

# Risk factors for clavicular midshaft fractures after hook plate fixation for the treatment of Neer type II clavicular fractures

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## Abstract

**Objective:** Neer type II fractures are common, and hook plate fixation is one of the recommended treatments. Although clavicular midshaft fractures after hook plate fixation are rare, such fractures increase patients' suffering and worsen their functional outcomes. This study was performed to identify the risk factors for this complication.

**Methods:** From 2009 to 2018, 425 patients were admitted with Neer type II clavicular fractures. According to the selection criteria, 352 patients were included in this retrospective observational study. All patients were divided into either the complications group (patients with midshaft fractures) or the control group (patients without midshaft fractures). Data collected included patient demographics and surgical, hook plate, and screw characteristics. The chi-square test was used to conduct between-group comparisons of risk factors. Statistically significant variables were included in a logistic regression model.

**Results:** In both the complications group ( $n = 21$ ) and control group ( $n = 331$ ), significantly more patients of advanced age and significantly more patients treated with hook plates that were not bent during surgery developed midshaft fractures.

**Conclusion:** The risk of a clavicular midshaft fracture after hook plate fixation may be significantly increased by advanced age or a lack of hook plate bending.

## Keywords

Clavicle, fracture fixation, postoperative complication, hook plate, plate fixation, midshaft

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## Introduction

Distal clavicular fractures are a common traumatic injury.<sup>1</sup> The rate of nonunion after nonoperative treatment may reach 33.3%; thus, surgical treatment is recommended for Neer type II clavicular fractures because of their unstable nature.<sup>2</sup> A clavicular hook plate is a recommended device for treating distal clavicular fractures.<sup>3-5</sup> The clavicular hook plate works according to the principle of leverage: the distal part is designed as a hook that is placed beneath the acromion, and the proximal part is designed as a plate. Although it is easy to manipulate the hook plate during surgery,<sup>6</sup> and although this surgery is associated with excellent functional outcomes for the shoulders,<sup>7</sup> the high complication rate of 40.7% is problematic.<sup>3,7</sup> Complications caused by the hook under the acromion are common and include acromial osteolysis, acromioclavicular joint arthrosis, subacromial impingement, and rotator cuff injury.<sup>8-12</sup> These complications have been discussed by many authors, and some are considered to be associated with highly concentrated subacromial stress.<sup>2</sup> However, clavicular midshaft fractures located on another stress concentration point are rarely reported because of their lower incidence (1.3%–9.8%).<sup>6,13,14</sup> One study showed that compared with patients without this complication treated with a hook plate, patients with midshaft fractures had worse shoulder functional outcomes and worse relationships with surgeons.<sup>15</sup> Surgeons should investigate the risk factors for this complication to lower the incidence of clavicular midshaft fractures after hook plate fixation and thus improve functional outcomes and relationships. To the best of our knowledge, few studies have investigated potential risk factors for clavicular midshaft fractures after hook plate fixation in the treatment of Neer type II clavicular fractures.<sup>13-15</sup>

This retrospective observational study was performed to analyze potential risk factors for this rare complication. We hypothesized that patients of advanced age, treated with hook plates not bent during surgery, a shorter plate, a plate with less depth, and an implanted locking screw at the most medial hole might have higher rates of postoperative clavicular midshaft fractures.

## Methods

The Beijing Chaoyang Hospital ethics committee, Capital Medical University (Beijing Chaoyang Hospital, Chaoyang District, Beijing, China) approved this study on 9 January 2020. The requirement for written informed consent was waived by the ethics committee because of the retrospective nature of this study. All included patients provided verbal consent before participation. The reporting of this study conforms to the STROBE statement.<sup>16</sup>

