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ORIGINAL PAPER

Complications with the clavicle hook plate after fixation of Neer type II clavicle fractures

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Abstract

Background and purpose There is no consensus on the optimal surgical procedure for treating Neer type-2 distal clavicle fractures. Hook plates provide better stability than other fixation methods for small fragments but have been related to multiple complications.

Methods Retrospective study on patients operated for Neer type-2 fractures using a hook plate. At the time of the study, we performed functional (UCLA and Constant scales) and radiographic (coracoclavicular distance CCD) evaluation and ultrasound assessments of the condition of the rotator cuff.

Results Twenty-four patients were included in the study, with a mean age of 43 years (18–81) and a mean follow-up of 40.4 months (22–67). All the fractures healed, except one. The plate was removed at a mean of five months (3–13). The Constant score was 85.7 and the UCLA score was 32. The mean increase in CCD at final follow-up was 9.6% ± 7.2% (range 1.9–54.3%) compared with the uninjured side. Nine patients showed acromioclavicular arthrosis (only one case was symptomatic), and 12% showed subacromial osteolysis. No acromion fractures were recorded. The implant failed in three cases due to medial movement of the material, and we found one peri-plate fracture.

Conclusions The use of hook plates in this particular type of fracture provides high consolidation rates and good functional outcomes, irrespective of the fracture subtype. However, it is essential to select the correct length and depth of the hook to prevent complications such as medial movement of the implant. Ultrasound assessment showed that rotator cuff injury is not a common complication if the implant is removed as soon as the fracture has consolidated.

Keywords Distal clavicle fracture · Neer type 2 · Fixation · Hook plate · Unstable · Coracoclavicular distance

Introduction

Neer type-2 distal clavicle fractures are more likely to displace as the coraco-clavicular ligaments are ruptured. Therefore, Neer type-2 fractures are accepted as unstable. Although surgical fixation is recommended as the treatment of choice, no consensus exists on the optimal method. The distal bone fragment is usually very small and fragile, making fixation with traditional plates or Kirschner wires very difficult and unstable. The clavicular hook plate has been extensively used and although several studies have shown good outcomes regarding union rate and shoulder function, the use of the hook plate has also been related to the presence of impingement symptoms or even rotator cuff tear, acromioclavicular joint arthrosis, acromial osteolysis, and peri-plate fracture [1–5]. With studies collecting complications rates of up to 40–50% [6, 7], our experience with the use of the hook-plate for this fracture type contrasts with the papers that collect such a high percentage of complications, and we aim to analyze our results.

The purpose of this study were as follows: (1) to investigate the complication rate and long-term clinical and radiological outcomes of hook-plate fixation for distal Neer type-II clavicle fracture, (2) to compare the outcomes between IIA/IIB subtypes, (3) to determine whether hook plate fixation could induce rotator cuff tear by dynamic musculoskeletal ultrasound.

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Material and methods

We retrospectively identified 28 patients with unstable distal clavicle fracture (Neer II) treated surgically with a AO hook locking compression plate (DePuy Synthes, Oberdorf, Switzerland), between 2011 and 2016 and with at least 12 months follow-up. The exclusion criteria are summarized in Table 1. Four patients were excluded because it was impossible to contact them. Therefore, eventually, 24 patients were enrolled in the study.

The AO hook plate is a precountered stainless steel, dynamic compression available from two to five holes and with three different hook depths (12, 15, and 18 mm).

The study was approved by the institutional review board of our institution (study 17/009-E_TFG). A retrospective review of radiographs and clinical notes was performed to assess time to radiographic union and to note any early complications, but also, after initial analysis, a prospective clinical, radiographic, and ultrasound evaluation was assessed at the most recent follow-up.

Surgical procedure

Surgical procedures were performed by one of the three senior shoulder surgeons (Y.L., C.G.-F., F.M.). Patients were operated under general anaesthetic and in the standard beach chair position. The lateral end of the clavicle and acromio-clavicular joint were exposed through a longitudinal skin incision. After the operation, a sling was used for two to three weeks, allowing pendulum exercises immediately, and passive range of motion after two weeks. Active range of motion started at four weeks.

