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Hook plate fixation versus locking plate fixation for distal clavicle fracture: a multicenter propensity score-matched study

Hiroshi Takahashi[1], Yasuhiko Takegami[1], Katsuhiro Tokutake[2], Yujiro Katayama[1] and Shiro Imagama[1]

[1]*Department of Orthopedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan*
[2]*Department of Hand Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan*

ABSTRACT

Hook plate fixation and locking plate fixation are two standard internal fixation implants for treating distal clavicle fractures. We aimed to clarify the following: 1) Does the locking plate offer better clinical outcomes than the hook plate? 2) Is bone union better with a locking plate than hook plate? and 3) Are complications different between the locking plate and hook plate? We conducted a retrospective multicenter study of 338 patients who underwent surgery from 2014 to 2018 in our 10 hospitals, which comprise the TRON group. Of them, 208 patients treated using any plates were eligible. After 30 patients were excluded for various reasons, 178 patients were included. We classified them into two groups, locking plate group (Group L) and hook plate group (Group H), using propensity score matching. We confirmed bone union with an X-ray, evaluated the UCLA shoulder score, and compared the frequency of complications. After matching, Group L and Group H included 49 patients each. The UCLA score was higher in Group L than in Group H at each follow-up point. We confirmed bone union in all patients in Group L, but it was not confirmed in three patients (6.1%) in Group H. No statistically significant differences were observed except for plate migration, which was observed in nine patients (18.4%) in Group H but in no patients in Group L. The postoperative UCLA score was significantly better in Group L. We recommend the locking plate as a surgical treatment for distal clavicle fractures.

Keywords: distal clavicle fracture, locking plate, hook plate, clavicle, propensity score matching

Abbreviations:
AC: acromioclavicular
ASA: American Society of Anesthesiologists
UCLA: University of California, Los Angeles

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Corresponding Author: Yasuhiko Takegami, MD, PhD
Department of Orthopedic Surgery, Nagoya University Graduate School of Medicine, 65 Tsurumai-cho, Showa-ku, Nagoya 466-8550, Japan
Tel: +81-52-741-2111, Fax: +81-52-744-2460, E-mail: takegami@med.nagoya-u.ac.jp

INTRODUCTION

Although distal clavicle fractures are relatively rare, representing only 15–28% of all clavicle fractures, they constitute 30–45% of the cases of nonunion.[1-3] Nonunion of a distal clavicle fracture causes pain and dysfunction. Various implants for fixation of distal clavicle fracture have been developed to prevent nonunion, including coracoclavicular fixation, tension band wiring, hook plates, and clavicular locking plates.[4,5] Hook plate fixation and locking plate fixation are two standard internal fixation implants for treating clavicle fractures. Recent systematic reviews have shown that both the hook plate and locking plate offer excellent bone union rates and provide comparative functional outcomes,[6,7] although hook plate fixation had higher complication rates.[6-12] However, these reviews were based on case series with relatively small sample size. In addition, only a few papers directly compare the two fixation methods. We hypothesized that clinical outcome with the clavicular locking plate would be better than that with hook plate fixation for distal clavicle fracture. The purpose of this multicenter study was to compare 1) the clinical outcomes of hook plate fixation to those of locking plate fixation for distal clavicle fracture, 2) bone union with the two devices, and 3) the incidence of complications.

MATERIALS AND METHODS

Study design and setting

This multicenter retrospective study used data obtained from the TRON (Trauma Research Group of Nagoya) database in which member hospitals have registered orthopedic trauma surgery cases annually since 2014. The hospitals participating in the database are all hospitals associated with the Department of Orthopedic Surgery of our university. Orthopedic surgeons perform the surgery at these hospitals in Central Japan. We collected cases of clavicle fractures from this database that were treated surgically.

Participants

From January 2014 to December 2018, 338 patients with distal clavicle fractures were admitted and underwent surgery in our 10 hospitals. Of them, 208 patients treated using any plates, clavicular locking plates, or clavicular hook plates were eligible. We excluded 19 patients lost to follow-up at six months after surgery, 10 patients with no University of California at Los Angeles (UCLA) shoulder score or follow-up X-ray, and one patient who received additional treatment of coracoclavicular fixation. Thus, 178 patients were included in this study group (Figure 1). We classified the patients into two groups according to the kind of treatment received: the locking plate group (Group L) and the hook plate group (Group H).

