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Surgical treatment options of displaced midshaft fractures of the clavicle in young adults: plate fixation versus intramedullary nailing

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Background: This study aimed to compare the outcomes and complications of active young adults undergoing open reduction and plate fixation (ORPF) and intramedullary nailing (IMN) for displaced midshaft clavicle fractures (MCFs).
Methods: A retrospective review was performed on all patients undergoing ORPF and IMN of complete MCFs at a single center between 2018 and 2022. Patients who were younger than 60 years with radiographic follow-up until union were included in the study. The mean age of the patients was 33.1 years. Outcome measures were achievement of union, time to healing, residual deformity, complications, and need for additional procedures.
Results: Of 39 patients, 29 underwent ORPF and 10 underwent IMN. Plate fixation provided faster functional recovery in the first 6 months, but no difference was observed after 1 year. All fractures in the IMN group healed (100%), compared to 90% in the ORPF group (P=0.08). Mean time to union was 21±8.9 weeks and was significantly different between the two groups (P<0.01), with the ORPF group averaging 23.1 weeks and the IMN group 20.8 weeks. Nonunion rates were higher in the ORPF group (10.3%) than in the IMN group (0%), but the difference was not significant (P=0.08).
Conclusions: Both methods restored patients to their pre-injury functional levels. However, IMN, with its higher healing rate, fewer required revision surgeries, and lower incisional numbness, appears to be the preferred method for treating MSFs without comminution in young adults.
Level of evidence: III.

Keywords: Young adult; Intramedullary fracture fixation; Clavicle

INTRODUCTION

Clavicle fractures stand as one of the most prevalent injuries in orthopedic trauma, comprising 2.6% of all fractures and 5% of adult fractures [1,2], predominantly afflicting children and adolescents. However, there has been a notable increase in incidence among individuals older than 40 years due to increased participation in sports activities among young adults [3]. These fractures frequently result from sports-related incidents or motor vehicle collisions. Approximately 80% of clavicle fractures occur in

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the midshaft, with more than 70% of these cases exhibiting displacement [4].

Recent evidence indicating higher non-union rates and functional deficits has led to a shift from traditional surgery toward internal fixation as a viable treatment for midshaft clavicle fracture (MCFs) [3]. While most clavicle fractures occur in the middle third of the bone and are generally addressed conservatively, fractures in the midshaft display a posterosuperior angular displacement of the medial fragment, penetrating the trapezius muscle and encountering soft tissue interposition that prevents fragments from aligning naturally [5,6]. Especially among young, athletic populations, the patterns of clavicle fractures have become increasingly complex due to high-energy injuries like traffic accidents, falls, and sports-related incidents. These incidents heighten the probability of complications such as nonunion, malunion, and re-fracture, contributing to suboptimal cosmetic and functional results and leading to an increasing trend in surgical interventions. As a result, recent studies have shown a paradigm shift toward operative treatment, with surgical methods such as plate fixation and intramedullary nailing (IMN) proving more effective due to higher non-union rates in non-operative treatments and better functional outcomes [4,7-10]. Despite the variety of fixation devices available, the optimal method remains debated, although the choice is primarily between plate fixation and IMN. Plate fixation offers immediate stability [6], but may result in scarring, irritation, infections, and implant failure [11].

Conversely, intramedullary nail fixation, while less invasive, raises concerns about radiation exposure, neurovascular damage, and potential migration. Meta-analyses comparing these methods yield conflicting conclusions, leaving clinicians uncertain in their choice of treatment. While techniques like IMN show promise in achieving stability with minimal invasiveness and rapid healing, plate fixation excels in stress shielding and ensuring stability for early recovery, particularly in managing displaced fractures [12]. This study hypothesizes that IMN will result in faster union times and fewer complications by relatively preserving the periosteum and reducing cosmetic problems in active young adults with MCFs.

This study aimed to compare internal fixation via open reduction and plate fixation (ORPF) against elastic stable IMN for displaced MCFs. The assessment will focus on union time, complications, and functional outcomes specifically within active young adult populations.

