

T-plate fixation for unstable proximal clavicle fractures

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ARTICLE INFO

Article history:

Received 3 September 2017

Received in revised form

30 October 2018

Accepted 28 November 2018

Available online 11 December 2018

Keywords:

Clavicle fracture

Proximal

Sternoclavicular ligament

Plate

Internal fixation

ABSTRACT

Objective: The aim of this study was to evaluate the clinical results of T-plate fixation and anterior sternoclavicular ligament repair in proximal clavicle fractures.

Methods: Between August 2013 and August 2016, a total 12 patients (10 men and 2 women; mean age: 44.1 ± 9.1 years (range, 25–59 years)) with unstable proximal clavicle fractures (Throckmorton, type D) were treated with T-type plate fixation, bridging the sternoclavicular joint, and anterior sternoclavicular ligament repair. Average operative time, associated injuries, postoperative complications, postoperative fracture healing time and follow-up time were recorded. The outcomes were evaluated with radiographic assessment, visual analog scale (VAS) pain score and Rockwood SCJ scoring system. All the patients were evaluated on postoperative 3rd, 6th, and 12th months.

Results: The average surgery time was 78.0 ± 8.47 minutes while fracture healing time was 4.51 ± 0.95 months. According to Rockwood SCJ scoring system, 9 cases (75%) were in excellent, 2 cases (16.7%) in good and 1 case (8.3%) in fair condition at 12 months follow-up. The average Rockwood SCJ score was 7.7 ± 0.75 preoperatively, 12.7 ± 0.86 by 3 months, 13.0 ± 0.73 by 6 months and 13.3 ± 0.49 by 12 months. The VAS pain score was 7.9 ± 1.15 (preoperative score), 3.4 ± 1.52 (3 months follow-up), 3.0 ± 1.32 (6 months follow-up) and 2.1 ± 1.07 (12 months follow-up). The VAS and Rockwood SCJ scores were significantly improved postoperatively ($p < 0.05$). There was no intraoperative complication, while one patient had redislocation of the sternoclavicular joint after implant removal.

Conclusion: T-type plate fixation with anterior sternoclavicular ligament repair might be a reliable and effective treatment method in unstable proximal clavicle fractures (type D) with few complications and satisfactory clinical results after 12 months follow-up.

Level of evidence: Level IV, therapeutic study.

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Introduction

Treatment of proximal clavicle fractures remains a controversial topic in orthopedics. Proximal clavicle fractures have lower incidence than fractures of the middle third and distal clavicle fractures, accounting for approximately 5% of all clavicle fractures.¹ Proximal clavicle fractures were first described by

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Peer review under responsibility of Turkish Association of Orthopaedics and Traumatology.

Robinson, who classified proximal fractures into 2 types, The majority of these cases could be successfully managed conservatively.² However, type D (Comminuted fracture, proposed by Throckmorton) poses a challenging problem.³ The fracture can be significantly displaced as a result of strong forces-the sternocleidomastoid muscle pulls the medial fragment superiorly.⁴ Consequently, malunion and sternoclavicular joint pain are common with conservative treatment. In addition, the recover period can be prolonged with nonsurgical treatment. Therefore, surgical management of proximal clavicle fracture is an attractive alternative method.

Currently, there are no standard methods for managing unstable and comminuted fractures of proximal clavicle fractures, although various techniques have been described, including Kirschner wires and plates fixation.⁵ However, complications of these methods are

relatively common, such as artery and vein injuries, sternoclavicular joint mobility.⁶

In order to overcome these problems, T-type plate fixation and anterior sternoclavicular ligament repair were applied in this study to assess the clinical therapeutic outcomes for the treatment of proximal clavicle fractures.

Patients and methods

Patients

Between August 2013 and August 2016, a total of 12 patients including 10 males and 2 females with unstable proximal clavicle fractures were treated with T-type plate fixation and anterior sternoclavicular ligament repair in our hospital for this prospective study (Table 1).

