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ORIGINAL STUDY

Conservative treatment for clavicle stress fractures following the clavicular hook plate fixation

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We investigated the outcome of conservative treatment and potential causes for clavicle stress fractures following the clavicular hook plate fixation. Six cases of clavicle stress fractures were retrospectively reviewed. All the stress fractures occurred near the medial end of the hook plates. The average interval between the hook plate fixation and the clavicle stress fractures was 28.3 days (range, 18 to 60 days). The mean follow-up was 27 months (range, 15 to 42 months). Fracture union was achieved in all 6 cases. The most proximal screws in the hook plates were found to be eccentric in the clavicular midshaft in 5 cases. At the final follow-up, the average Constant and Murley scores of the operated shoulders were 91.7 (range, 83 to 96). Clavicle stress fractures could be treated conservatively with satisfactory results. Attention should be paid to the position of the most proximal screws in the hook plates.

Keywords : stress fractures ; hook plates ; clavicle fractures ; conservative treatment

INTRODUCTION

The clavicular hook plate is a locking compression plate with a hook engaging below the acromion. It is commonly used in the treatment of distal clavicle fractures and acromioclavicular joint dislocations *(4,13)*. Despite with high rates of fracture union and overall satisfactory shoulder function, the clavicular hook plate fixation results in a rate of complications high to 40.7% *(14)*. Most complications are hardware-related and associated with the substantially increased stress at the both ends of the hook plate *(11)*. Among these adverse events, shoulder impingement and acromial osteolysis resulting from the placement of the hook portion are very common *(10,17)*. A variety of studies have thus been performed to investigate the morphological characteristics of the acromion and the biomechanical features of the hook plates *(3,9,11,19)*. However, on another stress riser point—the medial end of the hook plates, clavicle stress fractures were considered as a rare complication *(14)*. These secondary fractures may occur either after the bone consolidation or duing the healing process of the primary distal clavicle fractures *(8,15)*. Until now,

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no case series have been reported to specifically investigate the management of such stress fractures or analyze their potential causes. Therefore, the purpose of this study is to present the outcome of conservative treatment of 6 cases of clavicle stress fractures after the clavicular hook plate fixation for distal clavicle fractures. The potential causes of such fractures will also be analyzed.

PATIENTS AND METHODS

Between January 2009 and June 2015, 463 patients (291 male and 172 female) suffering distal clavicle fractures were treated with the clavicular hook plate fixation. A total of 6 cases of clavicle stress fractures occurred after the clavicular hook plate fixation. The details of the 6 patients were retrospectively reviewed (Table I). The mean age was 54 years (range, 44 to 76 years). Except 1 male patient, the rest 5 were female. All patients received hook plate fixation due to isolated unstable distal clavicle fractures, which were classified into Neer type II fractures. All the 6 fractures resulted from direct forces to the affected shoulders in traffic accidents or falls. Open reduction and internal fixation with a clavicular hook plate (Synthes, Switzerland) was performed within 2 weeks after the initial injury. The hook plate fixation was performed alone in 3 cases, in combination with a coracoclavicular screw in 1 case and with surgical repair of the coracoclavicular ligaments by anchored sutures in 2 cases. The coracoclavicular ligaments were reconstructed following the fixation of Neer type IIB fractures, in order to maintain the normal coracoclavicular distance after the removal of the hook plates. The most medial holes of the hook plates in 6 patients were filled with the standard locking screw.

Postoperatively, the operated shoulders were protected by an arm-sling. In the following weeks, 4 patients complained a sudden pain when they got up with the aid of the affected arms ; 2 complained asymmetrical appearance of both clavicles without pain. Radiographic evaluation demonstrated clavicle fractures near the medial end of the hook plates. Despite noticeable deformity at the medial end of the plates, all fractures were treated conservatively with a broad arm-sling until the secondary fractures healed. Physical exercises were as same as those receiving conservative treatment of the clavicle midshaft fractures. Briefly, during the first 2 weeks, patients used a sling and were advised to perform non-weight-bearing pendulum exercise ; then active movement up to the horizontal plane and strengthening exercises were started. Upon union of the stress fractures, patients resumed the rehabilitation program prescribed for the hook plate fixation.