Demographics

After applying the inclusion and exclusion criteria, the study sample contained 178 patients with distal clavicle fractures. Background and operative procedures of the patients are described in Table 1. We obtained patient characteristics data from the electronic records in each hospital. We extracted sex, age, body mass index, American Society of Anesthesiologists (ASA) Physical Status Classification System, operation time, surgical method, and the implant used.

Surgical procedure

Indications for surgical treatments were Neer type II with displacement or type V fracture. Patients were operated on under general anesthesia and in the standard beach chair position.

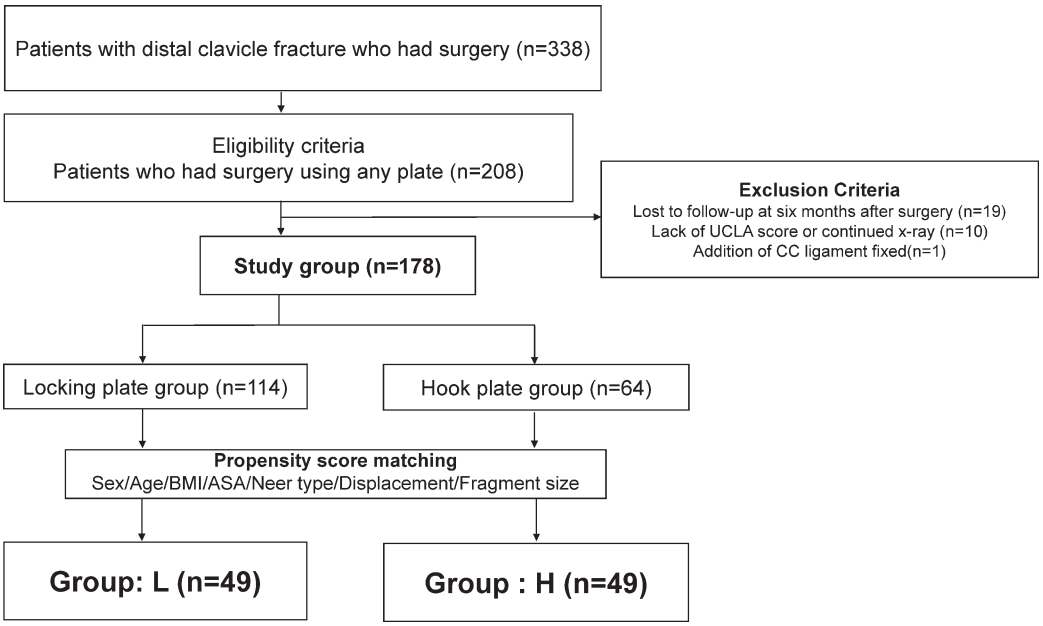

Fig. 1 Flow diagram showing the number of patients included in this study
BMI: body mass index
ASA: American Society of Anesthesiologists Physical Status Classification
CC: coracoclavicular

Table 1 Patients demographics (n=178)

Characteristic	Value
Implant (Locking plate/Hook plate), n	114/64
Sex (M/F), n (%)	159 (89.3)/19 (10.7)
Age, years (SD)	46.3 (14.4)
BMI, kg/m^2 (SD)	22.5 (3.05)
ASA (I/II/III/IV), n (%)	130 (73.0)/39 (21.9)/8 (4.5)/1 (0.6)
Neer type (II/V), n (%)	154 (86.5)/24 (13.5)
Dislocation, mm (range)	9.0 (0-32)
Fragment size, mm (SD)	20.3 (9.78)

BMI: body mass index
ASA: American Society of Anesthesiologists Physical Status Classification System

We used a standard anterosuperior approach to the clavicle. Electrocautery was used to control superficial bleeding and dissection directly to the clavicle. Care was taken not to damage the supraclavicular nerve and the superior acromioclavicular joint ligaments. After identifying the fracture site, all hematoma and debris were removed. Then, we used a tenaculum bone clamp to provide an efficacious reduction. The surgical methods are as follows.

Locking plate. We used an LCP™ (DePuy Synthes) or VariAx (Stryker) plate. The plate was

secured to the clavicle once the reduction was confirmed. We filled the medial holes with both locking and non-locking screws. Because the lateral fragment was often small and vulnerable, as much as possible, we inserted screws into the distal fragment. We confirmed proper hardware placement in that the plate did not cross over the acromioclavicular joint and that all screws remained extra-articular on the fluoroscopic image.

