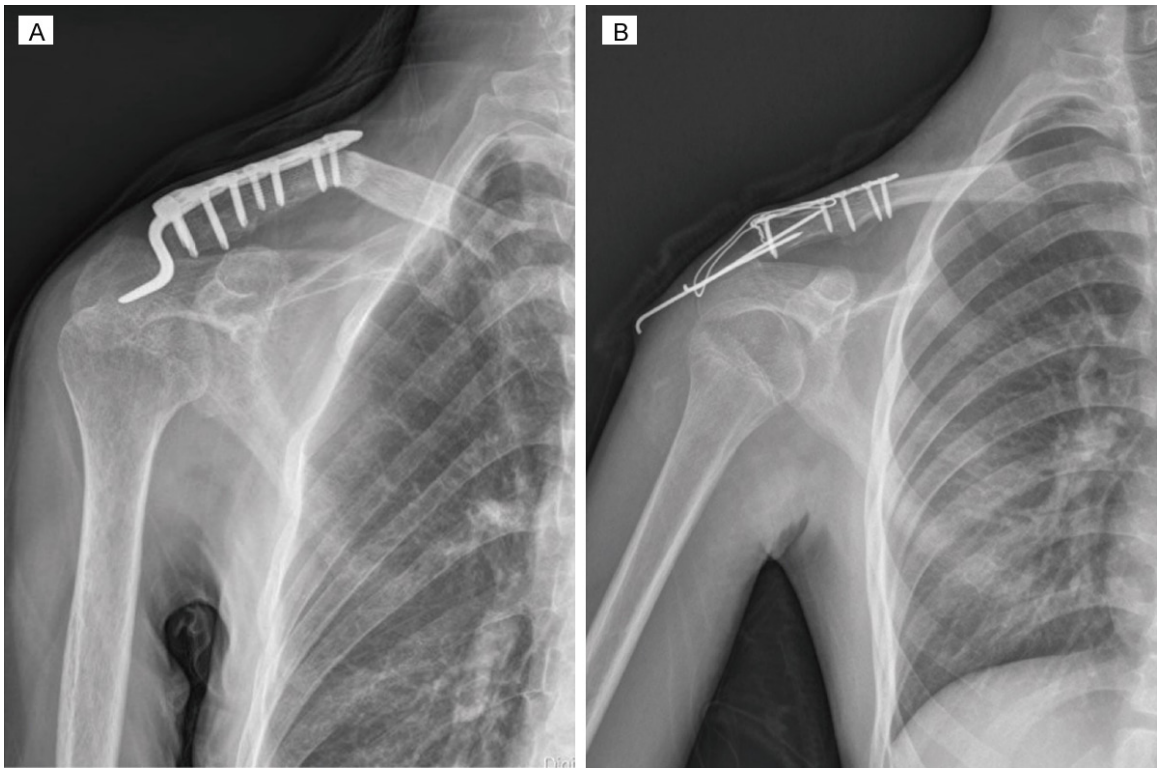

Figure 2. Complications in each group: A. One patient with hook plate fixation suffered midshaft clavicle fracture 3 months postoperatively due to heavy loading. B. One patient with a combined locking plate and tension band fixation had the pin withdrawn 8 weeks postoperatively.

ment but in a type II fracture, the CC ligaments are detached from the medial fragment. This fracture is sub-classified into type IIa and type IIb. A type IIa fracture occurs just medial to the CC ligaments and a type IIb fracture is located medial to the trapezoid ligament, with the conoid ligament torn from the proximal part [1, 15]. Both IIa and IIb fractures are unstable due to the unhindered downward pull of the arm on the distal fragment and the unimpeded upward pull on the medial fragment by the trapezius muscle [7].

Many authors have reported a high nonunion rate for Neer type-II fractures with conservative methods [2, 16]. With the strut function maintaining the thorax-scapul adistance and assistance with the external, upward and posterior rotation of the scapula, clavicular discontinuity will cause shoulder dyskinesis, leading to clinical symptoms [17, 18]. The hook plate has been widely used in the treatment of distal clavicle fractures because of a simple operation technique, an accurate maintenance of reduction and the low risk of implant migration. However, patients were advised to avoid movement above 90° in flexion or abduction postoperatively [19, 20] and many authors have reported that the hook plate may cause subacromial shoulder impingement, rotator cuff lesion, omalgia and even peri-implant fractures medial to the hook-plate fixation [9, 21-25]. In our study, we found poor shoulder function in patients fixed with a hook plate, especially before removal of the implant.