METHODS

This study was approved by the Institutional Review Board of the Ethics Committee of Korea University Medicine Center (No. 2023AS0358). Requirement for informed consent was waived by the Institutional Review Board because of the study retrospective design.

This retrospective cohort study involved analyses of medical records, postoperative clinical assessments, and comparative radiographs of patients who underwent surgical treatment for clavicle shaft fractures between April 2018 and April 2022. A total of 79 patients underwent surgery, with 39 analyzed in the present study. Patients treated surgically for displaced MCFs using plates and screws or elastic flexible titanium nails were assessed. The study was conducted at a single center by a consistent team of two shoulder specialists (JHP, JUK). Participants were selected based on specific inclusion and exclusion criteria. The study was conducted on patients younger than 60 years who had experienced displaced MCF treated with plate and screws or an intramedullary nail and were at least 12 months post-surgery. All patients had undergone implant removal after union. Displacement was characterized by an angle greater than 30º and shortening greater than 1.5 cm, while inclusion encompassed diaphyseal fractures falling within the Robinson classification type 2A2 or 2B1 [10,13,14]. Exclusion criteria included lateral third fractures (n = 9), refracture (n = 7), acromioclavicular injury (n = 4), intra-articular fracture (n = 1), open fracture (n = 1), fractures associated with neurovascular injuries or additional shoulder lesions (n = 6), infections (n = 0), unreachable or unwilling patients (n = 1), and severe comminuted fractures (AO Foundation/Orthopaedic Trauma Association fracture classification [AO/OTA classification] types C) (n = 11).

Both groups received general anesthesia. In the ORPF group, a Synthes precast blocked LCP plate (DePuy Synthes) was used. The procedure involved an upper, horizontal incision; muscle fascia opening; and superior plate fixation with at least three screws in each main fragment under the principle of stability. In the IMN group, a medial entry point into the clavicle was made through a 1 cm anterior horizontal incision. A flexible 2.5 mm or 3.0 mm Titanium Elastic Nail (TEN) System (DePuy Synthes), sized according to the medullary canal, was used for fixation. The groups followed a similar rehabilitation protocol. Immobilization was maintained for at least 4 weeks post-surgery in both groups, with no difference in the duration of immobilization between the ORPF and IMN groups.

Radiography in anteroposterior view was conducted on the day of evaluation, including both clavicles. Length and angulation of the clavicle were evaluated by two shoulder specialists (JHP, JUK). Clinical outcomes include time to fracture union and healing confirmed by radiological investigations and risk ratios

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of complication rates including mal-union, non-union, chronic neuropathy, and skin problems such as skin numbness, irritation, and protrusion by the end of the study follow-up. The functional outcome is the ranges of motion of the shoulder joint.

To identify significant differences in functional outcomes between the two interventions, appropriate parametric (Student t-test and Welch's t-test) and non-parametric tests (Fisher's exact test) were conducted using the SPSS software package version 21.0 (IBM Corp.). P-values <0.05 were considered significant.

RESULTS

In this retrospective cohort study, we compared the radiologic and clinical outcomes of 39 patients with MCFs treated with either ORPF group (n = 29) or IMN group (n = 10). There were no significant demographic differences between the two groups (Table 1). The mean age of the patients was 33.1 years, and the age difference between the groups was not significant (P = 0.11). The majority of the patients in both groups was male.

In terms of fracture pattern, AO-OTA Type A fractures were present in 19 patients (65.5%) in the ORPF group and in 4 patients (40%) in the IMN group. AO-OTA Type B fractures were present in 10 patients (34.5%) in the ORPF group and in 6 patients (60%) in the IMN group. The difference in fracture pattern between the groups was not significant (P = 0.77). Also, the difference in injury mechanism between the groups was not significant (P = 0.57).