Table 1 Exclusion criteria

Exclusion criteria
1) Patients without a full clinical history
2) Patients who had not undergone the relevant imaging tests
3) Patients that we could not contact at the time of undertaking the study (moved address, death, etc.) to perform functional and current radiological assessment
4) Patients who were unable to understand the questions of the functional scales
5) Clavicle fractures in skeletally immature patients
6) Pathological fractures
7) Previous pathology or previous surgery to the fractured shoulder (including rotator cuff pathology: partial, total tears, or tendinopathies)
8) Associated ipsilateral limb fractures

Functional and radiological assessment

At the final follow-up, shoulder function was evaluated with the Constant-Murley scoring system, the University of California, Los Angeles (UCLA) shoulder score, and the active range of motion (ROM) was measured with a goniometer. Functional evaluation was performed by an independent surgeon who was not involved with the original surgery (P.C.). Clinical diagnosis of subacromial impingement was established by the presence of a positive Neer's impingement sign.

Preoperative and serial radiographs (anteroposterior glenoid and scapular Y view) were evaluated by the above-mentioned independent surgeon in order to determine the type of fracture according to Neer classification (IIA and IIB) and time to bone union (defined as bridging callus across the fracture site or invisible fracture line in two views). The most recent radiograph was also taken at the final follow-up, in order to evaluate fracture reduction status and to confirm control of superior migration of the proximal fragment measuring the coracoclavicular distance (CCD) [5] and comparing the CCD of the injured side with the uninjured side. The acromioclavicular joint was also evaluated in these final follow-up radiographs and compared to the preoperative ones, in order to determine progression or new onset of acromioclavicular osteoarthritis, the presence, worsening, or the absence of radiologic signs related with AC arthritis (narrowing of the acromioclavicular joint, the presence of osteophytes and cysts) was registered.

Complications were only considered to be events that caused functional impairment or motivated an additional surgical procedure (symptomatic non-union or malunion, periimplant fracture, rotator cuff tear, symptomatic acromioclavicular arthritis, or infection requiring further surgery). Radiological findings that did not cause symptoms such as subacromial osteolysis or asymptomatic acromioclavicular arthritis were not considered complications in this study.

Finally, in order to determine whether the hook plate had caused any damage to the rotator cuff, an ultrasound evaluation was performed by a radiologist who specialized in musculoskeletal pathology with more than 20 years of clinical experience (MLV), Toshiba 14L5/PLT-1005BT 5–14 MHz Linear Array Ultrasound transducer on an Aplio 500 computer, Toshiba, following the above-mentioned protocol [6].

Statistical analysis

Statistical analysis was performed with SPSS 19.0 statistical software (SPSS, Inc., Chicago, IL). Continuous variables were presented as mean standard deviations and analyzed using the Student *t* test, while categorical data were

represented by both a number and a percentage and were analyzed with the $\chi 2$ test. $P < 0.05$ was regarded as significant.

Results

Epidemiological results

Epidemiological results are summarized in Table 2. Mean follow-up to latest functional and radiological assessment was 40.7 ± 15.4 months (range, 24–74). There were no statistically significant difference in age ($p = 0.73$) and sex distribution ($p = 0.42$), between the two groups of fractures (IIA/IIB). Mean time to implant removal was 5.1 ± 1.0 (3–8).

Functional results

The functional outcomes and ROM are shown in Table 3. At final follow-up, the mean Constant score of the 24 patients was 85.7 ± 11.7 (range, 56–100) with 82.6% having good or excellent results; and the UCLA score was 32.4 ± 3.4 (range, 21–35) with 87% having good or excellent results. There were no significant differences in Constant, UCLA, and active ROM between the two groups.

Only one case (4%) in the last follow-up functional evaluation made after implant removal had positive signs of subacromial impingement (positive Neer and Hawking signs).

Radiographic evaluation

Mean time to radiological union was 3.5 ± 1.1 months (range, 2–6 months).