Hook plate. We used an LCP (DePuy Synthes) plate. Without opening the acromioclavicular (AC) joint, the joint's location was marked with a needle and confirmed by fluoroscopy. We removed the dorsal soft tissue of the AC joint. An appropriate depth of plate was used and passed below the acromion. The shaft of the plate was placed on the superior aspect of the clavicle and checked for alignment. A deeper hook was used in case of difficulty lowering the plate shaft onto the clavicle. The clavicle portion of the plate was slightly bent to ensure central placement of the plate on the clavicle. The plate was then secured to the shaft with 3.5-mm cortical screws approximating the clavicle's plate. For either surgical method, once we were satisfied with the reduction and hardware placement, the wound was closed in layers. Drains were not used.

Aftercare

Patients were treated for about two weeks by use of a sling to allow for range-of-motion exercises. In both groups, active mobilization was allowed postoperatively. In Group L, full range of motion was allowed from 4 weeks postoperatively. In Group H, the postoperative elevation was limited to 90°, and full range of motion was allowed after plate removal. The implant was removed from all patients after bone union was confirmed.

Data evaluation

We evaluated the UCLA score at three and six months after surgery and at the final follow-up. The UCLA score system mainly grades five aspects: pain, function, active forward flexion, manual muscle testing, and patient satisfaction. The scoring standard has a maximum of 35 points (best possible outcome). There is no reported minimum clinically important difference for the UCLA score for clavicle fractures. However, the minimum clinically important difference for proximal humerus fractures was reported to be 2–2.4 points.[13]

We defined contracture, impingement, superficial and deep infections, scar problems, nonunion, reduction-loss, migration, and screw back-out as complications referring to previous reports.[6-12,14] Complications were collected from the electronic medical charts. We also compared the frequency of complications. Plate migration is defined as an obvious loss of reduction or plate breakage. As for hook plates, complications include radiographic evidence of osteolysis of the acromion around the hook.[15]

Radiographic analysis

Radiographic data were obtained by reading the computerized radiographic images available in the computer system of each institution. All patients underwent an X-ray before surgery for determination of the type of fracture according to the Neer classification. The radiographic evaluation comprised the analysis of conventional radiographic frontal views. We defined dislocation as the distance between the inferior rim of the proximal end and the superior rim of the distal end of the clavicle.[16] We defined the inferior cortex length of the distal fragment as the fragment size.[17] We obtained an X-ray at three and six months after surgery and at the final follow-up to confirm bone union.

Each measurement was taken twice at a two-week interval by one orthopedic surgeon (HT), and the final measurement was the average of the two values. Intraobserver reliability was measured using Cohen's kappa value and intraclass correlation coefficient. Intraobserver reliability

was found to be good (Cohen' kappa = 0.90, 95% confidence interval = 0.88–0.92, intraclass correlation coefficient = 0.931, 95% confidence interval = 0.88–0.97).

Statistical analysis

We used propensity score matching to mitigate the effects of confounding. When using propensity scores, we selected sex, age, body mass index, ASA Physical Status Classification System, Neer type, displacement, and fragment size as confounding factors referred to in previous studies.[18,19] We evaluated differences between the two groups using the Student *t*-test and Mann-Whitney U test for the continuous variables and Fisher's exact test for the categorical variables. P <0.05 was considered to indicate significance. We used EZR software version 1.40 (Jichi Medical School, Tochigi, Japan) for statistical analysis.

We used the results from a prior study to assume sample size using power analysis, which suggested a 3-point difference in the UCLA score. The standard deviation was 3.0. This resulted in 22 patients being required in each group.[20]

RESULTS

Group L included 114 patients, and Group H included 64 patients (Table 1). After propensity score matching, Group L and Group H included 49 patients each (Figure 1; Table 2). There were no statistically significant differences between the two groups. Plate removal was performed in all cases, and the average hardware removal period was shorter for Group H than for Group L.