All the hook plates were removed after fracture union confirmed by radiographic evaluation and clinical assessment. During the removal operation, the stress fracture sites were examined. Among the 6 patients, 3 received a CT scan to assess the relative position of the implants. The 100-point Constant and

Table I. — Details of the 6 patients

No.	Sex	Age (years)	Fracture side	Fixation methods	Hook plate (holes, depth)	Interval* (days)	Bone healing time† (weeks)	Plate removal time‡ (months)	Follow-up (months)	Constant score
1	Female	44	Left	Hook plate + CC screw	6, 15 mm	21	8	6	42	96
2	Female	48	Right	Hook plate alone	6, 15 mm	18	6	5	26	96
3	Male	76	Left	Hook plate alone	6, 15 mm	60	8	10	40	83
4	Female	56	Right	Hook plate alone	6, 12 mm	28	6	7	24	87
5	Female	52	Left	Hook plate + CC ligament repair	6, 15 mm	23	6	7	15	94
6	Female	48	Left	Hook plate + CC ligament repair	6, 15 mm	20	6	6	15	96
Average		54 ± 11.5				28.3 ± 16	6.7 ± 1	6.8 ± 1.7	27 ± 11.8	91.7 ± 6.0

* means the interval between the hook plate fixation and a second clavicle fracture. † refers to the bone healing time for the second fracture of the clavicle. ‡ indicates the plate removal time after operation. CC, coracoclavicular.

Murley Scores *(1)* was used to evaluate the shoulder function at the final follow-up. Continuous variables were expressed as mean ± standard deviations.

RESULTS

The average interval between the hook plate operation and the clavicle stress fractures was 28.3 days (range, 18 to 60 days) (Table I). Plain X-rays of the 6 stress fractures consistently showed an upward angular deformity at the second fracture site. The deformity was defined as the discernible change in the curvature of the clavicle on X-rays compared to that on the immediately postoperative X-rays. The average follow-up was 27 months (range, 15 to 42 months). Fracture union was seen at the initial and secondary fractures sites in all 6 patients. The mean union time for the stress fractures was 6.7 weeks (range, 5 to 8 weeks). Routine removal of the hook plates was performed at an average of 6.8 months (range, 5 to 10 months).

All the stress fractures occurred around the locking screws in the most medial holes in the hook plates (Fig.1), indicating that the stress fractures were probably associated with the insertion of the screws. During the plate removal surgery, the locking screws in the most medial holes in the hook plates were found to be noticeably eccentric in the midshaft of the clavicles in 5 cases. Prior to the plate removal, the CT scan, which was performed in 3 cases, also demonstrated that the most proximal screws were not in the axis of the clavicles (Fig.2). At the final follow-up, the average Constant and Murley scores of the operated shoulders were 91.7 ± 6.0. All 6 patients were satisfied with the final

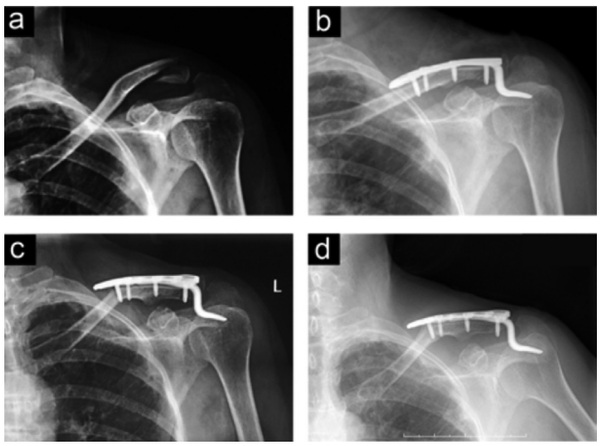

Fig. 1. — An illustrative case (Case 5) of clavicle stress fractures following the clavicular hook plate fixation. (a) the patient suffered a distal clavicle fracture. (b) 2 days later, hook plate fixation was performed. (c) at 3 weeks postoperatively, the patient complained a sudden pain when she got up from bed. X-ray showed a stress fracture at the most proximal screw in the hook plate. (d) the stress fracture healed after 6-week conservative treatment.

