Original Article
Clinics in Orthopedic Surgery 2025;17:922-929 • https://doi.org/10.4055/cios24406

Comparative Analysis of Minimally Invasive Versus Open Reduction Plate Osteosynthesis Using a Superior Clavicle Plate in Clavicle Shaft Fractures

Joon-Ryul Lim, MD*,†,#, Hyeongwon Ham, MD*, Hsien-Hao Chang, MD*,‡, Tae-Hwan Yoon, MD*,†,#, Yong-Min Chun, MD*, Yong-Jun Lee, MD*,#

*Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, Seoul,
†Department of Orthopedic Surgery, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul,
‡Department of Orthopedic Surgery, Yongin Severance Hospital, Yonsei University College of Medicine, Yongin, Korea

Background: Clavicle fractures are a common type of fracture, and the treatment of clavicle shaft fractures involves various implant options and approaches. This study aimed to compare the clinical and radiological outcomes of surgical treatment using the minimally invasive technique versus open reduction plate osteosynthesis with a superior clavicle plate featuring lateral extension for clavicle shaft fractures.

Methods: This retrospective case-control study included 70 consecutive patients who underwent surgery for displaced clavicle shaft fractures between March 2022 and August 2023: group M (n = 20), which underwent a minimally invasive technique, and group C (n = 41), which underwent open reduction plate osteosynthesis. Clinical outcomes, visual analog scale scores, Constant scores, and hypoesthesia in the area supplied by the superior clavicular nerve were assessed 1 year postoperatively. The time to clinical bone union was also measured from surgery to tenderness resolution. Radiological evaluation included assessment of the number of fracture fragments, measurement of the fracture gap interval, and determination of the time to radiographic bone union. Intraoperative exposure time using the C-arm was also recorded.

Results: We observed no significant differences in clinical outcomes and the bone union rates between the 2 groups. However, compared to group C, group M showed a shorter operation time ($p = 0.004$), less blood loss ($p < 0.001$), and a lower incidence of hypoesthesia ($p < 0.001$). Compared to group C, group M had a longer time to achieve radiologic bone union ($p < 0.001$); however, there was no difference in the clinical bone union time between the 2 groups. Regarding complications, there were 9 cases of hypoesthesia in group C and 1 case of nonunion in group M.

Conclusions: This minimally invasive technique, using a superior clavicle plate with lateral extension for clavicle shaft fractures, achieved clinical outcomes and bone union rates that were comparable to those of open reduction plate osteosynthesis, while also offering the advantages of shorter operation time, reduced blood loss, and a lower risk of hypoesthesia.

Keywords: *Clavicle shaft fracture, Superior clavicular nerve, Superior clavicle plate with lateral extension, Working length, Minimally invasive*

Clinics in Orthopedic Surgery • pISSN 2005-291X eISSN 2005-4408

Received October 11, 2024; Revised June 9, 2025; Accepted June 9, 2025
Correspondence to: Yong-Jun Lee, MD
Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Tel: +82-2-2228-2180, Fax: +82-2-363-1139, E-mail: yjyj90lee@naver.com
[#]Current affiliation:
Joon-Ryul Lim, Tae-Hwan Yoon: Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, Seoul and Department of Orthopedic Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea
Yong-Jun Lee: Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, Seoul and Department of Joint Center, Ansan Ace Hospital, Ansan, Korea

Clavicle fractures are a common type of fracture, accounting for approximately 2%–5% of all adult fractures.[1)] The majority of these fractures occur in the shaft of the clavicle.[1-3)] To prevent complications such as nonunion, malunion, and shortening, treatment of clavicle shaft fractures has shifted toward surgical intervention.[4-6)]

The treatment of clavicle shaft fractures involves various implant options and approaches, which are selected based on the fracture's pattern and severity.[7,8)] In fracture fixation, the plate's length and working length are critical for stability,[9,10)] and extending fixation to the short, flat distal clavicle is suggested to ensure adequate support and stabilization. However, commonly used pre-contoured clavicle shaft plates presented challenges in fully utilizing this anatomy when we used them. To address this limitation, we implemented a superior clavicle plate with lateral extension (Fig. 1), which facilitates adequate screw placement in the distal clavicle region. This plate design provides sufficient length and mechanical stability, rendering it particularly efficacious for open reduction and internal fixation procedures in clavicular shaft fractures.