Inclusion criteria and exclusion criteria

Selection criteria: (1) Type D fresh proximal clavicle fracture according to Throckmorton classification (Fig. 1); (2) the range of age was 25–60 years old; (3) patients without underlying diseases such as cardiac diseases. Exclusion criteria: (1) pathological fractures; (2) open fractures; (3) combined with injuries of blood vessels or nerves.

Standard protocol approvals and patient consents

All human studies were authorized by the Hospital Ethics Committee and conducted in accordance with the ethical standards. The written informed consent was obtained from all study patients.

Surgical procedures

Surgery was performed under general anesthesia in the semi-sitting position. All patients underwent the same surgical procedure (T plate fixation combining with repairing anterior

sternoclavicular ligament). A traverse small incision was made at the medium end of clavicle and sternoclavicular joint. The fracture was fully exposed and anatomically reduced by reduction forceps. After anatomic reduction, one 2-0 Ethibond Excel suture (Johnson Inc, New Brunswick, NJ, USA) was used to cross suture to repair anterior sternoclavicular ligament (Fig. 2A). Then a T-type locking plate (AO, Swiss) was bridged the sternoclavicular joint. A 2.5 mm limited depth drill was used to create 2 and 3 screw channels in proximal clavicle and manubrium sterni respectively to protect deep tissue (such as ascending and descending aorta, subclavicle aorta). Finally, the locking plate was fixed with screws. X-ray radiography below the shoulder was routinely used to examine the reduction of fracture and the location of plate (Fig. 2B). Moreover, similar medicine treatments before and after the operation were used to the patients.

Postoperative management

All 12 consecutive patients were enrolled in the study. All patients were treated with arm sling for 6 weeks after operation. In addition, 3 days after operation, patients were permitted to do passive anteflexion and abduction motion of shoulder joint under the guidance of physiotherapists, and the motion range could be increased gradually depending on the degree of pain and postoperative X-ray and CT scan images (Figs. 3 and 4). However, the weight-bearing exercise was not allowed. The weight-bearing exercise was begun gradually after 6 weeks postoperatively. The postoperative follow-up visits were scheduled every four weeks until bone union and every 3 months after bone union.

Evaluation of therapeutic efficiency

The operative data were recorded and analyzed, including operation time, postoperative complications. The standards of bone union included no tenderness of the fracture ends when performing active exercises and weight-bearing activities on the clinical examinations, the formation of continuous callus and the disappearance of fracture line. The evaluation was made by an independent surgeon, who was blinded to the operation and implants. The improvement of subjective pain was assessed with visual analog scale (VAS) pain score, sternoclavicular joint function was assessed with the Rockwood scoring system of sternoclavicular joint (range: 0–15 points, best: 15) at the consecutive follow-up. In detail, Rockwood scoring system of sternoclavicular joint is categorized as follows: excellent (13–15), good (10–12), satisfactory (7–9), and fair (<7).⁷

Statistical analysis

All the statistical analysis was performed with SPSS version 18.0 software (SPSS Inc, Chicago, IL, USA). The values were presented as mean \pm SD. The data were analyzed using the method of paired *t*-test and *P* < 0.05 was considered statistically significant.

Results

In this study, the average age was 44.1 ± 9.1 years (range, 25–59 years), 7 patients were in right proximal clavicle fracture and 5 in left. The causes of fractures included motor vehicle accident (5 cases), injuries of falling off bicycles (4 cases), falling down (3 cases) (Table 1). Two cases had unilateral femoral neck fracture, one patient had unilateral calcaneus fracture. The average operative time was 78.0 ± 8.47 min (range from 70 min to 98 min). All the cases were evaluated by the clinical function and imaging during the follow-up time (Figs. 5–7). The mean follow-up period was 22.7

Table 1
Gender/age (Years), Operative time (Min), Cause, Associated, Follow-up (Months) in 12 patients.