In total, 425 Neer type II clavicular fractures were surgically treated at our level I trauma center using various techniques from March 2009 to October 2018. The surgical techniques included clavicular hook plate fixation (Synthes, Solothurn, Switzerland), coracoclavicular fixation, and locking plate fixation. Adult patients ( $\geq 18$  years of age) diagnosed with Neer type II fractures and treated with hook plates only were eligible for inclusion in this study. The study population included 5 patients younger than 18 years, 2 patients treated with coracoclavicular fixation, and 39 patients treated with locking plate fixation. The exclusion criteria were fixation of fractures  $\geq 14$  days after the initial injury ( $n = 9$ ),  $< 2$  years of postoperative follow-up ( $n = 7$ ), open fractures ( $n = 0$ ), disabled shoulder function before the occurrence of the distal clavicular fracture ( $n = 8$ ), apparent dementia or other psychological problems ( $n = 3$ ), pathological fractures ( $n = 0$ ), and multiple fractures of the clavicle

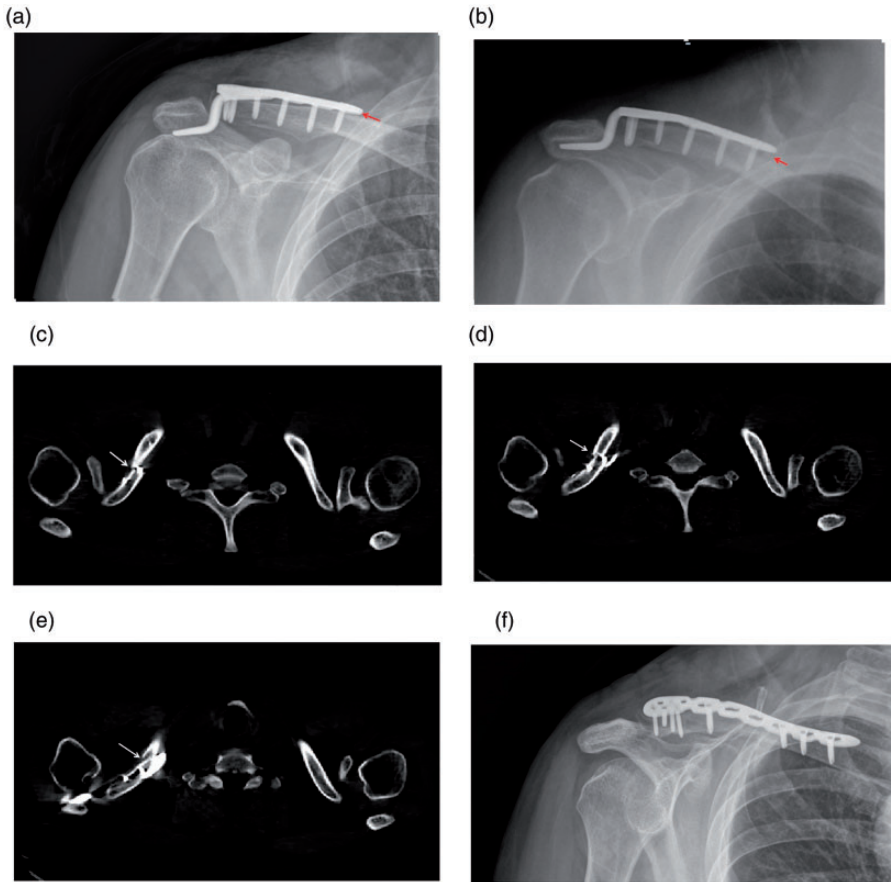
( $n = 0$ ). Seventy-three patients were excluded and 352 patients were enrolled in the study.

The complications group comprised 21 patients with clavicular midshaft fractures, and the control group comprised the remaining 331 patients. Patient demographic and other data were collected from all participants, including sex, age, affected side, body mass index, smoking status, drinking history, injury mechanism, American Society of Anesthesiologists grade, and the type of medial screw used. All surgeries were supervised or performed by a single orthopedic professor. In the complications group, patients who underwent further surgeries to fix the clavicular midshaft fractures were placed in the beach chair position. The skin and deep fascia were incised along the old incision above the clavicle. The incision was also extended medially to expose sufficient superior surfaces of the clavicle for further plate fixation. After exposing the hook plate, the hook plate and screws were removed. The old fracture line on the distal part of the clavicle fixed with the hook plate was detected. The area was inspected to determine whether sufficient fracture union was present on the distal part of the clavicle. After exposing the fracture line on the midshaft of the clavicle, all tissues between the fragments were removed. Kirschner wires were temporarily implanted across the fracture line when the reduction was satisfactory. The appropriate clavicular plate was chosen by the surgeon intraoperatively. At least three screws were implanted on the clavicular shaft on both sides of the midshaft fracture (see Figure 1). Another two orthopedic surgeons assessed the patients' plain radiographs and computed tomography scans. Furthermore, in the complications group, data on the type of treatment, time, and causes of the postoperative midshaft fracture as well as whether union of the midshaft fracture was achieved were also