The time elapsed from the onset of injury to treatment was significantly different between the two groups (P < 0.01) (Table 1). There was a significant difference in the mean follow-up peri-

Table 1. Demographics and clinical characteristics of patients treated with plate vs. nail for mid-shaft clavicle fractures

Variable	ORPF (n = 29)	IMN (n = 10)	P-value
Age (yr)	35.2 ± 12.3	27.0 ± 12.8	0.11
Sex (male:female)	19:10	6:4	0.68
Fracture pattern			0.77
AO-OTA type A	19 (65.5)	4 (40.0)	
AO-OTA type B	10 (34.5)	6 (60.0)	
Injury mechanism			0.57
Fall	15 (51.7)	6 (60.0)	
Motor vehicle accident	10 (34.5)	3 (30.0)	
Sports	4 (13.8)	1 (10.0)	
Time elapsed since onset (day)	5.0 ± 2.4	2.9 ± 1.4	< 0.01*

Values are presented as mean ± standard deviation or number (%).
ORPF: open reduction plate fixation; IMN: intramedullary nailing, AO-OTA: AO Foundation/Orthopaedic Trauma Association fracture classification.
*Statistically significant.

Table 2. Comparative outcomes and complications of patients treated with plate vs. nail for mid-shaft clavicle fractures

Variable	ORPF (n = 29)	IMN (n = 10)	P-value
Mean follow-up (mo)	16.5 ± 4.8	12.2 ± 1.2	< 0.01*
Surgery time (min)	64.2 ± 20.4	55.3 ± 6.3	0.04*
Achieved union	26 (90.0)	10 (100.0)	0.08
Time to union (wk)	23.1 ± 1.7	20.8 ± 1.2	< 0.01*
Nonunion	3 (10.3)	0	0.08
Malunion	0	0	NA
Shortening	0	0	NA
Angulation	0	0	NA
Infection	0	0	NA
Skin irritation	16 (55.2)	0	< 0.01*
Wound dehiscence	0	0	NA
Skin numbness	10 (34.5)	1 (10)	0.08
Revision operation	3 (10.3)	0	0.08

Values are presented as mean ± standard deviation or number (%).
ORPF: open reduction plate fixation, IMN: intramedullary nailing, NA: not applicable.
*Statistically significant.

ods between the ORPF group (16.5 months) and the IMN group (12.2 months) (P < 0.01) (Table 2). However, The difference in range of motion between the groups was not significant (all P > 0.05) (Table 3). Surgical duration was significantly shorter in the IMN group compared to the ORPF group. The mean surgery time for the IMN group was 55.3 minutes, while that for the ORPF group was 64.2 minutes, a statistically significant difference (P = 0.04).

Major complications, which include nonunion, malunion, shortening, angulation, and infection, were observed in 3 patients from the ORPF group, with all 3 cases experiencing nonunion. No such complications were reported in the IMN group. The majority of patients in both groups achieved union, with 90.0% in the ORPF group and 100.0% in the IMN group. This difference was not statistically significant (P = 0.08). The time to union was significantly different between the two groups (P < 0.01), with the ORPF group averaging 23.1 weeks and the IMN group averaging 20.8 weeks. Nonunion was observed in 3 patients (10.3%) from the ORPF group but none from the IMN group (P = 0.08).

No cases of wound dehiscence were observed in either group. However, skin irritation was significantly more common in the ORPF group (55.2%) compared to the IMN group (P < 0.01). Skin numbness was reported in 10 patients (34.5%) from the ORPF group and 1 patient (10%) from the IMN group (P = 0.08). Revision surgery due to implant failures was required in 3 patients (10.3%) from the ORPF group (Fig. 1) but none from the IMN group (P = 0.08) (Fig. 2).

