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.1 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.2 A clavicular hook plate is a recommended device for treating distal clavicular fractures.3–5 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,6 and although this surgery is associated with excellent functional outcomes for the shoulders,7 the high complication rate of 40.7% is problematic.3,7 Complications caused by the hook under the acromion are common and include acromial osteolysis, acromioclavicular joint arthrosis, subacromial impingement, and rotator cuff injury.8–12 These complications have been discussed by many authors, and some are considered to be associated with highly concentrated subacromial stress.2 However, clavicular midshaft fractures located on another stress concentration point are rarely reported because of their lower incidence (1.3%–9.8%).6,13,14 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.15 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.13–15

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.16 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 (≥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 ≥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...
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, the number of holes in the plate, and the hook plate depth. 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 ≥65 years, elderly control group; n = 39), and elderly patients in the complications group (age of ≥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,
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).

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

| No. | Sex | Age (y) | Side | BMI (kg/m²) | 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                                        | No                | 7                | 15                        | Cort                        | Con                 | Yes                       |
| 2   | M   | 49      | R    | 25.6        | I          | S               | No      | Yes             | 28                                            | No                                          | Yes                                       | 6                 | 18               | Yes                       | Lock                        | Con                 | Yes                       |
| 3   | M   | 76      | R    | 28.0        | III        | F               | No      | Yes             | 60                                            | No                                          | No                                        | 6                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 4   | Fe  | 69      | L    | 29.1        | II         | F               | No      | No              | 39                                            | No                                          | No                                        | No                | 6                 | 15                        | Lock                        | Cons                | Yes                       |
| 5   | M   | 68      | R    | 25.6        | II         | F               | No      | No              | 42                                            | No                                          | Yes                                       | 6                 | 15               | Yes                       | Cort                        | Con                 | Yes                       |
| 6   | M   | 56      | R    | 25.5        | I          | F               | No      | No              | 158                                           | Yes                                         | Yes                                       | 6                 | 15               | Yes                       | Lock                        | Sur                 | Yes                       |
| 7   | M   | 53      | L    | 28.8        | III        | TA              | No      | Yes             | 21                                            | Yes                                         | No                                        | 6                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 8   | M   | 56      | L    | 31.1        | II         | F               | No      | No              | 20                                            | No                                          | No                                        | 7                 | 15               | Yes                       | Cort                        | Con                 | Yes                       |
| 9   | M   | 72      | L    | 24.0        | II         | F               | Yes     | Yes             | 3                                             | No                                          | No                                        | 6                 | 15               | Yes                       | Lock                        | Sur                 | Yes                       |
| 10  | M   | 62      | R    | 26.4        | I          | F               | No      | No              | 283                                           | Yes                                         | Yes                                       | 6                 | 18               | Yes                       | Cort                        | Con                 | Yes                       |
| 11  | Fe  | 51      | R    | 28.0        | I          | TA              | Yes     | No              | 28                                            | No                                          | No                                        | 6                 | 15               | Yes                       | Lock                        | Cons                | Yes                       |
| 12  | M   | 68      | R    | 27.7        | II         | F               | No      | Yes             | 18                                            | No                                          | No                                        | 6                 | 15               | Yes                       | Cort                        | Con                 | Yes                       |
| 13  | M   | 67      | L    | 28.5        | II         | F               | No      | No              | 433                                           | Yes                                         | Yes                                       | 6                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 14  | M   | 59      | R    | 28.4        | I          | F               | No      | No              | 18                                            | No                                          | Yes                                       | 6                 | 18               | Yes                       | Cort                        | Con                 | Yes                       |
| 15  | Fe  | 52      | R    | 26.6        | I          | F               | No      | No              | 85                                            | No                                          | No                                        | 5                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 16  | Fe  | 70      | L    | 28.5        | III        | TA              | No      | No              | 29                                            | No                                          | No                                        | 6                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 17  | M   | 52      | R    | 25.7        | I          | F               | No      | No              | 38                                            | No                                          | No                                        | 7                 | 15               | Yes                       | Cort                        | Con                 | Yes                       |
| 18  | M   | 48      | R    | 32.5        | I          | S               | Yes     | Yes             | 367                                           | Yes                                         | Yes                                       | 6                 | 15               | Yes                       | Cort                        | Con                 | Yes                       |
| 19  | M   | 63      | R    | 26.8        | I          | TA              | No      | No              | 17                                            | No                                          | No                                        | 6                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 20  | Fe  | 52      | L    | 27.6        | I          | F               | No      | No              | 33                                            | No                                          | No                                        | 7                 | 15               | Yes                       | Lock                        | Con                 | Yes                       |
| 21  | M   | 48      | L    | 30.2        | I          | S               | No      | Yes             | 10                                            | No                                          | No                                        | 6                 | 15               | Yes                       | Cort                        | Con                 | Yes                       |