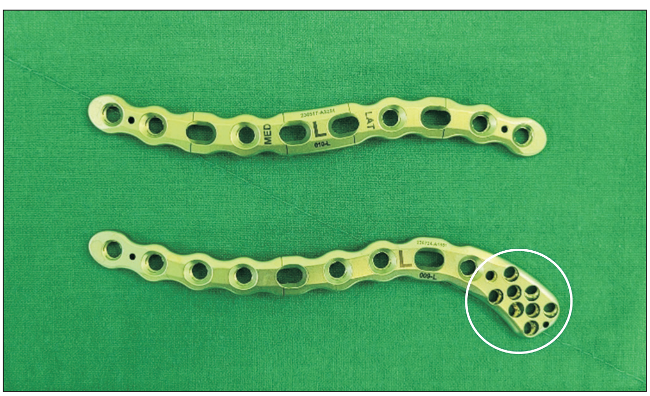

Fig. 1. The gross features of the superior clavicle plate. A pre-contoured clavicle shaft plate (top) and a plate with lateral extension (bottom) are shown. The extended portion is marked with a white circle.

Surgical treatment for clavicle fractures often involves open reduction and internal fixation; however, this approach can disrupt periosteal biology and cause numbness in the clavicle area due to supraclavicular nerve damage.[11,12)] Furthermore, with comminuted fractures occurring in about 10%–15% of clavicle shaft fractures,[13)] open reduction may not always be suitable. Therefore, minimally invasive plate osteosynthesis (MIPO) has gained attention for clavicle fracture surgeries, as it involves smaller incisions and can reduce the risk of hypoesthesia.[14-16)] The use of a superior clavicle plate with lateral extension in MIPO could offer significant advantages, although the safety and efficacy of this plate for fixation using the MIPO technique have not yet been established.

The present study aimed to compare the clinical and radiological outcomes of surgical treatment using the MIPO technique versus open reduction plate osteosynthesis with a superior clavicle plate and lateral extension for clavicle shaft fractures. We hypothesized that the MIPO technique, when used with a superior clavicle plate and lateral extension, would provide union rates, clinical outcomes, complication rates, and radiologic outcomes that are comparable to those of open reduction osteosynthesis, while reducing blood loss and hypoesthesia.

METHODS

The Institutional Review Board of Severance Hospital approved this study (IRB No. 4-2024-0831) and waived the requirement for informed consent due to the retrospective nature of the study.

Study Population

This retrospective case-control study included 70 consecutive patients who underwent surgery for displaced clavicle shaft fractures that were reviewed between March 2022 and August 2023. Clavicle shaft fractures classified as AO Foundation/Orthopaedic Trauma Association (AO/OTA) type 15.2 B and C were included in this study. The participants were divided into 2 groups according to the surgical technique used, with group M (minimally invasive) undergoing the MIPO technique and group C (conventional) undergoing traditional open reduction. Regarding the selection of surgical methods, open reduction plate osteosynthesis was performed in the early stages of the study (2022), whereas minimally invasive techniques were used more recently (2023). In both groups, a superior clavicle titanium plate with lateral extension (JEIL Medical Corp.) was used. Patients with a follow-up period of less than 1 year (n = 9) were excluded from the study. As a result, a total of 61 patients were included, with 20 patients in group M and 41 in group C.