There was no statistically significant difference in the operation time for open reduction and internal fixation between the two groups (Group L, 92 min vs Group H, 85 min; P = 0.15). Figure 2 shows the values of the UCLA score at three and six months and at the last follow-up. The UCLA score in Group L was higher than that in Group H at each follow-up point (median

Table 2 Study group demographics

Characteristic	Group L	Group H	P Value
Number, n	49	49	
Sex (M/F), n (%)	44 (89.8)/5 (10.2)	43 (87.8)/6 (12.2)	1
Age, years (SD)	43.4 (12.7)	45.9 (15.1)	0.379
BMI, kg/m^2 (SD)	22.0 (3.4)	21.9 (2.5)	0.951
ASA (I/II/III/IV), n (%)	38 (77.6)/7 (14.3)/3 (6.1)/1 (2.0)	33 (67.3)/14 (28.6)/2 (4.1)/0 (0)	0.226
Neer type (II/V), n (%)	42 (85.7)/7 (14.3)	42 (85.7)/7 (14.3)	1
Operative time, min (SD)	92 (32.2)	85 (34.4)	0.147
Follow-up period, months (range)	12.9 (6–22)	9.0 (6–23)	
Hardware removal, months (range)	13.0 (6.4–15.1)	8.9 (6.4–12.4)	

BMI: body mass index
ASA: American Society of Anesthesiologists Physical Status Classification System

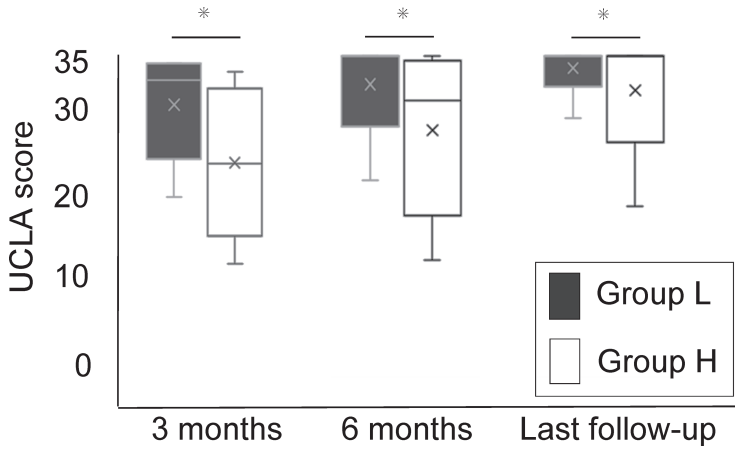

Fig. 2 Box plots of UCLA score at 3 and 6 months after surgery and at the final follow-up visit for both groups

Each box represents the 25th and 75th percentiles, and lines within the boxes represent the median. Crosses in the boxes represent the mean, and whisker bars represent the 10th and 90th percentiles.
*P <0.05

Table 3 UCLA shoulder scores at three and six months and at last follow-up

Score	3 months			6 months			Last follow-up		
Category	Group L	Group H	P value	Group L	Group H	P value	Group L	Group H	P value
Pain	8.00 [4.00, 10.00]	8.00 [1.00, 10.00]	0.076	10.00 [6.00, 10.00]	10.00 [2.00, 10.00]	0.008*	10.00 [8.00, 10.00]	10.00 [2.00, 10.00]	0.067
Function	10.00 [6.00, 10.00]	8.00 [4.00, 10.00]	<0.001*	10.00 [8.00, 10.00]	10.00 [4.00, 10.00]	0.001*	10.00 [8.00, 10.00]	10.00 [8.00, 10.00]	0.021*
Active forward flexion	5.00 [2.00, 5.00]	3.00 [2.00, 5.00]	<0.001*	5.00 [3.00, 5.00]	4.00 [2.00, 5.00]	<0.001*	5.00 [4.00, 5.00]	5.00 [3.00, 5.00]	0.212
Manual muscle testing	5.00 [4.00, 5.00]	5.00 [2.00, 5.00]	0.007*	5.00 [4.00, 5.00]	5.00 [3.00, 5.00]	0.001*	5.00 [4.00, 5.00]	5.00 [3.00, 5.00]	0.044*
Satisfaction	5.00 [0.00, 5.00]	5.00 [0.00, 5.00]	<0.001*	5.00 [0.00, 5.00]	5.00 [0.00, 5.00]	0.004*	5.00 [0.00, 5.00]	5.00 [0.00, 5.00]	0.156

*Indicates statistical significance (p <0.05)

at 3 months, 6 months, and last follow-up: 33 vs 27, P <0.001; 35 vs 30.5, P <0.001; and 35 vs 35, P = 0.03, respectively). Table 3 shows the UCLA subscale scores for pain, function, active forward flexion, manual muscle testing, and patient satisfaction in both groups. All values except the pain subscale in Group L were significantly better than those in Group H up to 6 months after surgery. Group L values for the subscales of function and manual muscle testing were higher than those in Group H to the last follow-up.