collected (see Table 1). In both the complications and control groups, data on several potential risk factors identified in previous studies were collected, including whether the plate or hook was bent during the surgery,<sup>17,18</sup> the number of holes in the plate,<sup>19</sup> and the hook plate depth.<sup>20</sup> All collected patient data were retrieved from the hospital's electronic medical record system. The two study groups were also divided into four subgroups based on patient age: young patients in the control group (age of <65 years, young control group;  $n = 292$ ), young patients in the complications group (age of <65 years, young complications group;  $n = 14$ ), elderly patients in the control group (age of  $\geq 65$  years, elderly control group;  $n = 39$ ), and elderly patients in the complications group (age of  $\geq 65$  years, elderly complications group;  $n = 7$ ).

Categorical variables are presented as count data, and continuous variables are presented as categorical data. Comparisons between the complications group and control group were made using the chi-square test. A difference was regarded as statistically significant and the variable was regarded as predictive when the  $p$ -value was  $< 0.05$ . To determine the independent risk factors, logistic regression was used to analyze differences in variables between the complications and control groups. The sample size of the complications group was small; therefore, only the statistically significant predictive variables were included in the logistic regression analysis. The predictors are presented as unadjusted and adjusted odds ratios (ORs) and the 95% confidence interval (CI). Finally, the rates of plate bending were compared between the young control and complications groups and between the elderly control and complications groups using the chi-square test.

IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY,



**Figure 1.** Radiological images of Patient 6 (56-year-old man). (a) Immediately after surgery. Arrow: Small gap between the plate and clavicle. (b) 158 days after surgery at the time of midshaft fracture. Arrow: Enlarged gap between the plate and clavicle. (c–3) Computed tomography images at the time of midshaft fracture. Arrow: fracture line. (f) 221 days after surgery (58 days after secondary surgery).

USA) was used to perform the logistic regression and chi-square tests.

## Results

In the control group, 325 patients underwent removal of the hook plate during the 24-month follow-up period. Among these patients, the average duration of device retention was 10 months (range, 4–14 months). In the complications group, 20 patients complained of sudden pain in the affected shoulder; the remaining patient

developed obvious skin tenting on the affected clavicle. Diagnosis of postoperative clavicular midshaft fracture was made based on plain radiographs or computed tomography scans taken within 10 days of the initial complaint. The rate of clavicular midshaft fracture after hook plate fixation was 6.0%. In the complications group, all midshaft fractures occurred at the most medial hole implanted with a screw, and five of them were caused by secondary trauma (three falls and two vehicle accidents).