Clinical and Radiological Evaluation

The evaluation conducted in this study entailed assessing clinical outcomes, visual analog scale (VAS) scores, and Constant scores at 1 year postoperatively. Additionally, at the last follow-up, we examined the condition of hypoesthesia in the area supplied by the superior clavicular nerve. Sensory assessment was performed bilaterally using light touch and pinprick stimuli. Outcomes were classified as follows: "normal" was defined as full sensory perception equivalent to that of the contralateral side, and "hypoesthesia" was defined as reduced sensory perception compared to the contralateral side. Operation time and blood loss during the surgery were also measured. Preoperative radiological evaluation included assessing the number of fracture fragments to determine the degree of comminution and measuring the fracture gap interval by calculating the shortest vertical distance between adjacent fracture fragments using computed tomography.[17] The time to clinical bone union was defined as the time between surgery and the point when the fracture site was free of tenderness, and this time point was measured accordingly. Radiographic evaluation at each visit until union included anteroposterior and cephalad views of the fracture site acquired at monthly intervals. Union was confirmed by the disappearance of gaps and callus formation. Based on this, the bone union rate was measured. Radiological outcomes were assessed by 2 orthopedic specialists (HH and YJL), and the average value was recorded when the values differed. Additionally, interobserver consistency (intraclass coefficient) was calculated to determine the reliability of the radiographic measurements.

Surgical Procedure

All surgical procedures were performed by an experienced senior surgeon (JRL). All patients were placed under general anesthesia in the supine position, with the operating table tilted upward by approximately 30°, and the fracture site was confirmed using a intraoperative fluoroscopy. For minimally invasive surgery, the fracture site was identified using the C-arm to ensure accurate localization. Once the fracture site was confirmed, the length and position of the plate were predetermined. Two separate skin incisions, approximately 3 cm in length each, were made over the designated locations for the proximal and distal screw insertions, as guided by C-arm imaging (Fig. 2A). Through the proximal incision, a Cobb elevator was carefully inserted beneath the periosteum to create a submuscular tunnel along the superior aspect of the clavicle. This tunnel facilitated passage of the superior distal clavicular plate to the fracture site. With the plate positioned appropriately, reduction forceps were utilized to ensure proper alignment of the fracture fragments and to minimize displacement during plate fixation (Fig. 2B).

The plate was positioned on the superior surface of the clavicle and securely fixed. Initially, 2 cortical screws were inserted into the medial and lateral holes closest to the fracture site for plate fixation. Additional fixation was achieved by placing 3.5-mm locking screws medially and 2.5-mm locking screws into the distal clavicular holes. After securing all the screws, fracture reduction and screw length were confirmed using fluoroscopy, and the incision

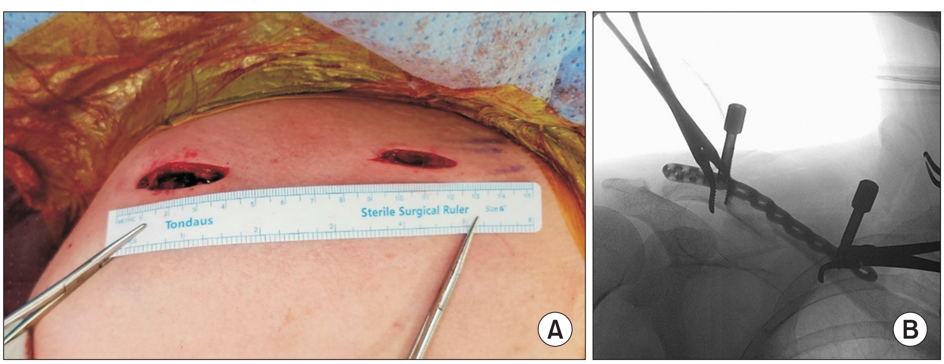

Fig. 2. (A) Incisions, approximately 3 cm in length, were made at the sites of the medial and distal screw insertions. (B) C-arm imaging confirmed the use of reduction forceps to maintain proper positioning.

was sutured. An illustration was provided to enhance understanding of the overall surgical procedure (Fig. 3).

In the open reduction procedure, the surgeon used a superior approach to the clavicle, during which the supraclavicular nerve was preserved to the greatest extent possible. The fracture site was identified, and reduction forceps were used to align the bone fragments. Fixation was achieved through the application of several lag screws, if necessary. After verifying the length and contouring, the plate was positioned on the superior portion of the clavicle and the screws were securely fixed.