| Type of most medial screw | Total | No. | ≥ 65: | L: n = 9 | > 30.0: | ≥ III: | F: n = 13 | Yes: | Yes: | Yes: | > 6: | 18: n = 3 | Cort: | Sur: | Yes: |
|---------------------------|-------|-----|-------|---------|---------|--------|-----------|-------|-------|-------|-------|-----------|--------|------|-------|
| Cort                      | 9     | 9   | 9     | 9       | 9       | 9      | 9         | 9     | 9     | 9     | 9     | 9         | 9      | 9    | 9     |
| Lock                      | 8     | 8   | 8     | 12      | 12      | 12     | 12        | 12    | 12    | 12    | 12    | 12        | 12     | 12   | 12    |
| Yes                       | 12    | 12  | 12    | 12      | 12      | 12     | 12        | 12    | 12    | 12    | 12    | 12        | 12     | 12   | 12    |

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.
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.\(^{21,22}\) Therefore, many authors recommend surgical treatment.\(^{23,24}\) 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\(^2\) | 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                            | 15                       | 129                      |
| Bending of the plate        | 2                            | 24                       | 163                      |
various techniques for treating Neer II fractures have been reported, 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. 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. 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; these complications are almost always associated with the hook part of the device. Shih et al. 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. 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. Elderly patients are more likely to develop fragility fractures caused by osteoporosis. 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. In their retrospective clinical study of 150 patients published in 2019, Shih et al. analyzed the potential risk factors for clavicular midshaft fractures after hook plate fixation. These risk factors

| Predictive variables | Unadjusted OR (95% CI) | p | Adjusted OR (95% CI) | p |
|----------------------|------------------------|---|----------------------|---|
| Age of ≥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.

|                      | 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                                  |         |

Table 4. Results of logistic regression.

Table 5. Comparison of rates of hook plate bending between control and complications groups in young and elderly patients using chi-square tests.
included patient diagnosis (distal clavicle fracture or acromioclavicular dislocation), sex, and age. 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. 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., 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. 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. In a clinical study published in 2020, Ni et al. 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. 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. 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. 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. 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.20 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.31 Our findings are consistent with the results reported by Ni et al.14

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**

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**References**

1. Postacchini F, Gumina S, De Santis P, et al. Epidemiology of clavicle fractures. *J Shoulder Elbow Surg* 2002; 11: 452–456.
2. Gu X, Cheng B, Sun J, et al. Arthroscopic evaluation for omalgia patients undergoing the clavicular hook plate fixation of distal clavicle fractures. *J Orthop Surg Res* 2014; 9: 46. doi: 10.1186/1749-799X-9-46.
3. Oh JH, Kim SH, Lee JH, et al. Treatment of distal clavicle fracture: a systematic review of treatment modalities in 425 fractures.
4. Seo J, Heo K, Kim SJ, et al. Comparison of a novel hybrid hook locking plate fixation method with the conventional AO hook plate fixation method for Neer type V distal clavicle fractures. Orthop Traumatol Surg Res 2020; 106: 67–75. doi: 10.1016/j.otsr.2019.10.014.

5. Chen MJ, DeBaun MR, Salazar BP, et al. Hook versus locking plate fixation for Neer type-II and type-V distal clavicle fractures: a retrospective cohort study. Eur J Orthop Surg Traumatol 2020; 30: 1027–1031. doi: 10.1007/s00590-020-02658-7.

6. Ding M, Ni J, Hu J, et al. Rare complication of clavicular hook plate: clavicle fracture at the medial end of the plate. J Shoulder Elbow Surg 2011; 20: e18–e20.

7. Baunach D, Eid K, Ricks M, et al. Long-term clinical and radiological results after hook plate osteosynthesis of lateral clavicle fractures. J Orthop Trauma 2020. doi:10.1097/BOT.0000000000002007.[Online ahead of print.]

8. Ochen Y, Frima H, Marijn Houwert R, et al. Surgical treatment of Neer type II and type V lateral clavicular fractures: comparison of hook plate versus superior plate with lateral extension: a retrospective cohort study. Eur J Orthop Surg Traumatol 2019; 29: 989–997.

9. Charity RM, Haidar SG, Ghosh S, et al. Fixation failure of the clavicular hook plate: a report of three cases. J Orthop Surg (Hong Kong) 2006; 14: 333–335.