DISCUSSION

This study aimed to compare the optimal fixation strategy for unstable MCFs in young adults. Both methods were effective in returning patients to their pre-injury functional levels. However, IMN, with its lower rates of skin problems and implant failure, appears to be the preferred method for MCFs in young adults. Our results indicate that nails were more frequently used in younger patients and those with a shorter time onset, although there was no significant difference. This trend aligns with existing research, which suggests that plates are more effective for anatomical alignment and stability [15,16]. Consequently, plates were often chosen for relatively older patients or those with a longer duration from trauma to surgery (P < 0.01), in whom the stability of bone union might be compromised.

Table 3. Ranges of shoulder motions in patients treated with plate vs. nail for mid-shaft clavicle fractures

Variable	ORPF (n = 29)	IMN (n = 10)	P-value
Forward flexion (°)	168.1 ± 11.4	172.2 ± 10.6	0.43
Abduction (°)	160.4 ± 19.2	163.8 ± 19.3	0.12
External rotation (°)	73.6 ± 5.1	73.1 ± 11.4	0.83
Internal rotation (°)	69.3 ± 8.6	71.4 ± 6.9	0.60

Values are presented as mean ± standard deviation.
ORPF: open reduction plate fixation, IMN: intramedullary nailing.

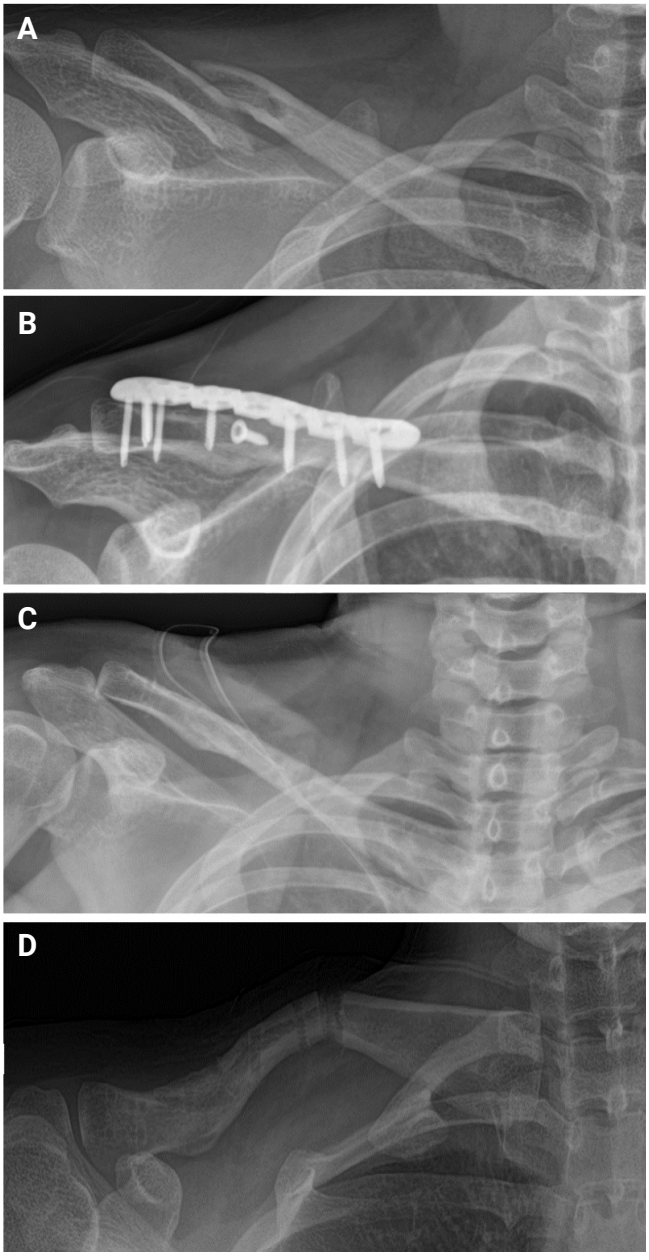

Fig. 1. A 22-year-old woman with a right-sided displaced mid-shaft clavicle fracture underwent plate fixation. (A) The preoperative radiograph shows a midclavicular fracture (Robinson 2B1). (B) A radiograph at 1 year postoperative shows successful union of the fracture with the implanted plate and screw. (C) After implant removal, the radiograph shows achieved union. (D) A radiograph obtained 4 weeks after hardware removal shows a new onset fracture at a different site due to hardware removal.