Statistical Analysis

The Shapiro-Wilk test was used to evaluate the normality of each variable. For continuous variables, an independent samples *t*-test or the Mann-Whitney *U*-test was used for group comparisons. In contrast, categorical data were assessed using chi-square or Fisher's exact tests. All statistical analyses were conducted using IBM SPSS Statistics software version 26.0 (IBM Corp.), with the significance level set at $p < 0.05$.

RESULTS

Patient Characteristics

Table 1 presents the patient demographic information. No significant differences were observed between the 2 groups in terms of sex, age, body mass index, smoking status, or the interval between injury and surgery. However, a significant difference in the operation time was evident be-

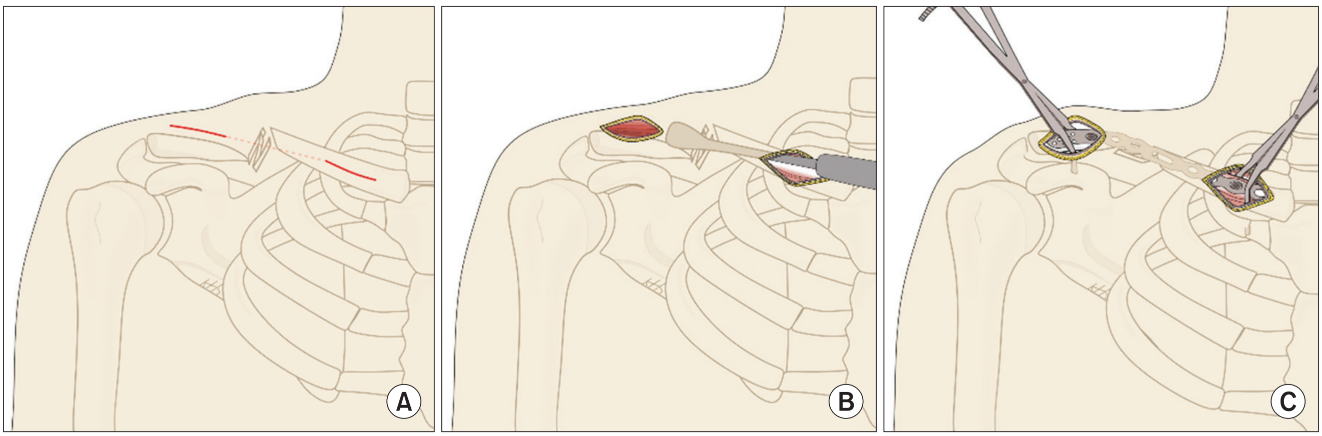

Fig. 3. Illustration of the overall surgical procedure. (A) Skin incisions for proximal and distal screw insertion sites. (B) Submuscular tunnel creation along the superior clavicle using a Cobb elevator. (C) Reduction forceps ensuring fracture alignment and minimizing displacement during plate fixation.

Table 1. Patient Demographics

Variable	Group M (n = 20)	Group C (n = 41)	*p*-value
Sex (male : female)	17 : 3	36 : 5	0.761
Age at surgery (yr)	45.6 (28.0–57.0)	41.0 (22.5–55.5)	0.222
Body mass index (kg/m^2)	23.1 (22.1–25.1)	23.5 (22.3–25.0)	0.565
Smoking (%)	15.0	17.1	0.837
Involvement of other fractures (%)	10.0	14.6	0.615
Interval between injury and surgery (day)	2.0 (1.0–3.5)	2.0 (1.0–3.0)	0.486
Operation time (min)	60.0 (50.0–77.5)	70.0 (60.0–85.0)	0.004
Blood loss (mL)	50.0 (32.5–50.0)	80.0 (50.0–100.0)	< 0.001
Fluoroscopy time (shot counts)	10.5 (7.0–13.8)	2.0 (2.0–2.0)	< 0.001