Several methods have been designed to prevent the hook plate from affecting the shoulder joint. Chen and colleagues suggested coracoclavicular suture fixation with Mersilene tape could provide early recovery of shoulder motion and avoid further morbidity of the acromion for acute unstable distal clavicle fracture [26]. Shin et al recommended inter-fragmentary fixation with a suture tension band and reconstruction of the coracoclavicular ligament with two suture anchors [27]. In addition, a double button device and tightrope fixation between the proximal fracture and coracoid undersurface were also advised for unstable distal clavicle

fracture with or without arthroscopic treatment [5]. However, these procedures were relatively complicated and usually resulted in wide exposure of the coracoid process and increased the danger of neurovascular injury.

Other surgical techniques not involving the coracoid process have been introduced as well. Fann et al [4] introduced a transacromial threaded Knowles pin for Neer type-II distal clavicle fracture. In their study, all 32 patients showed excellent results with solid union. There was only 1 case of acromioclaviculararthrosis. To avoidacromioclavicular injury, Wang and Wong recommended extra-articular Knowles pin fixation in conjunction with coracoclavicular ligament repair and achieved 92% uneventful unions [28]. However, these techniques were not suitable for distal comminuted fractures, and early functional exercise may not be allowed for the relatively low stability of fixation compared to the plate.

A distal clavicle locking plate possesses expanded precontoured ends incorporating more screws for fixation, to provide a stronger holding force, even for small fragments. It could also avoid the acromioclavicular joint, preventing arthrosis and subacromial impingement. Fleming et al [7] reported the fixation of type II fractures by superior precontoured locking plates supplemented with a cerclage suture to hold the distal comminuted fragments, resulting in 100% union and excellent functionality. However, the stability they provided was limited given the micro movement of the trans-acromioclavicular joint.

Tsuei et al [29] suggested that the trans-acromioclavicular joint tension band couldconvert tensile forces from the upper limb and trapezius muscle into compression at the fracture site. In their study, trans acromial pins with additional tension band wire resulted in fewer complications for Neer type-II fractures than trans acromial pins alone. In our opinion, for cases of distal comminution fractures, which necessarily makes the application of extra-articular fixation difficult, a trans-acromioclavicular joint tension band is more applicable. Distal clavicle fracture is often combined with acromioclavicular joint injury, including a slack acromioclavicular ligament and a widened joint space, unstable fixation of comminuted fragments and the injured acromioclavicular joint may be the major reasons for implant failure, delayed or nonunion, and usually resulted in shoulder pain that inhibited active motion. In our study, we stably fixed the acromioclavicular joint and the distal clavicle fracture together with a trans-acromioclavicular joint tension band, without affecting shoulder function significantly due to amphiarthrosis. Therefore, under stable fixation, patients were permitted active functional exercise soon after their operations and a full range of movement was possible 2 weeks postoperatively.

For a Neer type-IIb fracture with the conoid ligament torn and irregularly detached from the proximal fragment, direct suturing of the ruptured ligament remains difficult, Therefore, indirect ligament construction and expecting healing with a scar became popular [26, 27]. Moreover, we considered that because in a Neer type-II fracture, the CC or the trapezoid ligaments still remain intact and attached to the distal clavicle fragment, it is unnecessary to repair the CC ligament. The strength of fracture fixation with a plate and tension band, and the fixation of the acromioclavicular joint, resists the upward pull on the medial fragment by the trapezius muscle.

In our study, we combined a distal clavicle locking plate with atrans-acromioclavicular tension band and achieved excellent clinical outcomes. With this technique, we strengthen the fixation with the plate alone, avoiding the lateral screw pullout due to the pull of the proximal clavicle part. In some situations, the comminuted distal fracture makes application of these plates technically difficult buttension band fixation aided the reduction and fixation of comminuted fragments.

Magnetic resonance images showed that during arm abduction, the scapula moved relative to the clavicle [30]. Rotation of the clavicle due to shoulder movement may cause migration of the K-wire. However, bending the blunt end and fixing the tension band minimized pin migration. We observed pin migration in all patients and only one patient had mild irritation of the acromial skin. We did not observe any acromioclavicular joint arthritis, which could cause chronic pain of the shoulder after implant removal. Bony union was observed in all patients and there were no fixation failures.

In addition, 1 patient in our study was observed with local incision numbness, which recovered 6 weeks later. The numbness might have been caused by the injury of the lateral branch of the supraclavicular nerve along the incision. However, the branch is too thin to figure out and not important as a local sensory nerve. Therefore, we did not pay close attention to this nerve branch during surgery.

Conclusion

As an alternative fixation procedure for treating Neer type-II clavicle fracture, adistal clavicle locking plate combined with a trans-acromioclavicular tensionband is promising. This method can provide anatomical reduction and stable fixation and allow early shoulder movement after the operation.

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Disclosure of conflict of interest

None.

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