We confirmed bone union in all patients in Group L. However, we could not confirm bone union in three patients (6.1%) in Group H (P = 0.24), and these fractures were all Neer classification type II.

Table 4 shows the incidence of complications related to the two implant types. No statistically significant differences were observed except for plate migration between the two groups. Plate

Table 4 Complications in the two groups

Complication	Group L	Group H	P value
Number, n	49	49	
Impingement, n (%)	0 (0.0)	4 (8.2)	0.117
Infection, n (%)	4 (8.2)	3 (6.1)	1
Scar problem, n (%)	0 (0)	1 (2.0)	1
Reduction loss, n (%)	0 (0)	3 (6.1	0.242
Plate migration, n (%)	0 (0)	9 (18.4)	0.003*
Screw backout, n (%)	1 (2.0)	2 (4.1)	1
Re-operation, n (%)	2 (4.1)	1 (2.0)	1

L: locking plate
H: hook plate
*Indicates statistical significance ($p < 0.05$)

migration was observed in nine patients (18.4%) in Group H but in no patients in Group L.

DISCUSSION

The ideal surgical management of distal clavicle fractures continues to be controversial. We compared the postoperative results of the locking plate and the hook plate for distal clavicle fracture repair in terms of clinical outcomes, bone union, and the incidence of complications.

Clinical outcomes

As for clinical outcomes, as shown in Figure 2, the UCLA scores indicated that the hook plate group performed worse than the locking plate group at three months, six months, and at the last follow-up. A meta-analysis reported that compared with the locking plate, the hook plate for the treatment of distal clavicle fractures was associated with worse recovery of shoulder function.[6]

We showed that the clinical outcomes in the patients with hook plates were worse than those in the patients with locking plates. We assume that the irritation of bone and soft tissue by the hooks affects the clinical outcome. In a morphometric analysis study, the hook penetrated the synovial bursa in 89% of the specimens, was in contact with the supraspinatus muscle in 60%, and came into contact with the acromion after inserting the hook plate in 60%. The space under the scapula narrowed, causing an increase in synovial bursa pressure.[21] The presence of the hook plate restricts rotation of the large tuberosity of the humerus, and direct collision with the large tuberosity can stimulate and damage the supraspinatus muscle, resulting in pain and weakness.[22] A finite element analysis also showed that the force generated by the hook plate was concentrated on the acromion's lower surface.[23] In addition, the compression force can lead to local inflammatory stimulation of soft tissue.[24]

Rehabilitation progress was slower in the hook plate group. We speculated that rehabilitation might not proceed as expected due to the reduced opportunity for the patient to move the shoulder joint, causing contracture of the shoulder joint and, eventually, dysfunction. Therefore, we considered that the pain remained, range of motion was impaired, and muscle strength decreased, which eventually led to the decrease in patient satisfaction. In contrast, locking plates provide excellent fixation of bone fragments but do not contribute to AC joint stability. The treatment

of Neer type II distal clavicle fractures with a titanium cable plus a locking plate has a good curative effect, few complications, and good postoperative recovery.[25] Further studies are required to evaluate the efficacy of additional ligament reconstruction.

Bone union

Our results regarding bone union were similar to those of several previous studies. No significant difference was found between the locking plate and hook plate groups in the rate of bone union.[24] Another systematic review showed there to be no statistically significant difference between the groups in terms of the occurrence of delayed union.[25] Further, a biomechanical study showed no significant difference in the strength of fixation between the locking plate and hook plate.[26]

Complications between the two plate types

Among the complications, only plate migration was significantly more common in Group H. The nonunion present in the 3 patients (6.1%) in Group H may have been due to slightly inferior fixation. The design of the hook plate maintains the typical stability of the AC joint, which means that the stability of the hook plate depends on the stability of the AC joint. The movement of the AC joint causes rotation of the scapula and clavicle. Biomechanical studies have shown that scapular and clavicular rotations are relatively small until the humerus reaches approximately 90° of elevation. However, when the upper humerus reaches 150°, the clavicle's posterior rotation increases to 27°, and the elevation increases to 21°.[27] The rotation and elevation occurring during arm elevation cause subacromial hook movement. However, shoulder arthroscopy has shown that the subacromial hook appears to move under the acromion at the same time that the shoulder joint raised.[28] When the scapula and clavicle rotate, movement of the hook occurs.