Values are presented as median (interquartile range) unless otherwise indicated. Group M: patients who underwent minimally invasive plate osteosynthesis, Group C: patients who underwent conventional open reduction and internal fixation.

tween the 2 groups; group M had a median operation time of 60.0 minutes (range, 50.0–77.5 minutes), whereas group C had a median operation time of 70.0 minutes(range, 60.0–85.0 minutes) ($p = 0.004$). Similarly, we observed significant differences in blood loss, with group M experiencing a median blood loss of 50.0 mL (range, 32.5–50.0 mL) and group C experiencing a median blood loss of 80.0 mL (range, 50.0–100.0 mL) ($p < 0.001$).

Clinical and Radiologic Outcomes

Table 2 presents the patient clinical outcomes. Notably, no significant difference was observed between the 2 groups in terms of the VAS and Constant scores upon clinical assessment 1 year postoperatively. Moreover, both groups showed a median time to clinical bone union of 12.0 weeks (group M: 12.0 weeks [range, 9.0–16.0 weeks], group C: 12.0 weeks [range, 9.0–12.0 weeks]), with no significant difference. Moreover, preoperative radiological evaluation revealed no significant difference in the fracture gap or number of fracture fragments between the 2 groups (Table 3), and the screws used for distal fragment fixation were similar between the groups (Table 3). However, the time to bone union differed significantly, with median values of 20.0 weeks (range, 16.0–24.0 weeks) in group M (Fig. 4)

Table 2. Clinical Outcome Measures

Variable	Group M (n = 20)	Group C (n = 41)	*p*-value
Clinical score			
Visual analog scale	0.5 (0.0–1.0)	1.0 (0.0–1.0)	0.786
Constant	95.0 (91.0–97.0)	97.0 (91.0–100.0)	0.270
Time to clinical bone union (wk)	12.0 (9.0–16.0)	12.0 (9.0–12.0)	0.812

Values are presented as median (interquartile range). Group M: patients who underwent minimally invasive plate osteosynthesis, Group C: patients who underwent conventional open reduction and internal fixation.

Table 3. Radiological Outcome Measures

Variable	Group M (n = 20)	Group C (n = 41)	*p*-value
Fracture gap (mm)	1.2 (0.9–2.0), ICC=0.821	1.5 (1.1–1.8), ICC=0.864	0.318
Number of fracture fragments	3.0 (2.0–4.0), ICC=0.921	3.0 (2.0–3.0), ICC=0.922	0.179
Number of distal screws	8.0 (6.0–9.0)	8.0 (7.0–9.0)	0.259
Time to bone union (wk)	20.0 (16.0–24.0), ICC=0.973	13.0 (12.0–20.0), ICC=0.969	< 0.001

Values are presented as median (interquartile range), followed by the intraclass correlation coefficient (ICC). Group M: patients who underwent minimally invasive plate osteosynthesis, Group C: patients who underwent conventional open reduction and internal fixation.

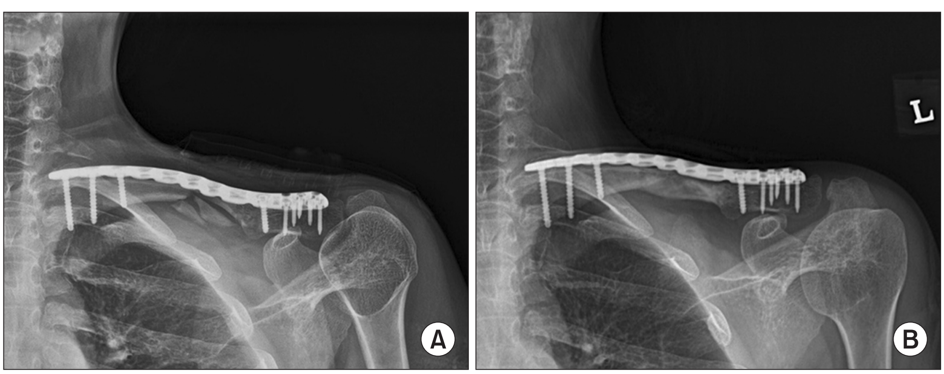

Fig. 4. Radiographic images of the immediate postoperative status (A) and 6-month postoperative status (B) of a patient treated using the minimally invasive technique.