Patient number	Gender/age (Years)	Operation time (Min)	Cause	Associated injury	Follow-up (Months)
1	M/42	79	motor vehicle accident	No	23
2	M/37	68	falling off bicycles	No	12
3	F/52	75	motor vehicle accident	No	24
4	M/50	70	falling off bicycles	No	27
5	M/25	72	motor vehicle accident	No	18
6	M/48	82	falling down	femoral neck fracture	26
7	M/41	80	motor vehicle accident	No	16
8	M/40	68	motor vehicle accident	No	21
9	F/59	78	falling off bicycles	No	30
10	M/36	83	falling down	calcaneus fracture.	25
11	M/51	98	falling down	femoral neck fracture	24
12	M/49	84	falling off bicycles	No	27

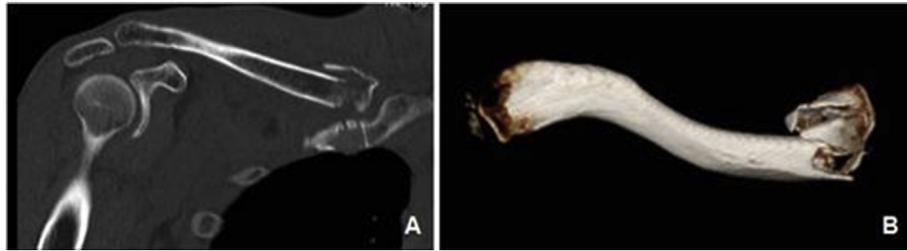


Fig. 1. A: Preoperative CT scan; B: 3-dimentional CT of proximal clavicle fracture.

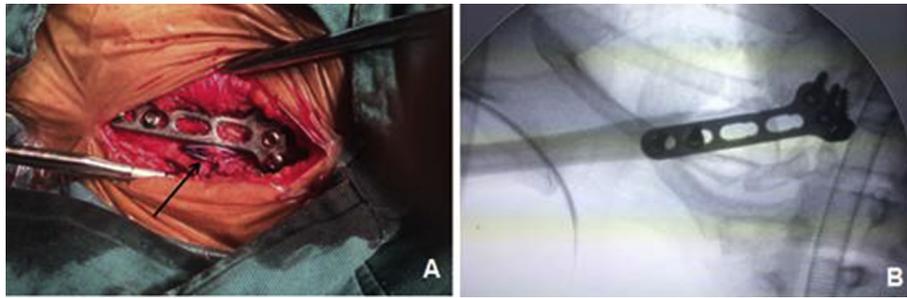


Fig. 2. A: repaired sternoclavicular ligament; B: Intraoperative X-ray showed good reduction of proximal clavicle fracture.

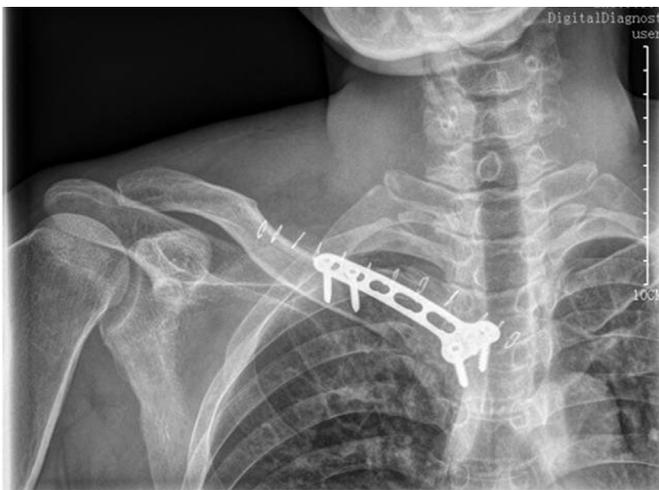


Fig. 3. Postoperative A-P X-rays.

months (range: 12–30 months). No nonunion case was found in all the patients. The mean time of bone union was 4.51 ± 0.95 months. Postoperative complications, such as infection, incision numbness, withdrawal of screws, were not found. The T-plates were removed after a mean time of 15 months after operation, no re-fracture occurred after removal. 11 cases were found with no reduction failure during postoperative follow-up, whereas 1 patient was revealed redislocation of the sternoclavicular joint after removing implants.