Table 2 Patient demographics and clinical characteristics

Patient demographics	Total ($n = 24$)
Sex, female/male	4/20
Average follow-up	40.7 ± 15.4 (24–74)
Age (years)	42.5 ± 15.6 (18–71)
Side of injury, left/right	14/10
Fracture type, IIA/IIB	15/9
Dominant/non dominant hand	11/13
Time to surgery (days)	7 ± 6 (1–13).
Time to implant removal (months)	5.1 ± 1.0 (3–8)
Fall down	12/24
Sport injury	8/24
High energy accident	4/24

Non-union occurred in one patient (4%) with a Constant score of 94. Because there was no functional impact of the non-union, no additional treatment after removing the plate was applied.

The mean pre-operative CCD was 16.1 ± 5.2 mm (range, 9.5–26.5 mm), and the mean post-operative CCD at final follow-up was 10.3 ± 2.6 mm (range, 4.2–14.6 mm). The mean increase in CCD at final follow-up was 9.6% ± 7.2% (range, 1.9–54.3%) compared with the uninjured side. There were no significant differences in active ROM between the two groups ($p < .001$).

In relation to the acromioclavicular joint at final follow-up, nine cases (37.5%) had acromioclavicular joint arthritis, which was present at the time of fracture in four cases. Eight (89%) out of nine patients had no symptoms related to the acromioclavicular joint.

Subacromial osteolysis was present at final follow-up in three cases (12.5%) not related to age, gender, fracture pattern, or implant characteristics. There were no cases of acromial fracture.

On ultrasound evaluation, one patient (4%) had a supraspinatus tendon tear. The patient was a 68-year-old male with no positive signs of subacromial impingement.

Complications

There were no intra-operative complications in this series.

Three cases (12.5%) have an implant failure due to medial hardware mobilization (Fig. 1) at an average post-operative time of 3.2 weeks. The hardware displacement did not affect fracture reduction, so the three cases were treated maintaining the hardware until fracture union. They were three males with diaphyseal 2-hole plates in two cases and diaphyseal 3-hole plate in one case. All of them had a 15-mm-deep hook plate, and the fracture types were IIA in two cases and IIb in one case. The other complication was a peri-implant fracture (4%) that needed additional surgery with a longer plate synthesis (Fig. 1).

Discussion

Conservative treatment for unstable distal clavicle fractures has been described by some authors with non-union rates of 20–44% but with similar functional scores to those of surgically treated groups [7]. However, the paucity of studies with non-operative treatment, the small number of patients included in previous studies, and the absence of well-designed randomized control trials make surgical treatment of displaced lateral clavicle fractures the treatment of choice. The most

Table 3 Functional outcomes

	Global	IIA	IIB	*P* value IIA/IIB
Constant*	85.7 ± 11.7 (56–100)	88.2 ± 8.5 (70–100)	81.1 ± 11.5 (56–100)	0.506
UCLA*	32.4 ± 3.4 (21–35)	32.8 ± 7.5 (25–35)	30.7 ± 3.8 (21–35)	0.546
Mean increase in CCD	19.6%	16.3%	24.3%	0.513
Forward elevation	165° ± 23° (100°–180°)	166° ± 23° (110°–180°)	153° ± 23° (100°–180°)	0.719
Abduction	160° ± 20° (100°–180°)	162° ± 18° (120°–180°)	156° ± 21° (100°–170°)	0.543
External rotation	80° ± 8° (55°–90°)	83° ± 8° (65°–90°)	77° ± 9° (55°–85°)	0.184

* Mean and standard deviation

appropriate surgical reconstruction method remains controversial.

An earlier meta-analysis [7] recognizes that hook-plate fixation is the most frequently used method for fixating type-II clavicle fractures but has a higher complication rate than others. They conclude that this plate is not the method of choice to fix this particular fracture, and it should be used only in specific indications. However, our findings suggest that the clavicular hook plate may provide stable fixation with satisfactory functional outcomes and high union rates, as reported previously by other authors, with no significant differences between the fracture type [3, 5, 8].