Table 4. Complications

Complication	Group M (n = 20)	Group C (n = 41)	*p*-value
Nonunion	1 (5)	0	0.149
Hypoesthesia	0	9 (22)	0.023

Values are presented as number (%). Group M: patients who underwent minimally invasive plate osteosynthesis, Group C: patients who underwent conventional open reduction and internal fixation.

and 13.0 weeks (range, 12.0–20.0 weeks) in group C ($p < 0.001$).

Complications

Regarding postoperative complications (Table 4), no skin hypoesthesia was observed in group M, whereas 9 of 41 cases (22%) in group C experienced hypoesthesia, a significant difference between the 2 groups. Moreover, group M had 1 case of hardware failure due to nonunion, whereas group C had none. No other significant complications were observed in either group.

DISCUSSION

The study results showed that group M demonstrated shorter operation time, less blood loss, and a lower incidence of hypoesthesia compared to group C. While a significant difference was observed in the radiologic bone union time between the 2 groups, there was no difference in the clinical bone union time. Additionally, there were no significant differences in clinical outcomes and clinical bone union rates between the 2 groups. These findings partially support our hypothesis that the MIPO technique using a superior clavicle plate with lateral extension could offer advantages over open reduction plate osteosynthesis for treating clavicle shaft fractures.

In terms of radiological outcomes, group M appeared to take longer to achieve radiological bone union, compared with group C. The earlier radiological bone union observed in group C can be attributed to direct bone contact during surgery, which minimizes the visible fracture gap and accelerates the radiographic appearance of union. In contrast, group M preserves a fracture gap, requiring callus formation for healing, which may delay radiological union. This prolonged radiographic healing time, while not accompanied by differences in clinical union, should nonetheless be recognized as a potential drawback of the MIPO technique. However, it is important to note that radiological assessments are not the sole determinants of fracture healing. Clinical evaluations to determine the absence of pain or tenderness at the fracture site are also crucial for evaluating the healing process.[18)] Notably, the median time for the disappearance of fracture tenderness was 12 weeks in both groups, and there was no significant difference in the time to clinical bone union between the groups. There was no statistically significant difference in union and nonunion rates between the 2 groups at the final follow-up. The single case of nonunion in the MIPO group involved an elderly patient with poor bone quality due to low bone mineral density. Although radiographic nonunion was observed, the patient remained pain-free without implant failure, and revision surgery was not performed; instead, the patient has been managed with careful observation. While not statistically significant, we believe this case warrants clinical attention and has been discussed accordingly. Therefore, although radiological union may have taken longer in group M than in group C, there was no significant intergroup difference in terms of clinical bone union.

Previous MIPO studies have generally used pre-contoured anatomical clavicle shaft plates to treat haft fractures.[19,20)] However, in our study, we used a superior clavicle plate with lateral extension, which differs from commonly used pre-contoured anatomical clavicle shaft plate in that it is shaped to fit the distal portion of the clavicle and allows for multiple 2.5-mm distal locking screws to be inserted. Unlike traditional shaft plates, which primarily rely on midshaft fixation, the lateral extension plate provides a distal fixation option that adapts to anatomical variations. Previously, a biomechanical comparison between low-profile 2.7-mm and 3.5-mm distal locking screws in hook plates showed that the 2.7-mm screws, when used in greater numbers, resulted in less stress concentration and provided comparable biomechanical results.[21)] Another study reported that distal clavicle fixation with two 2.7-mm locking screws demonstrated comparable mechanical pull-out strength to fixations with two 3.5-mm hook plates.[22)] Although the screw size and number differ, and there are differences compared to our surgery, this mechanical study suggests that the superior clavicle plate with lateral extension using multiple 2.5-mm screws provides stability and plate length comparable to that of conventional shaft plates.