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In a national population-based survey, age 45–64 years was an independent risk group for clavicle fractures [17]. Within this bracket, the incidence stood at 37.5/100,000 person-years, significantly higher than in all other age cohorts except teenagers [18]. This trend was linked to the prevalent active lifestyles within this demographic. Echoing previous research that identified a bimodal age peak in MCFs among both adolescents and active young adults, our study sought to compare and analyze the two predominant surgical treatments—plate fixation (ORPF group) and intramedullary nailing (IMN group) —within these age groups. The mean time to union was 23.1 ± 1.7 weeks for the ORPF group and 20.8 ± 1.2 weeks for the IMN group, with a significant difference ($P < 0.01$). This indicates that the IMN group experienced a shorter healing period compared to the ORPF group.

In our study, the ORPF group demonstrated an overall complication rate of 10%, consistent with findings from similar studies [15,16,19]. Previous studies on the clinical outcomes of plate fixation have reported complications such as nonunion, malunion (pseudoarthrosis, shortening, angulation), infections, paresthesia at incision sites, injuries to neurovascular structures, skin irritations and discomfort due to the presence of implants, and refracture following implant removal [15,19]. Incisional numbness has been reported at a prevalence of 41.7% of ORPF cases [20]. Our study showed similar results, with 10 patients (34.5%) in the ORPF group and 1 patient (10%) in the IMN group experiencing incisional numbness.

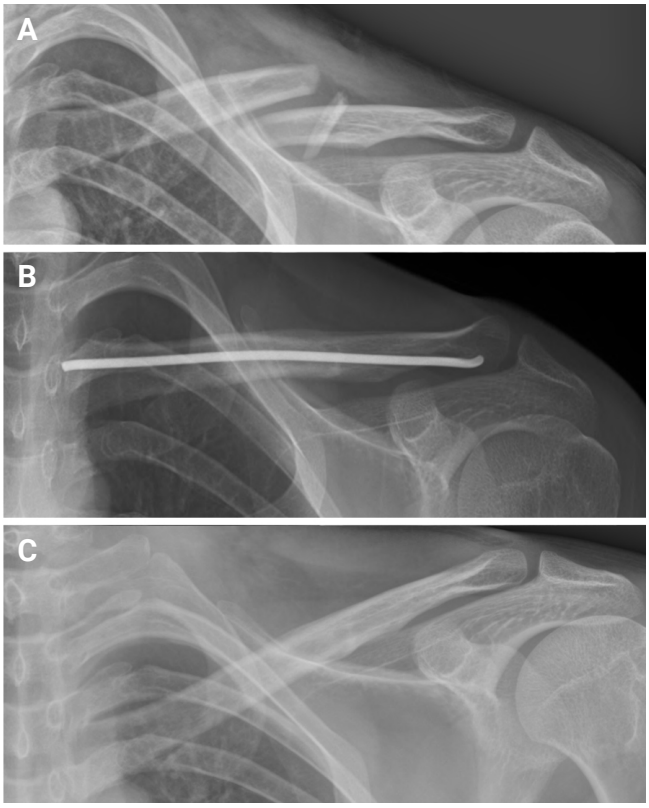

Fig. 2. A 24-year-old man with a left-sided displaced mid-shaft clavicle fracture underwent intramedullary nailing. (A) The preoperative radiograph shows a midclavicular fracture (Robinson 2B1). (B) A radiograph at 1 year postoperative shows successful union of the fracture with the nail. (C) After implant removal, the radiograph shows persistent union.