**Table 1.** Data on patients in the complications group.

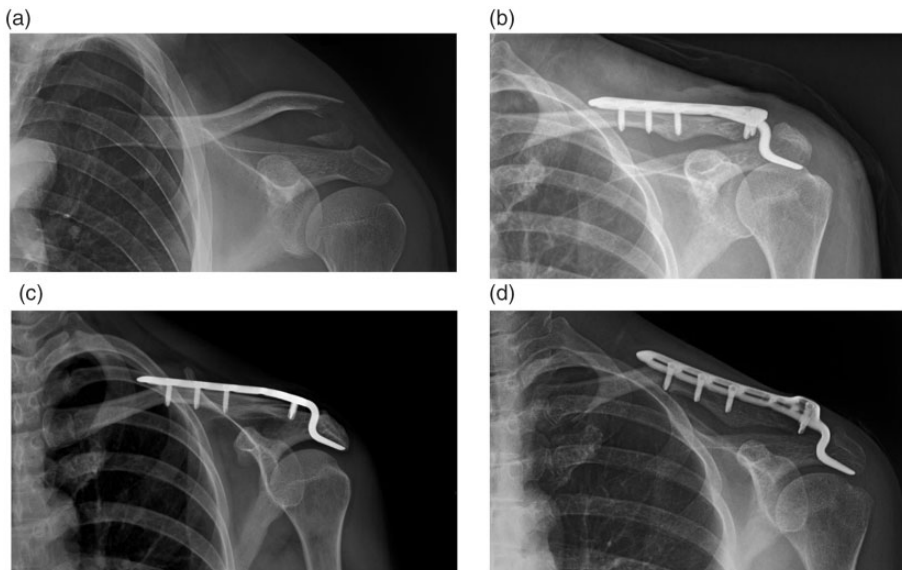
No.	Sex	Age (y)	Side	BMI (kg/m <sup>2</sup> )	ASA grade	Injury mechanism	Smoking	Drinking history	Time of post-op clavicular midshaft fracture (days)	Midshaft fracture caused by secondary trauma	Bending of the hook plate during surgery	No. of holes in plate	Depth of hook (mm)	Type of most medial screw	Treatment of midshaft fractures	Midshaft fracture union
1	Fe	44	L	30.6	I	S	Yes	No	40	No	No	7	15	Cort	Con	Yes
2	M	49	R	25.6	I	S	No	No	28	No	Yes	6	18	Lock	Con	Yes
3	M	76	R	28.0	III	F	No	Yes	60	No	No	6	15	Lock	Con	Yes
4	Fe	69	L	29.1	II	F	No	No	39	No	No	6	15	Lock	Cons	Yes
5	M	68	R	25.6	II	F	No	No	42	No	Yes	6	15	Cort	Con	Yes
6	M	56	R	25.5	I	F	No	No	158	Yes	Yes	6	15	Lock	Sur	Yes
7	M	53	L	28.8	III	TA	No	Yes	21	Yes	No	6	15	Lock	Con	Yes
8	M	56	L	31.1	II	F	No	No	20	No	No	7	15	Cort	Con	Yes
9	M	72	L	24.0	II	F	Yes	Yes	3	No	No	6	15	Lock	Sur	Yes
10	M	62	R	26.4	I	F	No	No	283	Yes	Yes	6	18	Cort	Con	Yes
11	Fe	51	R	28.0	I	TA	Yes	No	28	No	No	6	15	Lock	Cons	Yes
12	M	68	R	27.7	II	F	No	Yes	18	No	No	6	15	Cort	Con	Yes
13	M	67	L	28.5	II	F	No	No	433	Yes	Yes	6	15	Lock	Con	Yes
14	M	59	R	28.4	I	F	No	No	18	No	Yes	6	18	Cort	Con	Yes
15	Fe	52	R	26.6	I	F	No	No	85	No	No	5	15	Lock	Con	Yes
16	Fe	70	L	28.5	III	TA	No	No	29	No	No	6	15	Lock	Con	Yes
17	M	52	R	25.7	I	F	No	No	38	No	No	7	15	Cort	Con	Yes
18	M	48	R	32.5	I	S	Yes	Yes	367	Yes	Yes	6	15	Cort	Con	Yes
19	M	63	R	26.8	I	TA	No	No	17	No	No	6	15	Lock	Con	Yes
20	Fe	52	L	27.6	I	F	No	No	33	No	No	7	15	Lock	Con	Yes
21	M	48	L	30.2	I	S	No	Yes	10	No	No	6	15	Lock	Con	Yes
Total Fe:	≥65:	≥65:	L: n=9	>30.0:	≥III:	F: n=13	Yes:	Yes:	-	Yes:	Yes:	>6:	18:	n=3	Sur:	Yes:
n=6	n=7	n=4	n=4	n=3	n=4	n=4	n=4	n=6	n=5	n=7	n=4	n=4	n=3	n=9	n=2	n=21

No., number; Y, years; Fe, female; M, male; L, left; R, right; BMI, body mass index; ASA, American Society of Anesthesiologists; F, fall; S, sports injury; TA, traffic accident; Post-op, postoperative; Con, Conservative; Sur, Surgical; Cort, cortical; Lock, locking.