According to Rockwood SCJ scoring system, the average score was 7.7 ± 0.75 (preoperative score), 12.7 ± 0.86 (3 months follow-up), 13.0 ± 0.73 (6 months follow-up) and 13.3 ± 0.49 (12 months follow-up) (Table 2). Meanwhile, VAS pain score was 7.9 ± 1.15 (preoperative score), 3.4 ± 1.52 (3 months follow-up), 3.0 ± 1.32 (6 months follow-up) and 2.1 ± 1.07 (12 months follow-up). Statistics differences was showed between preoperative and 3,6,12 months follow-up score of Rockwood SCJ score and VAS pain score

($p < 0.05$). According to Rockwood SCJ scoring system, 75% patients showed excellent results, 16.7% showed good results, 8.3% showed fair results.

Discussion

Proximal clavicle fractures are rare in clinical activities. In general, proximal clavicle fractures can be treated non-operatively except for comminuted proximal clavicle fractures.^{8,9} However, there is no standard method to deal with comminuted proximal clavicle fracture. Proximal clavicle fracture was proposed by Robinson, Throckmorton refined the classification of proximal clavicle fractures, which were divided into five types.³ On the other hand, the sternoclavicular joint (SCJ) allows clavicle movement in three planes, the most common mechanism of SCJ injury is a direct blow to the shoulder from a fall or during sports-related activities.¹⁰ A direct lateral impact might have caused proximal clavicle fracture and disrupted the sternoclavicular ligaments according to a lever mechanism at the end of medial clavicle head.^{11,12} Similar to other medial clavicle injuries, the proximal clavicle fractures and sternoclavicular ligaments injuries are difficult to detect through plain X-ray alone. Thus, early CT scanning is recommended to confirm the injury types.

Proximal clavicle fractures (Throckmorton type A, B, C) were treated with nonsurgical methods.¹³ As for type D, Early techniques (kirschner wires, plate fixation) combined with high rates of relative complications.^{14,15} Painful sternoclavicular joint and malunion frequently occurred with kirschner wires fixation. In addition, implant migration, irritation of screws were common, most researchers recommend the removal in all patients once fracture healing is confirmed.^{16,17} On the other hand, the anterior sternoclavicular ligament was the most affected structure during retraction and depression.¹⁸ Many fixation techniques were available. According to previous researches, some techniques were used to repair capsuloligament through ligamentoplasty by means of natural or synthetic implants, internal fixation devices such as cerclage wirings, cannulated screws with subclavious muscle tendon.^{19,20}

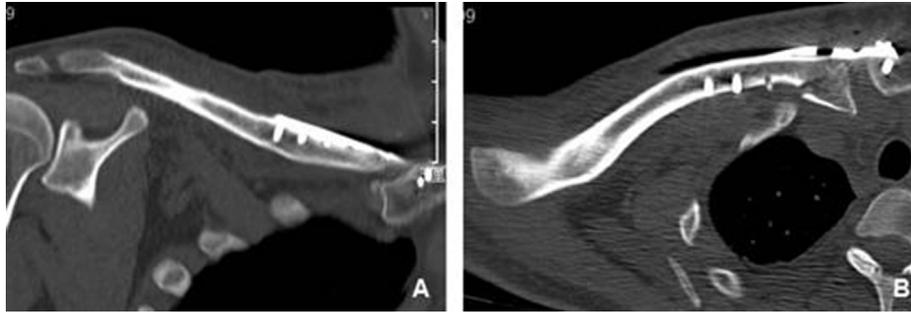


Fig. 4. Postoperative CT scan images.