During clavicle fracture surgery, hypoesthesia due to supraclavicular nerve injury is a prevalent issue that requires consideration due to the nerve's distribution and branches. In fact, a significant proportion of patients who undergo clavicle plate fixation ultimately require removal surgery due to discomfort and pain, making the minimization of nerve injury and prevention of further complications involving additional nerve damage essential.[13,14) Previous research has shown that the supraclavicular nerve's lateral branch is located approximately 59.7 mm from the acromioclavicular joint, whereas the medial branch is located 48.2 mm from the sternoclavicular joint, with the safe zone located within 2.7 cm medially and 1.7 cm laterally.[23) In the present study, using the MIPO plate, the wound incision was only approximately 2–3 cm at the most lateral and medial aspects of the acromioclavicular and sternoclavicular joints, respectively, which is considered a sufficiently safe zone. Indeed, in group M, there were no cases of hypoesthesia due to supraclavicular nerve injury.

Minimally invasive techniques can sometimes lead to increased fluoroscopic exposure due to the challenge of direct visualization. In our study, fluoroscopy was utilized before skin incision to determine the fracture site and plate length and intraoperatively to monitor the surgical progress. We took protective measures to minimize exposure by positioning the C-arm from the opposite side for patients and using protective lead aprons to ensure a safe distance from the imaging device. Although the literature does not specify a safe duration for fluoroscopy exposure, it is crucial to continuously reduce exposure time through these efforts and increased expertise.

This study has some limitations. First, this was a non-randomized retrospective study, which may have led to selection bias. Also, despite efforts to maintain objectivity, potential interpretive bias in favor of the MIPO technique, even in the presence of a nonunion case, should be acknowledged as a limitation. Second, the sample size was relatively small, which may have decreased statistical power and increased the likelihood of type II errors. Third, long-term clinical outcomes were difficult to assess, as the hardware is often removed after 1 year due to discomfort.

In conclusion, we performed a minimally invasive technique using a superior clavicle plate with lateral extension for clavicle shaft fractures, achieving clinical outcomes and bone union rates comparable to those of open reduction plate osteosynthesis. This approach also offered the advantages of shorter operation time, reduced blood loss, and a lower risk of hypoesthesia.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Joon-Ryul Lim https://orcid.org/0000-0002-0123-7136
Hyeongwon Ham https://orcid.org/0009-0000-6467-1602
Hsien-Hao Chang https://orcid.org/0000-0003-1858-5863
Tae-Hwan Yoon https://orcid.org/0000-0002-2859-5240
Yong-Min Chun https://orcid.org/0000-0002-8147-6136
Yong-Jun Lee https://orcid.org/0009-0001-9760-5510

REFERENCES

1. van der Meijden OA, Gaskill TR, Millett PJ. Treatment of clavicle fractures: current concepts review. J Shoulder Elbow Surg. 2012;21(3):423-9.
2. Donnelly TD, Macfarlane RJ, Nagy MT, Ralte P, Waseem M. Fractures of the clavicle: an overview. Open Orthop J. 2013;7:329-33.
3. Katta D, Y BR, Nishanth MV. Patient oriented outcome of surgical fixation of clavicle fractures in a rural tertiary care centre. Int J Orthop Sci. 2021;7(1):934-40.
4. Khoriati AA, Fozo ZA, Al-Hilfi L, Tennent D. Closed midshaft clavicle fractures: an evidence-based triage management algorithm. Bone Jt Open. 2022;3(11):850-8.
5. Waldmann S, Benninger E, Meier C. Nonoperative treatment of midshaft clavicle fractures in adults. Open Orthop J. 2018;12:1-6.
6. Guerra E, Previtali D, Tamborini S, Filardo G, Zaffagnini S, Candrian C. Midshaft clavicle fractures: surgery provides better results as compared with nonoperative treatment: a meta-analysis. Am J Sports Med. 2019;47(14):3541-51.
7. Alzahrani MM, Cota A, Alkhelaifi K, et al. Are clinical outcomes affected by type of plate used for management of midshaft clavicle fractures? J Orthop Traumatol. 2018;19(1):8.
8. Huang JI, Toogood P, Chen MR, Wilber JH, Cooperman DR. Clavicular anatomy and the applicability of precontoured plates. J Bone Joint Surg Am. 2007;89(10):2260-5.
9. Byun YS. Minimally invasive plate osteosynthesis, MIPO. J Korean Fract Soc. 2007;20(1):99-114.
10. Muller TS, Sommer C. Reduction techniques for minimally invasive plate osteosynthesis. Unfallchirurg. 2019;122(2):103-9.
11. Huang D, Deng Y, Cheng J, Bong YR, Schwass M, Policinski I. Comparison of patient reported outcomes following clavicle operative fixation using supraclavicular nerve sparing and supraclavicular nerve sacrificing techniques: a cohort