The secondary surgery indications for clavicular midshaft fractures after fixation with the hook plate were set as follows: serious deformity, shortening of  $>2$  cm, vascular or neurological injury, ipsilateral upper extremity fracture, displacement of  $>2$  cm, comminuted clavicular midshaft fracture with more than three fragments, and patient interest in rapid return of function. When the patient met one of the secondary surgery indications, the surgeon discussed the advantages and disadvantages of surgical and conservative treatments with the patient and advised him or her to undergo a secondary surgery to fix the clavicular midshaft fracture. Further surgery was performed by the surgeon when the patient provided written informed consent. Further surgery to remove the hook plate and fix the fracture was performed in two patients (Patients 6 and 9) after the diagnosis of this complication. Most patients in the complications group chose conservative treatment because of the absence of secondary surgery indications for the clavicular

midshaft fracture and concerns regarding its cost and probable complications. Bony union was diagnosed based on radiological evidence of bridging callus formation or invisible fracture lines together with the absence of pain in the affected shoulder upon physical examination within 1 year postoperatively. The remaining 19 patients were treated conservatively with sling fixation (see Figure 2). No fracture non-union occurred in the complications group. We found no significant differences in the smoking status, drinking history, American Society of Anesthesiologists grade, injury mechanism, length of the hook plate, side of the affected shoulder, depth of the hook, body mass index, type of medial screw used, or sex between the two groups.

Compared with the control group, the complications group contained significantly more elderly patients (11.8% vs. 33.3%,  $p=0.012$ ) and significantly more patients treated with hook plates that were not bent during surgery (43.5% vs. 66.7%,



**Figure 2.** Radiological images of Patient 20 (52-year-old woman). (a) Before surgery. (b) Immediately after surgery. (c) 33 days after surgery. (d) 61 days after surgery.

$p = 0.039$ ) (see Table 2). Based on the logistic regression analysis, elderly patients were more likely to develop clavicular midshaft fractures (unadjusted OR, 3.744; 95% CI, 1.424–9.844;  $p = 0.007$ ; adjusted OR, 3.904; 95% CI, 1.464–10.411;  $p = 0.007$ ). Patients treated with hook plates that were not bent during surgery were more likely to develop midshaft fractures (unadjusted OR, 2.597; 95% CI, 1.022–6.602;  $p = 0.045$ ; adjusted OR, 2.700; 95% CI, 1.049–6.948;  $p = 0.039$ ) (see Tables 3 and 4). Therefore, these two predictive variables (advanced age and lack of bending of the plate) were independent risk factors for clavicular midshaft fractures after hook plate

fixation. The difference in the rate of hook plate bending between the young control and complications groups (55.8% vs. 35.7%) was smaller than the difference in this rate between the elderly control and complications groups (61.5% vs. 28.6%). Although both differences were great, they were not statistically significant (Table 5).

## Discussion

Neer type II fractures are known for their low union rate of <70% without surgical fixation.<sup>21,22</sup> Therefore, many authors recommend surgical treatment.<sup>23,24</sup> Although

**Table 2.** Comparison of variables between the control group and complications group using the chi-square test.

	Control group (n = 331)	Complications group (n = 21)	p value
Female	113	6	0.601
Age of $\geq 65$ years	39	7	0.012*
Left side affected	185	9	0.244
BMI of $\geq 30$ kg/m <sup>2</sup>	82	4	0.554
ASA grade of $\geq$ III	49	3	1.000
Injury mechanism			0.998
Fall	205	13	
Sports and traffic accidents	126	8	
Smoking	75	4	0.909
Drinking history	79	6	0.625
Locking screw implanted at most medial hole	137	12	0.157
Lack of bending of plate during surgery	144	14	0.039*
<6 holes in plate	215	17	0.134
Depth of hook $\leq 15$ mm	230	18	0.114

BMI, body mass index; ASA, American Society of Anesthesiologists.

\*Statistically significant difference.