The complication rate in this study, 16%, is lower than those previously reported at around 40–50% [6, 7]. As defined in "Material and methods," we only consider complications to be those that alter the normal fracture course or that have required reoperation. Radiological findings without clinical significance, such as subacromial osteolysis, caused by the design of the clavicle hook were not considered complications.

Subacromial osteolysis has a high incidence with reported rates of 55%. The rate in this series was 12.5%, and all the cases were without clinical impact as reported previously [9]. Probably the midterm follow-up (average of 41 months) reduces the osteolysis rate since, as previously reported by Tiren et al., [3] the osteolysis disappears on the follow-up radiographs after plate removal.

Clavicle fracture at the medial end of the plate is a rare complication of clavicular hook plate and few reports have been published [1, 9–13]. Although this rare complication has been described without injury related to osteoporosis, plate stress shielding, or line fracture, the case described in

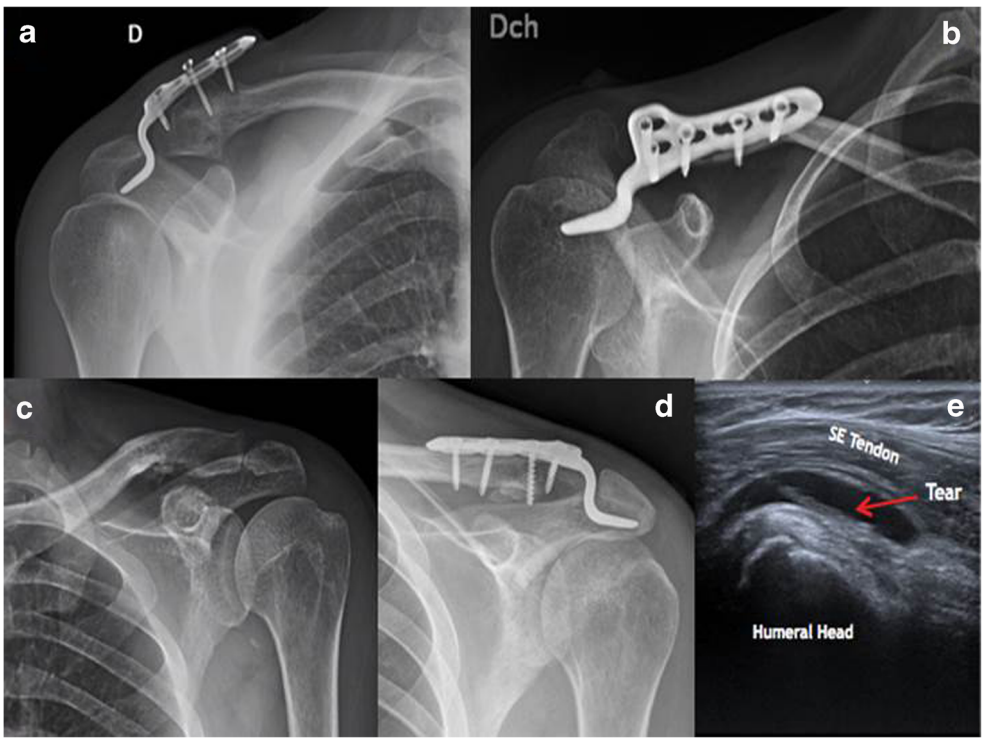

Fig. 1 Complications with clavicle hook plate. **a** Implant failure due to medial hardware mobilization **b** perimplant fracture **c** Acromioclavicular arthritis **d** subacromial osteolysis **e** supraespinatus tendon tear seen with ultrasound

Table 4 Studies that used the clavicular hook plate for fixation of Neer type II clavicular fractures