study. Injury. 2021;52(3):501-5.

12. Zhuang Y, Zhang Y, Zhou L, Zhang J, Jiang G, Wu J. Management of comminuted mid-shaft clavicular fractures: comparison between dual-plate fixation treatment and single-plate fixation. J Orthop Surg (Hong Kong). 2020;28(2): 2309499020915797.

13. Naimark M, Dufka FL, Han R, et al. Plate fixation of midshaft clavicular fractures: patient-reported outcomes and hardware-related complications. J Shoulder Elbow Surg. 2016;25(5):739-46.

14. Zhao E, Zhang R, Wu D, Guo Y, Liu Q. Comparison between minimally invasive plate osteosynthesis and conventional open plating for midshaft clavicle fractures: a systematic review and meta-analysis. Biomed Res Int. 2019;2019: 7081032.

15. Burkhard MD, Michelitsch C, Stillhard PF, Muller T, Sommer C. Minimally invasive plate osteosynthesis for clavicle shaft fractures. Br J Surg. 2022;109(Supplement_3):znac187-003.

16. La Banca V, Lima GH, Vigano AV, et al. Complications and clinical outcomes with minimally invasive plate osteosynthesis (MIPO) technique for midshaft clavicle fractures: a systematic review and meta-analysis. JSES Int. 2024;8(2): 257-67.

17. Kim JY, Yoo BC, Yoon JP, Kang SJ, Chung SW. A comparison of clinical and radiological outcomes of minimally invasive and conventional plate osteosynthesis for midshaft clavicle fractures. Orthopedics. 2018;41(5):e649-54.

18. Corrales LA, Morshed S, Bhandari M, Miclau T. Variability in the assessment of fracture-healing in orthopaedic trauma studies. J Bone Joint Surg Am. 2008;90(9):1862-8.

19. Ko SH, Kim MS. Comparison of supraclavicular nerve injuries after clavicle mid-shaft surgery via minimally invasive plate osteosynthesis versus open reduction and internal fixation. Arch Orthop Trauma Surg. 2022;142(8):1895-902.

20. Mendes Junior AF, Mota Neto JD, Oppe IG, de Simoni LF, Giordano V, Labronici PJ. Surgical treatment of comminuted midshaft clavicle fracture by minimally invasive technique: description and preliminary results. Rev Bras Ortop (Sao Paulo). 2021;56(4):490-6.

21. Lee JW, Song MJ, Lee SJ, Song HS, Jung YS, Kim H. Biomechanical comparison between low profile 2.7 mm distal locking hook plate and 3.5 mm distal locking hook plate for acromioclavicular joint injury: a finite element analysis. Injury. 2024;55(10):111657.

22. Yoon TH, Choi CH, Choi YR, Ju HJ, Chun YM. Relation between diameter of a lateral screw and pull-out strength in distal clavicle fracture in plates with different geometry: a cadaveric biomechanical study. J Orthop Res. 2022;40(7): 1577-83.

23. Nathe T, Tseng S, Yoo B. The anatomy of the supraclavicular nerve during surgical approach to the clavicular shaft. Clin Orthop Relat Res. 2011;469(3):890-4.