**Table 3.** Patients' data assessed by logistic regression.

	Complications group (n = 21)		Control group (n = 331)	
	Age of $\geq 65$ years	Age of <65 years	Age of $\geq 65$ years	Age of <65 years
Lack of bending of the plate	5	9	15	129
Bending of the plate	2	5	24	163

**Table 4.** Results of logistic regression.

Predictive variables	Unadjusted		Adjusted	
	OR (95% CI)	p	OR (95% CI)	p
Age of $\geq 65$ years	3.744 (1.424–9.844)	0.007	3.904 (1.464–10.411)	0.007
Lack of bending of hook plate during surgery	2.597 (1.022–6.602)	0.045	2.700 (1.049–6.948)	0.039

OR, odds ratio; CI, confidence interval.

**Table 5.** Comparison of rates of hook plate bending between control and complications groups in young and elderly patients using chi-square tests.

	Young control group (n = 292)	Young complications group (n = 14)	p value	Elderly control group (n = 39)	Elderly complication group (n = 7)	p value
Lack of bending of the hook plate	129	9	0.140	15	5	0.105
Bending of the plate	163	5		24	2	

various techniques for treating Neer II fractures have been reported,<sup>3</sup> the gold standard of surgical treatment is still under debate. As one of the latest recommended surgical treatments, arthroscopically assisted coracoclavicular fixation may improve functional outcomes and lower complication rates.<sup>25</sup> There is no need for secondary surgery to remove the implanted device after fracture union; this is regarded as a prominent advantage of arthroscopically assisted coracoclavicular fixation over hook plate fixation. However, Ding et al.<sup>6</sup> concluded that a lower rate of fixation failure, consistently maintained reduction when the patient undergoes rehabilitation, and convenient device insertion are the notable advantages of hook plates and the possible reasons for their popular use. During the last 5 years, many studies have investigated the complications associated with hook plates;<sup>8–12</sup> these complications are almost always associated with the hook part of the device. Shih et al.<sup>15</sup> argued that clavicular midshaft fractures

associated with the plate part have a negative effect on the relationship between the patient and the surgeon, especially when secondary fixation surgery is required. However, few studies have analyzed the potential risk factors for this complication.<sup>6</sup>

Significantly more patients of advanced age developed postoperative midshaft fractures in this study (unadjusted OR, 3.744;  $p=0.007$ ; adjusted OR, 3.904;  $p=0.007$ ). Many studies have shown higher rates of osteoporosis and lower bone mineral density in elderly patients than in young patients.<sup>26,27</sup> Elderly patients are more likely to develop fragility fractures caused by osteoporosis.<sup>28</sup> Therefore, the higher incidence of clavicular midshaft fractures after fixation with hook plates among elderly patients seems reasonable and is consistent with the results reported by Shih et al.<sup>15</sup> In their retrospective clinical study of 150 patients published in 2019, Shih et al.<sup>15</sup> analyzed the potential risk factors for clavicular midshaft fractures after hook plate fixation. These risk factors



included patient diagnosis (distal clavicle fracture or acromioclavicular dislocation), sex, and age.<sup>15</sup> They reported that clavicular midshaft fractures after hook plate fixation for the treatment of either distal clavicular fractures or coracoclavicular joint dislocation were more likely to occur in patients of advanced age than in younger patients.<sup>15</sup> In contrast, only adult patients diagnosed with Neer type II clavicular fractures were included in the current study. Compared with the study by Shih et al.,<sup>15</sup> more potential risk factors were analyzed in the current study, including the type of medial screw, whether the hook plate was bent during surgery, the number of holes in the plate, and the depth of the hook.

In theory, eccentric drilling causes more cortical bone defects, and the results reported by Xie et al.<sup>13</sup> implied an association between midshaft fractures and eccentric drilling. During surgery, implantation of cortical screws allows for variation in the direction of drilling, which can theoretically decrease the incidence of eccentric drilling. However, the implantation of cortical screws was not associated with a reduced incidence of midshaft fractures in the current study. Similar findings were also reported by Ni et al.<sup>14</sup> In a clinical study published in 2020, Ni et al.<sup>14</sup> demonstrated that the type of the most medial screw did not significantly influence the incidence of postoperative clavicular midshaft fractures (cortical screw: 8.3% vs. locking screw: 13.3%).