Strengths and limitations

The strength of this study was the use of propensity score matching, by which the patient backgrounds were matched for sex, age, body mass index, ASA Physical Status Classification System and Neer type. Our study had several limitations. First, there remained unmeasured confounding factors after using the propensity score-matching method. Second, our subjects included only a single race, Asians, whose average height and weight are relatively small. Third, we did not evaluate rotator cuff injuries with imaging, ultrasonography, or magnetic resonance imaging. Fourth, we did not evaluate conservative treatment. Asymptomatic nonunion does not appear to adversely affect the functional outcome in the medium term.[28] Fifth, assessment of the AC joint including instability is not available at all institutions. Sixth, we obtained the information on complications only from the medical chart; thus, observer bias may be present. Seventh, to include the effect of implant removal in this study, the timing of removal of the implant may have affected the clinical results.

CONCLUSION

We compared postoperative results between the locking plate and hook plate for distal clavicle fractures after propensity score matching. The postoperative UCLA score was significantly worse in the hook plate group than the locking plate group. We recommend the locking plate as a surgical treatment for distal clavicle fractures.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

1 Flinkkilä T, Ristiniemi J, Hyvönen P, Hämäläinen M. Surgical treatment of unstable fractures of the distal clavicle: a comparative study of Kirschner wire and clavicular hook plate fixation. *Acta Orthop Scand.* 2002;73(1):50–53. doi:10.1080/000164702317281404.

2 Tsuei YC, Au MK, Chu W. Comparison of clinical results of surgical treatment for unstable distal clavicle fractures by transacromial pins with and without tension band wire. *J Chin Med Assoc*. 2010;73(12):638–643. doi:10.1016/S1726-4901(10)70139-8.

3 Zheng YR, Lu YC, Liu CT. Treatment of unstable distal-third clavicule fractures using minimal invasive closed-loop double endobutton technique. *J Orthop Surg Res.* 2019;14(1):37. doi:10.1186/s13018-019-1073-5.

4 Bakota B, Chan G, Staresinic M, Rajput V, Phadnis J, Korac Z. Safe intramedullary fixation of displaced midshaft clavicle fractures with 2.5mm Kirschner wires - technique description and a two-part versus multifragmentary fracture fixation outcome comparison. *Injury*. 2017;48(Suppl5):S27–S33. doi:10.1016/S0020-1383(17)30735-0.

5 Tiren D, van Bemmel AJ, Swank DJ, van der Linden FM. Hook plate fixation of acute displaced lateral clavicle fractures: mid-term results and a brief literature overview. *J Orthop Surg Res.* 2017;7:2. doi:10.1186/1749-799X-7-2.

6 Asadollahi S, Bucknill A. Hook plate fixation for acute unstable distal clavicle fracture: a systematic review and meta-analysis. *J Orthop Trauma*. 2019;33(8):417–422. doi:10.1097/BOT.0000000000001481.

7 Malik SS, Tahir M, Remtulla M, Malik S, Jordan RW. A systematic review and meta-analysis comparing the use of hook plates and superior plates in the treatment of displaced distal clavicle fractures. *Arch Orthop Trauma Surg.* 2022. doi:10.1007/s00402-021-04287-z.

8 Good DW, Lui DF, Leonard M, Morris S, McElwain JP. Clavicle hook plate fixation for displaced lateral-third clavicle fractures (Neer type II): a functional outcome study. *J Shoulder Elbow Surg.* 2012;21(8):1045–1048. doi:10.1016/j.jse.2011.07.020.

9 Hsu KH, Tzeng YH, Chang MC, Chiang CC. Comparing the coracoclavicular loop technique with a hook plate for the treatment of distal clavicle fractures. *J Shoulder Elbow Surg.* 2018;27(2):224–230. doi:10.1016/j.jse.2017.08.017.

10 Kashii M, Inui H, Yamamoto K. Surgical treatment of distal clavicle fractures using the clavicular hook plate. *Clin Orthop Relat Res.* 2006;447:158–164. doi:10.1097/01.blo.0000203469.66055.6a.

11 Renger RJ, Roukema GR, Reurings JC, Raams PM, Font J, Verleisdonk EJ. The clavicle hook plate for Neer type II lateral clavicle fractures. *J Orthop Trauma*. 2009;23(8):570–574. doi:10.1097/BOT.0b013e318193d878.