According to a previous systematic review, infection rates in plate treatment were less than 10% in nine analyzed articles, lower than in prior articles [21]. Within our study, we observed that skin irritation was present in 55.2% (n = 16) of the cases in the ORPF group. However, we did not encounter infections such as skin erosion leading to deep infection post-plate exposure. On the other hand, the IMN group exhibited a lower overall complication rate of 0.0% compared to the ORPF group. The principal drawbacks of nail utilization include radiographic malunion and superficial wound infection [22]. Biomechanically, IMN can result in poor anti-rotation and anti-shortening forces, which may lead to reduced rotational stability and potential for malunion [23]. Complications such as medial perforations, lateral penetrations, elastic nail breakage, and dislocation have also been reported [24].

Traditionally, IM nailing after closed reduction is recommended for simple fractures, whereas plate fixation is preferred for comminuted cases, enabling faster recovery and better clinical outcomes with reduced implant removal [13]. Previous studies have shown that patients treated with nails reported higher satisfaction due to smaller scars compared to those who underwent plate treatment [25]. According to meta-analysis, intramedullary nailing and plating provide equivalent long-term functional outcomes. However, plating may lead to higher risk of treatment failure and non-operative complications [26]. Similarly, in our study, at a mean follow-up of 1 year, the healing rate was 100% in the IMN group and 90.0% in the ORPF group, but this difference was not significant ($P = 0.08$). Our results indicated a higher need for revision surgery in the ORPF group compared to the IMN group.

Our study, being retrospective in nature, had varying follow-up times for the groups, which complicated comparative evaluations. The study relied on medical records for data collection, which may be subject to information bias. The number of patients was relatively small, limiting the generalizability of the results. Moreover, this study was conducted at a single center, so the results may differ in other regions or population groups. Last, we did not provide clinical outcome scores, but we aimed to compensate for this by offering detailed radiologic outcomes, complication rates, and range of motion. To gain conclusive insights into the optimal surgical treatments for these prevalent

and impactful orthopedic fractures, it is crucial to conduct age-matched prospective studies with long-term follow-up.

CONCLUSIONS

Both ORPF and IMN restore pre-injury functional levels in patients with MCFs. IMN presents advantages in certain aspects like higher healing rate and fewer revision surgeries compared to the ORPF group. Additionally, IMN was associated with lower rates of incisional numbness. Therefore, IMN is recommended as the preferred treatment method for MCF in young adults due to its superior outcomes.

NOTES

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Conflict of interest

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Data availability

Contact the corresponding author for data availability.