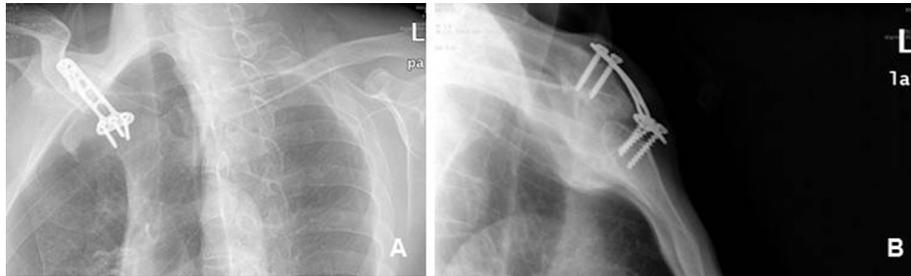


Fig. 5. A: Postoperative A-P X-ray of the patient after 3 months follow up; B: lateral chest X-ray.



Fig. 6. A, B: General views of the patients after 3 months follow up.



Fig. 7. A, B: Postoperative A-P X-ray of the patient after 12 months follow up; B: lateral chest X-ray.

T-type plate fixation with repairing anterior sternoclavicular ligament presented a challenge to surgeons because of anatomic complexity of the area (such as ascending and descending aorta, subclavicle aorta). However, the previous studies also indicated that it was safe and feasible to place three 2.7 mm screws on presternum.²¹

The indications of this technique include comminuted fracture of the medium end of clavicle, dislocation of sternoclavicular joint,

revision operation (such as malunion or nonunion of proximal clavicle fracture).

The clinical results of 12 patients validate the use of T-type plate and repairing anterior sternoclavicular ligament for type D proximal clavicle fracture. Fracture union was observed in all cases, Statistics difference was showed between preoperative and 3,6,12 months follow-up Rockwood SCJ score and VAS pain score ($p < 0.05$), whereas 1 patient was revealed redislocation of the

Table 2
Rockwood scoring system of sternoclavicular joint of preoperation, 3,6,12 months follow-up.

Patient number	Rockwood score (pre-op)	Rockwood score (3 months post-op)	Rockwood score (6 months post-op)	Rockwood score (12 months post-op)
1	7	12	13	14
2	8	13	13	13
3	7	14	14	14
4	9	12	12	13
5	7	14	14	14
6	8	12	13	13
7	8	12	12	13
8	7	13	13	13
9	9	14	14	14
10	8	12	13	13
11	7	12	12	13
12	8	13	13	13
Mean \pm s	7.7 \pm 0.75	12.7 \pm 0.86	13.0 \pm 0.73	13.3 \pm 0.49
t		15.08	17.23	21.48
P		0.00	0.00	0.00

Data are presented as mean \pm SD or number, pre-op: preoperation, post-op: postoperation.

sternoclavicular joint after removing implants. Excellent clinical results were obtained in 9 cases, whereas 2 good results and 1 fair result were also showed in the cases.

The causes of redislocation of the sternoclavicular joint after removing implants in one case may be related to premature weight bearing in the patient due to incomplete healing of the sternoclavicular ligament and overweight of the patient (BMI = 29). We recommend preventive measures as follows: (1) reconstructing sternoclavicular ligament closely; (2) full suspension for ligament repair; (3) removing the internal fixation gently to avoid damage to the repair of the sternoclavicular ligament and articular capsule.

There are some limitations in the current study. Due to lack of randomized control group, the problems of whether our technique was better than other methods used in the treatment of unstable proximal clavicular fractures (type D) should be further studied in the future clinical practice. Besides, small sample size and short follow-up time were also the limitations in the study. Thereby, a study of large population and long follow-up time should be performed to assess the clinical values of our methods in the treatment of unstable proximal clavicular fractures. In addition, more biomechanical study of rotational and axial stability of the implant should be researched in the future.

Conclusion

T-type plate fixation with repairing anterior sternoclavicular ligament might be a reliable and effective treatment for unstable proximal clavicular fractures (type D) with few complications and satisfactory clinical effects in more than 12 months follow-up.

Acknowledgement

This study was supported by Ningbo science and technology enriching people project (No. 2015C50034) and Ningbo Natural Science Foundation (No. 2016A610142).

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