Author	*N*	Union rate	Plate removal	Average time to removal	Functional scores	Complications/radiographic findings
Lee et al. [20]	32	100.0%	32	4.8	Constant 90	One material loosening
Zang et al. [11]	30	97.0%	30	7.1	Constant 93.3	Three symptomatic hardware
						Two losses of reduction
						One delayed union
						One hardware failure
Haidar et al. [21]	22	95.0%	21	4.6	Constant 89	One material loosening
						One delayed union and malunion
						One non-union
					DASH 4.6	One clavicular stress fracture
						One wound breakdown
Klein et al. [22]	22	94.7%	13	–	ASES 72.4	Three peri-implant fractures
						Unscrew failure
						One infection
Kashii et al. [14]	34	100.0%	34	5.3	JOA score 98.3	One material loosening
						One fracture of the acromion
						One rotator cuff tear
Tan et al. [17]	23	100.0%	15	10	UCLA 30.91	One wound infection
Mizue et al. [23]	16	100.0%	14	12.5	JOA score 95.1	Four acromial osteolysis
						Four pain
Meda et al. [15]	31	100.0%	25	–	Constant 94	Six subacromial impingement
					ASES 26	Two superficial infections
Muramatsu et al. [8]	16	100.0%	12	4.5	Constant 89	Thirteen material loosening
Tambe et al. [9]	18	93.0%	17	5	Constant 88.5	Five asymptomatic acromial osteolysis
						One peri-implant fracture
						One deep wound infection
Renger et al. [2]	44	95.0%	–	8.4	Constant 92.4	Thirty subacromial impingement
						Three acromial osteolysis
						Two hipertrofic scar
						Two infections
Lu et al. [24]	7	100%	7	4.9	Constant 93.9	None
Tiren et al. [3]	28	96%	27	6	Constant 97	One wound infection
					DASH 3.5	One ACJ arthrosis
Lee et al. [5]	35	100%	35	4.4	UCLA 32.6 ASES 83.5	Eight shoulder stiffness
						Six acromial osteolysis
						One delayed union
Sükur et al. [19]	16	100%	12	4.8	UCLA 32.7	Ten acromial osteolysis
						Seven subacromial impingement
						Three superficial wound infection
						One peri-implant fracture
Good DW et al. [1]	36	95%	33	4.5	Constant 83.8	Two peri-implant fracture
					Oxford score 43.8	One non-union
Mechchat et al. [12]	14	100%	14	6	Constant 90.9	One subacromial impingement
						One acromial osteolysis
Chen et al. [25]	28	100%	28	5.7	UCLA 33.1	Two acromial osteolysis
					Oxford score 46.9	One fracture of the acromion
Flinkkilä et al. [13]	19	94.7%	–	4.8	Constant 89 DASH 11	One peri-implant fracture
						One infection
						One shoulder stiffness

Table 4 (continued)

Author	*N*	Union rate	Plate removal	Average time to removal	Functional scores	Complications/radiographic findings
Yan et al. [26]	21	100.0%	21	–	Constant 97.2	Seven subacromial impingement
Erdle et al. [27]	19	94.7%	19	4.7	Constant 88.7 Oxford score 40.8	Eight ACJ arthrosis
						Five acromial osteolysis
						Two delayed union
						One non-union
						One peri-implant fracture
Hsu KH et al. [4]	49	91.8%	49	6.2	Constant score 87 UCLA 30	Five ACJ arthrosis
						Four non-unions
						Three peri-implant fractures
						Two rotator cuff tear
						One implant malposition
						One loss of reduction
Lópiz et al. (present study)	24	95.8%	23	5.1	Constant 85.7 UCLA 32	Nine ACJ arthrosis
						Three acromial osteolysis
						Three material loosening
						One peri-implant fracture
						One non-union

this series had a previous fall, so it seems not to be related with the osteoporosis.