10. Kashii M, Inui H, Yamamoto K, et al. Surgical treatment of distal clavicle fractures using the clavicular hook plate. Clin Orthop Relat Res 2006; 447: 158–164.

11. Lee YS, Lau MJ, Tseng YC, et al. Comparison of the efficacy of hook plate versus tension band wire in the treatment of unstable fractures of the distal clavicle. Int Orthop 2009; 33: 1401–1405.

12. Meda PVK, Machani B, Sinopidis C, et al. Clavicular hook plate for lateral end fractures: a prospective study. Injury 2006; 37: 277–283.

13. Xie X, Dong Y, Wang L, et al. Conservative treatment for clavicle stress fractures following the clavicular hook plate fixation. Acta Orthop Belg 2019; 85: 283–288.

14. Ni PL, Lin KC, Chen CY, et al. Peri-implant fractures following hook plate fixation for unstable distal clavicle fractures. Orthopedics 2020; 43: e359–e363.

15. Shih JT, Wu CC, Wang CC, et al. Midshaft clavicle fracture following osteosynthesis with a hook plate: a retrospective case analysis. Arch Orthop Trauma Surg 2020. doi:10.1007/s00402-020-03397-4. Online ahead of print.

16. Von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med 2007; 147: 573–577.

17. Lee KW, Lee SK, Kim KJ, et al. Arthroscopic-assisted locking compression plate clavicular hook fixation for unstable fractures of the lateral end of the clavicle: a prospective study. Int Orthop 2010; 34: 839–845.

18. Hung LK, Su KC, Lu WH, et al. Biomechanical analysis of clavicle hook plate implantation with different hook angles in the acromioclavicular joint. Int Orthop 2017; 41: 1663–1669.

19. Shih CM, Huang KC, Pan CC, et al. Biomechanical analysis of acromioclavicular joint dislocation treated with clavicle hook plates in different lengths. Int Orthop 2015; 39: 2239–2244.

20. Lee CH, Shih CM, Huang KC, et al. Biomechanical analysis of implanted clavicle hook plates with different implant depths and materials in the acromioclavicular joint: a finite element analysis study. Artif Organs 2016; 40: 1062–1070.

21. Rokito AS, Zuckerman JD, Shaari JM, et al. A comparison of nonoperative and operative treatment of type II distal clavicle fractures. Bull Hosp Jt Dis 2002–2003; 61: 32–39.

22. Robinson CM and Cairns DA. Primary nonoperative treatment of displaced lateral fractures of the clavicle. J Bone Joint Surg Am 2004; 86: 778–782.

23. Muramatsu K, Shigetomi M, Matsunaga T, et al. Use of the AO hook-plate for treatment of unstable fractures of the distal...
clavicle. *Arch Orthop Trauma Surg* 2007; 127: 191–194.

24. Lee W, Choi CH, Choi YR, et al. Clavicle hook plate fixation for distal-third clavicle fracture (Neer type II): comparison of clinical and radiologic outcomes between Neer types IIA and IIB. *J Shoulder Elbow Surg* 2017; 26: 1210–1215.

25. Kapicioglu M, Erden T, Bilgi E, et al. All arthroscopic coracoclavicular button fixation is efficient for Neer type II distal clavicle fractures. *Knee Surg Sports Traumatol Arthrose* 2020. doi: 10.1007/s00167-020-06048-8. Online ahead of print.

26. Zhang ZQ, Ho SC, Chen ZQ, et al. Reference values of bone mineral density and prevalence of osteoporosis in Chinese adults. *Osteoporos Int* 2014; 25: 497–507.

27. Chan WP, Liu JF and Chi WL. Evaluation of bone mineral density of the lumbar spine and proximal femur in population-based routine health examinations of healthy Asians. *Acta Radiol* 2004; 45: 59–64.

28. Chang KP, Center JR, Nguyen TV, et al. Incidence of hip and other osteoporotic fractures in elderly men and women: Dubbo Osteoporosis Epidemiology Study. *J Bone Miner Res* 2004; 19: 532–536.

29. Tiren D, Van Bemmel AJM, Swank DJ, et al. Hook plate fixation of acute displaced lateral clavicle fractures: mid-term results and a brief literature overview. *J Orthop Surg Res* 2012; 7: 2.

30. Kim YS, Yoo YS, Jang SW, et al. In vivo analysis of acromioclavicular joint motion after hook plate fixation using threedimensional computed tomography. *J Shoulder Elbow Surg* 2015; 24: 1106–1111.

31. ElMaraghy AW, Devereaux MW, Ravichandiran K, et al. Subacromial morphometric assessment of the clavicle hook plate. *Injury* 2010; 41: 613–619.