12 Tambe AD, Motkur P, Qamar A, Drew S, Turner SM. Fractures of the distal third of the clavicle treated by hook plating. *Int Orthop.* 2006;30(1):7–10. doi:10.1007/s00264-005-0019-1.

13 Dabija DI, Jain NB. Minimal clinically important difference of shoulder outcome measures and diagnoses: a systematic review. *Am J Phys Med Rehabil.* 2019;98(8):671–676. doi:10.1097/PHM.0000000000001169.

14 Sambandam B, Gupta R, Kumar S, Maini L. Fracture of distal end clavicle: A review. *J Clin Orthop Trauma.* 2014;5(2):65–73. doi:10.1016/j.jcot.2014.05.007.

15 Lee KW, Lee SK, Kim KJ, Kim YI, Kwon WC, Choy WS. 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(6):839–845. doi:10.1007/s00264-009-0925-8.

16 Yoon JP, Lee BJ, Nam SJ, et al. Comparison of results between hook plate fixation and ligament reconstruc-

tion for acute unstable acromioclavicular joint dislocation. *Clin Orthop Surg.* 2015;7(1):97–103. doi:10.4055/cios.2015.7.1.97.

17 Jou IM, Chiang EP, Lin CJ, Lin CL, Wang PH, Su WR. Treatment of unstable distal clavicle fractures with Knowles pin. *J Shoulder Elbow Surg*. 2011;20(3):414–419. doi:10.1016/j.jse.2010.08.009.

18 Sajid S, Fawdington R, Sinha M. Locking plates for displaced fractures of the lateral end of clavicle: Potential pitfalls. *Int J Shoulder Surg.* 2012;6(4):126–129. doi:10.4103/0973-6042.106226.

19 Hall JA, Schemitsch CE, Vicente MR, et al. Operative versus nonoperative treatment of acute displaced distal clavicle fractures: a multicenter randomized controlled trial. *J Orthop Trauma.* 2021;35(12):660–666. doi:10.1097/BOT.0000000000002211.

20 Tan HL, Zhao JK, Qian C, Shi Y, Zhou Q. Clinical results of treatment using a clavicular hook plate versus a T-plate in Neer type II distal clavicle fractures. *Orthopedics.* 2012;35(8):e1191–e1197. doi:10.3928/01477447-20120725-18.

21 ElMaraghy AW, Devereaux MW, Ravichandiran K, Agur AM. Subacromial morphometric assessment of the clavicle hook plate. *Injury*. 2010;41(6):613–619. doi:10.1016/j.injury.2009.12.012.

22 Hung LK, Su KC, Lu WH, Lee CH. Biomechanical analysis of clavicle hook plate implantation with different hook angles in the acromioclavicular joint. *Int Orthop.* 2017;41(8):1663–1669. doi:10.1007/s00264-016-3384-z.

23 Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech (Bristol, Avon)*. 2003;18(5):369–379. doi:10.1016/s0268-0033(03)00047-0.

24 Zhang C, Huang J, Luo Y, Sun H. Comparison of the efficacy of a distal clavicular locking plate versus a clavicular hook plate in the treatment of unstable distal clavicle fractures and a systematic literature review. *Int Orthop.* 2014;38(7):1461–1468. doi:10.1007/s00264-014-2340-z.

25 Wang J, Guan J, Liu M, Cui Y, Zhang Y. Treatment of distal clavicle fracture of Neer type II with locking plate in combination with titanium cable under the guide. *Sci Rep.* 2021;11(1):4949. doi:10.1038/s41598-021-84601-2.

26 Bishop JY, Roesch M, Lewis B, Jones GL, Litsky AS. A biomechanical comparison of distal clavicle fracture reconstructive techniques. *Am J Orthop (Belle Mead NJ).* 2013;42(3):114–118.

27 Fung M, Kato S, Barrance PJ, et al. Scapular and clavicular kinematics during humeral elevation: a study with cadavers. *J Shoulder Elbow Surg.* 2001;10(3):278–285. doi:10.1067/mse.2001.114496.

28 Robinson CM, Cairns DA. Primary nonoperative treatment of displaced lateral fractures of the clavicle. *J Bone Joint Surg Am*. 2004;86(4):778–782. doi:10.2106/00004623-200404000-00016.