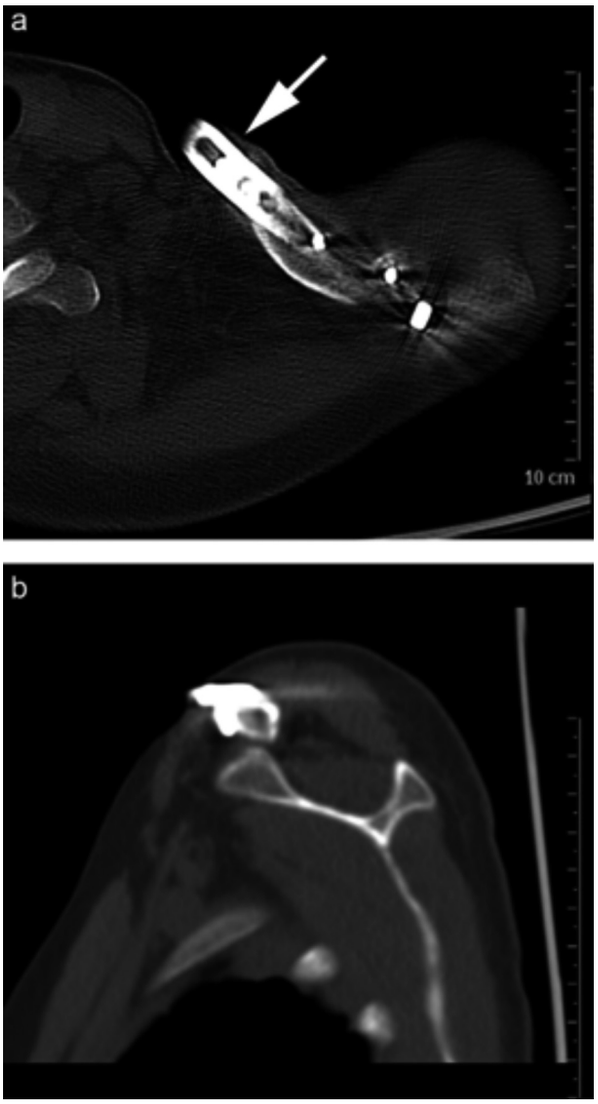

Fig. 2. — The CT scan demonstrated the malposition of the most proximal screw in the hook plate (Case 5). (a) the transverse section showed the screw (white arrow) deviate from the central axis of the clavicle. (b) the coronal section confirmed the malposition of the most proximal screw.

Table II. — The retrospective series that reported secondary clavicle fracture(s) following the clavicular hook plate fixation

Authors	Number of patients	Initial diagnosis	Peri-implant fractures	A second injury	Interval between 2 fractures	Treatment	Outcome
Ding *et al* (*2*)	1	Distal clavicle fracture	1 clavicle fracture	No injury	40 days	ORIF; plate exchange	uneventful
Flinkkilä *et al* (*5*)†	17	Distal clavicle fractures	1 clavicle fracture	A second injury	NR	Conservative	uneventful
Flinkkilä *et al* (*6*)†	63	Distal clavicle fractures	3 clavicle fractures	A second fall	NR	Nonoperative in 1; plate fixation in 2	All united eventually
Good *et al* (*7*)	36	Distal clavicle fractures	2 clavicle fractures	Fall onto the affected shoulders	1 and 2 months, respectively	ORIF; maintain the hook plates in situ	NR
Haidar *et al* (*8*)	22	Distal clavicle fractures	1 clavicular stress fracture	A fall	4 weeks	Immobilize in a sling	Fracture healed; Constant score 77
Lee *et al* (*12*)	23	Distal clavicle fractures	1 clavicle fracture	No injury	7 weeks	Immobilize in a sling	Fracture healed
Persico *et al* (*15*)	14	Distal clavicle fractures	1 clavicle fracture	A second fall	9 months	ORIF; plate exchange and bone graft	NR
Tambe *et al* (*18*)	18	Distal clavicle fractures	1 clavicle fracture	A second injury	4 months	Conservative	NR
Wu *et al* (*20*)	92	Distal clavicle fractures	7 periprosthetic fractures	NR	NR	NR	NR

† We are not sure whether there were overlap in cases between the 2 studies. ORIF, open reduction and internal fixation ; NR, no record.

outcome. No other complications except the clavicle stress fractures were recorded during the follow-up.

DISCUSSION

The clavicular hook plate device is easy to apply with predominately good results and notoriously high rates of complications *(14)*. There is a lack of studies concerning the management of these complications. In this study, we reported 6 clavicle stress fractures following the clavicular hook plate fixation. Conservative treatment of the secondary fractures of the hook-plated clavicles yielded satisfactory shoulder functions.