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REFERENCES

1. Nordqvist A, Petersson C. The incidence of fractures of the clavicle. Clin Orthop Relat Res 1994;(300):127–32.
2. Postacchini F, Gumina S, De Santis P, Albo F. Epidemiology of clavicle fractures. J Shoulder Elbow Surg 2002;11:452–6.
3. McKee MD, Pedersen EM, Jones C, et al. Deficits following nonoperative treatment of displaced midshaft clavicular fractures. J Bone Joint Surg Am 2006;88:35–40.
4. Zlowodzki M, Zelle BA, Cole PA, Jeray K, McKee MD. Treatment of acute midshaft clavicle fractures: systematic review of 2144 fractures: on behalf of the Evidence-Based Orthopaedic Trauma Working Group. J Orthop Trauma 2005;19:504–7.
5. Hillen RJ, Burger BJ, Pöll RG, van Dijk CN, Veeger DH. The effect of experimental shortening of the clavicle on shoulder kinematics. Clin Biomech (Bristol, Avon) 2012;27:777–81.
6. Wilson DJ, Scully WF, Min KS, Harmon TA, Eichinger JK, Arrington ED. Biomechanical analysis of intramedullary vs. superior plate fixation of transverse midshaft clavicle fractures. J Shoulder Elbow Surg 2016;25:949–53.
7. Vander Have KL, Perdue AM, Caird MS, Farley FA. Operative versus nonoperative treatment of midshaft clavicle fractures in adolescents. J Pediatr Orthop 2010;30:307–12.
8. Yadav S, Phalak MO, Shevate I, et al. Comparative study of postoperative outcomes of clavicle midshaft fracture treated by nailing vs. plating. Cureus 2022;14:e22862.
9. Song HS, Kim H. Current concepts in the treatment of midshaft clavicle fractures in adults. Clin Shoulder Elb 2021;24:189–98.
10. Yan MZ, Yuen WS, Yeung SC, et al. Operative management of midshaft clavicle fractures demonstrates better long-term outcomes: a systematic review and meta-analysis of randomised controlled trials. PLoS One 2022;17:e0267861.
11. Choudhari P. Displaced mid-shaft clavicle fractures: a subset for surgical treatment. Malays Orthop J 2014;8:1–5.
12. Chan G, Korac Z, Miletic M, Vidovic D, Phadnis J, Bakota B. Plate versus intramedullary fixation of two-part and multifragmentary displaced midshaft clavicle fractures: a long-term analysis. Injury 2017;48 Suppl 5:S21–6.
13. Duan X, Zhong G, Cen S, Huang F, Xiang Z. Plating versus intramedullary pin or conservative treatment for midshaft fracture of clavicle: a meta-analysis of randomized controlled trials. J Shoulder Elbow Surg 2011;20:1008–15.
14. Robinson CM. Fractures of the clavicle in the adult: epidemiology and classification. J Bone Joint Surg Br 1998;80:476–84.
15. 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;19:8.
16. Wolf S, Chitnis AS, Manoranjith A, et al. Surgical treatment, complications, reoperations, and healthcare costs among patients with clavicle fracture in England. BMC Musculoskelet Disord 2022;23:135.
17. Chen W, Zhu Y, Liu S, et al. Demographic and socioeconomic factors influencing the incidence of clavicle fractures, a national population-based survey of five hundred and twelve thousand,

https://doi.org/10.5397/cise.2024.00605

one hundred and eighty seven individuals. Int Orthop 2018;42:651–8.
18. Kihlström C, Möller M, Lönn K, Wolf O. Clavicle fractures: epidemiology, classification and treatment of 2 422 fractures in the Swedish Fracture Register. An observational study. BMC Musculoskelet Disord 2017;18:82.
19. Ostergaard PJ, Hall MJ, Xiong G, Zhang D, Earp BE. Risk factors for implant removal after surgical fixation of midshaft clavicle fractures. Orthopedics 2022;45:e201–6.
20. Park JS, Ko SH, Hong TH, et al. Plate fixation versus titanium elastic nailing in midshaft clavicle fractures based on fracture classifications. J Orthop Surg (Hong Kong) 2020;28:2309499020972204.
21. Wijdicks FJ, Van der Meijden OA, Millett PJ, Verleisdonk EJ, Houwert RM. Systematic review of the complications of plate fixation of clavicle fractures. Arch Orthop Trauma Surg 2012;132:617–25.
22. Osateerakun P, Limpaphayom N. Elastic stable intramedullary nail: the viable technique for pediatric long bone fixation. Thai J Orthop Surg 2014;38:31–7.
23. Jubel A, Andermahr J, Prokop A, Isenberg J, Rehm KE. Minimal invasive biological osteosynthesis of the clavicle with a titanium nail. Kongressbd Dtsch Ges Chir Kongr 2002;119:485–90.
24. Frigg A, Rillmann P, Perren T, Gerber M, Ryf C. Intramedullary nailing of clavicular midshaft fractures with the titanium elastic nail: problems and complications. Am J Sports Med 2009;37:352–9.
25. Vajrangi A, Shetty SV, Shenoy RM. A comparative study between plate fixation and intramedullary fixation for displaced mid-shaft clavicle fractures in adults. Malays Orthop J 2022;16:40–5.
26. Hussain N, Sermer C, Prusick PJ, Banfield L, Atrey A, Bhandari M. Intramedullary nailing versus plate fixation for the treatment displaced midshaft clavicular fractures: a systematic review and meta-analysis. Sci Rep 2016;6:34912.