Significantly more patients treated with hook plates that were not bent during surgery developed postoperative clavicular midshaft fractures in the current study (unadjusted OR, 2.597;  $p=0.045$ ; adjusted OR, 2.700;  $p=0.039$ ). Tiren et al.<sup>29</sup> reported difficulty with fixation of hook plates due to the need to use forceful clamping to push the plate down to the surface of the clavicular midshaft. With the use of a forceful clamp, the stress on the hook

dramatically increases in accordance with the principle of leverage. Meanwhile, the stress on the clavicular midshaft at the most medial screw will also increase after implantation of the screw and removal of the clamp. Kim et al.<sup>30</sup> indicated that high elevation of the shoulder results in spontaneous posterior tilt of the scapula. The hook of the plate is also depressed by the acromion under rotation of the acromioclavicular joint. Therefore, during rehabilitation or secondary injury of the affected shoulder, the force on the hook shifts to the most medial screw in accordance with the principle of leverage, possibly causing a midshaft fracture. However, instead of forceful clamping, bending of the hook plate can achieve easy fixation of the hook plate to the clavicular midshaft. Theoretically, there is little stress at the medial screw with the affected shoulder in the resting position. Thus, compared with bending of the plate, the stress around the most medial screw is essentially higher when a forceful clamp is applied for fixation or reduction. To date, there has been a paucity of literature on the association between modification of a hook plate's contour and stress risers at the medial screw. However, several studies have revealed a lower complication rate and lower stress on the clavicular midshaft when the hook or plate is bent.<sup>14,17,18</sup> In the current study, bending of the hook plate had a greater effect on decreasing the rate of occurrence of midshaft fractures among elderly than young patients. Although the effect was not statistically significant, it seems reasonable that bending of the hook plate should be encouraged during surgery, especially for elderly patients.

When comparing the control group and complications group, we found no significant differences in the hook plate length or depth. In a biomechanics study, Shih et al.<sup>19</sup> found that the stress around the most medial screw after fixation of a

six-hole hook plate was greater than the stress after fixation of longer hook plates. Therefore, in this study, the six-hole plate was chosen as the cut-off for studying the effect of the number of holes on the risk of clavicular midshaft fractures. In the control group, hook plates of different lengths were used (five holes,  $n = 38$ ; six holes,  $n = 166$ ; seven holes,  $n = 125$ ; eight holes,  $n = 0$ ). Given that no patients in this study received eight-hole plates, there was likely no dramatic reduction in stress on the midshaft with the six-hole hook plate as compared with the seven-hole plate. In another biomechanics study, Lee et al.<sup>20</sup> chose a hook plate depth of 15 mm as the cut-off to analyze the distribution of stress after surgeries with hook plates of different depths. They reported that stress on the clavicular midshaft decreases with increasing hook plate depth. In the current study, most of the hook plates that were used had a depth of 15 mm or 18 mm. Therefore, 15 mm was chosen as the cut-off depth. However, the depth of the hook plate did not differ between the control and complications groups, perhaps because of individual variation in the thickness of the acromion.<sup>31</sup> Our findings are consistent with the results reported by Ni et al.<sup>14</sup>

This retrospective observational study had several limitations. Our findings indicated that significantly more elderly patients developed clavicular midshaft fractures after fixation with hook plates. This might have been due to their lower bone mineral density than young patients. However, sufficient data are lacking on the bone mineral density in patients of advanced age and young patients to support our theory in this study. Selection bias cannot be avoided in retrospective studies such as this one, and some of the patients were excluded because of a lack of data integrity. This study had a large sample size of 352 patients; however, the sample size in the complications group

was relatively small, which decreased the reliability of the results. Although many potential risk factors associated with clavicular midshaft fractures were analyzed, it is possible that there are still some important unmeasured predictive variables. A multi-center prospective randomized controlled study is required to confirm our results.

## Conclusion

Clavicular midshaft fractures are a severe complication after hook plate fixation. The incidence of this complication may be significantly increased by advanced age and decreased by hook plate bending.

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## Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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