While no case series were published to exclusively report clavicle stress fractures, such complications were briefly mentioned in literatures *(2,5-8,12,15,18,20)* (Table II). Wu et al. reported 7 cases of peri-prothetic fractures among 92 clavicular hook plate operations *(20)*. However, neither the specific fracture sites nor the management methods was described. Ding et al. presented 1 case of a clavicle stress fracture similar to our case series *(2)*. A 68-year-old woman complained sudden pain when she got up with her affected arm at 40 days after surgery. The patient received a plate exchange and thereafter recovered uneventfully. In another case report of a clavicle stress fracture at 7 weeks postoperatively, however, the stress fracture was only immobilized in a sling and healed eventually *(12)*.

In our case series, 5 of 6 patients suffered the clavicle stress fractures within 4 weeks after the hook plate operation. Prior to the bone union of the distal clavicle fractures, the surgical treatment of a clavicle stress fracture would be challenging. Besides an exchange with a longer plate, an additional plate placed anteriorly to the clavicle may be an alternative to fix the fracture. But a second

operation within weeks after the initial surgery would not only further damage the blood supply to the fracture ends, likely leading to non-union and infection, but also increase the medical costs. In this case series, patients did not experience significant trauma, and the stress fractures thus did not much displaced. Therefore, the stress fractures could be treated conservatively as same as the minimally displaced clavicle midshaft fractures.

As for the causes of the clavicle stress fractures observed in our study, we postulated 2 aetiological factors. The first reason may be the substantially increased stress around the locking screws in the most medial holes of the hook plates. A finite analysis study showed that the screw in the most medial hole of a hook plate resisted higher stress than any other screws in the same plate *(11)*. If the hook depths were inappropriately small, resulting in over-reduction of the acromioclavicular joints, the stress around the screw in the most medial hole will also be increased *(11)*. In this series, all the hook plates were either 12-mm-deep or 15-mm deep, rather than 18-mm. Another reason may be the findings that the screw in the most medial hole was not placed in the axis of the clavicle and disrupted the integrity of the bone cortex. Generally, the most proximal screws are usually placed at the middle third of the clavicles, the most common fracture site of the clavicles. If the screw hole was not drilled along the central axis of the clavicle, the integrity of the cortices would be destroyed, undermining the normal strength of the clavicles. It is reported that the Young's modulus of the clavicular cortical bone could achieve 17 000 MPa, compared to the 1 000 MPa of the cancellous bone *(11)*. The preoperative CT-scan in 3 patients and intraoperative examination in 5 patients found the eccentric position of the locking screws in the most medial holes. Therefore, based on the 2 factors aforementioned, the clavicle stress fractures might be attributed to the substantially increased stress at the weakened points of the clavicle. Once the clavicle fractured, the accumulated stress would be released and the fractures may thus heal spontaneously. In order to avoid further deformity of the clavicle, we adopted an arm-sling in our series to decrease the downward pull of the shoulder girdle.

An interesting point is that all the distal clavicle fractures in 6 patients were fixed with 6-hole hook plates. Theoretically, the longer plates provide greater strength than the shorter ones *(16)*. However, we found that it was difficult to adjust the position of the medial end of the long hook plates when the fractured clavicles were thin or had great variations, as the position of the distal end had to be engaged under the acromion. Furthermore, the acromion has a wide range of dimensions, leading to a high degree of variability of the positioning of the hook portion below the acromion *(3)*. Under such circumstances, instead of a locking screw, an ordinary screw may be used in the most medial hole to obtain a good position and maintain the integrity of the adjacent cortex.

There are a few limitations of this study. To begin with, only 6 cases were retrospectively included. Despite noticeable appearance, the clavicle stress fractures did not have much displacement in this case series. So all the fractures healed uneventfully after conservative treatment. It remains unclear whether such treatment would also achieve satisfactory results for those significantly displaced fractures, in particular after high-energy trauma. Furthermore, we did not perform the measurements of the clavicle midshaft width and the accurate position of the proximal screws, as the callus formation during fracture union would change the relative position of the screw holes.

CONCLUSION

Clavicle stress fractures resulting from the hook plate fixation could be treated conservatively with satisfactory results. To reduce such complications, attention should be paid to the position of the most proximal screws in the hook plates.

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