However, the main concern about this plate is that it may cause subacromial shoulder impingement or even rotator cuff tear. The impingement rates vary considerably in different studies and can range from approximately 5 to 68%. [2, 14,_15]. Lin H. et al. [6] after evaluating 40 patients with dynamic musculoskeletal ultrasound, found 37.5% impingement syndrome and 15% rotator cuff injury. The problem is that most of the previous papers do not describe the signs or symptoms they considered for a subacromial impingement diagnosis, making it difficult to compare results. Hackenberge J. et al. [16] after an MRI study on the effect of the plate on the subacromial space in 28 patients did not find any case of rotator cuff tear. Kashii M. et al. [14] in a retrospective study of 34 patients operated with hook plates and shoulder arthrography performed on 16 patients found one rotator cuff tear and also concluded that rotator cuff tears are relatively rare. Our good clinical and ultrasound results also support these assertions. We found only one case (4%) with positive subacromial impingement signs (Neer sign) and only one case (4%) with rotator cuff tear confirmed by ultrasound; it is likely that plate removal immediately after fracture healing plays a role in this sense.

Other complications such as the mild or severe shoulder pain reported in 74% of the patients by Tan et al. [17] or acromial fracture and hook cutout reported by Kashii et al. [14] were not observed in this series.

In relation to implant failure, all three cases occurred at the beginning of our series by medial fixation loosening. This complication may be related to an inappropriate selection of the length of the plate and the depth of the hook. The length of the plate may be adjusted to the fracture line; insufficient holes in the three cases were located medial to the fracture line. A mismatch between the plate and the subacromial space because of an inadequate selection of the hook depth can lead to the well-described complications by increasing the medial forces borne by the plate. Also the hook angle has been related to this mechanical failure. Hung L et al. with a study using finite elements analysis have pointed out the importance of the hook angles in the biomechanics of the acromion, clavicle, hook plate, and screws. Smaller hook angle increases the stress on the middle third of the clavicle [10].

Previous clinical studies [18, 19] have pointed out the importance of optimizing the shape, length, and angle of the hook-plate employing different implants according to the individuals' characteristics to decrease the complication rate. Smaller angles have been related with an increase in the presence of osteolysis and an excessive reduction of the joint.

The necessity of removing the plate is the main drawback of this technique because it increases medical cost and the morbidity of the procedure. However, in comminuted fracture cases, if stabilization (repair or augmentation) of the coracoclavicular ligament is not performed (alone or in combination with a conventional synthesis), the clavicular hook plate is a very good alternative because of the difficulty in inserting a screw in the distal fragment and achieving a stable fixation.

Although removing hook plate is not regarded as essential [15], several authors have reported that complications are

related to late implant removal with excellent outcomes when the plates are removed before 6 months noting that the presence of impingement symptoms can occur but tend to be confined to patients in whom there is prolonged retention of the implant [1]. Plates were removed at a mean of 5.1 months in the present series.

The mean increase in CCD compared with the uninjured side was 9%, a little higher than previously reported, [5] which suggests that the plate acts to prevent superior medial fragment displacement by maintaining the acromioclavicular joint level although it doesn't achieve a complete fracture reduction. Only one patient has an increase CCD superior to 10% compared with the uninjured side and belongs to the nonunion case.

The functional outcomes were satisfactory with high consolidation rates and without differences in fracture pattern (IIA/IIB) as previously published [5]. Table 4 summarizes the previous studies that used the clavicular hook plate for fixation of Neer type II clavicular fractures.

Study limitations

Our study has several limitations. It was a retrospective study with a limited sample size and without a control group to compare with other fixation methods. Although the patients with ultrasound-diagnosed shoulder pathology denied any shoulder pain or disability before trauma, the possible effect of trauma or degeneration on rotator cuff attrition could not be totally excluded. Another limitation is that anteroposterior residual displacement, which has been related to bad functional results, was not evaluated in the present study. Finally, the fact of not including subacromial osteolysis or hardware removal as complications may decrease the overall complication rate.

Conclusions

Hook plate fixation may promote good bone union rates and functional results with earlier implant removal for Neer type II distal clavicle fracture regardless of subtype. The short duration of the implant in situ will not cause serious changes in the subacromial space (rotator cuff tear and lower surface of the acromion). Although subacromial osteolysis is common, it disappears after implant removal without clinical impact on shoulder function. An appropriate plate length and hook depth in accordance with the fracture line and individual anatomy may lower the rates of implant failure.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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