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Anteroinferior plating is an independent factor for decreasing symptomatic implant removal rates after plate fixation for midshaft clavicle fractures

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Abstract

Objectives: The factors that significantly influence the symptomatic implant removal rates after plate fixation for midshaft clavicle fractures remain controversial. The purpose of this study was to compare the symptomatic implant removal rates between 2 different types of plating technique and to evaluate independently associated factors.

Design: Retrospective cohort study.

Setting: Acute care center.

Patients/Participants: A total of 71 patients 16 years or older who were diagnosed with displaced midshaft clavicle fractures from April 2016 to March 2020.

Intervention: Thirty-nine patients were treated with superior plating (Group SP), and the remaining 32 patients were treated with anteroinferior plating (Group AIP).

Main Outcome Measurements: Symptomatic implant removal rates after plate fixation for midshaft clavicle fractures.

Results: Symptomatic implant removal rates were significantly lower in Group AIP (28.1%) than in Group SP (53.8%) ($P = 0.033$). Multivariate analyses showed that symptomatic implant removal rates were significantly decreased by three independent factors, namely AIP (odds ratio [OR] = 0.323) ($P = 0.037$), greater age (45 years or older) (OR = 0.312) ($P = 0.029$), and high body mass index ($\geq$25 kg/m^2) (OR = 0.117) ($P = 0.034$).

Conclusions: AIP significantly and independently decreased the symptomatic implant removal rate. Among the three explanatory factors showing significant difference, plating technique is the only factor that can be altered by medical institutions. Therefore, we recommend this technique for displaced midshaft clavicle fractures to reduce a second surgery such as symptomatic implant removal.

Level of Evidence: Level 3, retrospective cohort study

Keywords: midshaft clavicle fracture, anteroinferior plating, superior plating, symptomatic implant removal rate

1. Introduction

The strategy for treating midshaft clavicle fractures has been discussed for the past 2 decades. Conventionally, nonoperative treatment has been the mainstream approach. The report by the Canadian Orthopaedic Trauma Society demonstrated that primary plate fixation for displaced midshaft clavicle fractures resulted in improved functional outcome and a lower rate of malunion and nonunion compared with those with nonoperative treatment.[1] Subsequently, surgical treatment has been increasingly applied for acute midshaft clavicle fractures for more than 10 years.[2]

Regarding plate fixation for midshaft clavicle fractures, the superior plating technique has been predominant for a long time.[3,4] However, classic superior plating is accompanied by postoperative complications, including prominence and soft tissue irritation. Therefore, to minimize the risks of plate prominence and soft tissue irritation and to maximize the merit of biomechanical strength with greater resistance to cantilever bending,[5–7] the anteroinferior plating technique has gradually become popular.[8–10] In fact, some publications have reported that implant removal rates after anteroinferior plating for midshaft clavicle fractures were lower than those after superior plating,[11,12] whereas other authors have also reported that the occurrence of implant-related irritation did not correlate with plating positions.[13] Those studies solely compared implant removal rates without considering various biases, including patients' background, plating positions, and intraoperative factors, resulting in inconsistent results from article to article. Therefore, it remained controversial whether plate positioning had a significant and independent effect on the implant removal rates.

Although superior plating has been used in our institution for several years, we have drastically shifted our standard surgical

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procedure from superior to anteroinferior plating since April 2018, anticipating longer bicortical screw paths and theoretically lower risks of neurovascular damage by drilling.[14,15] Therefore, we retrospectively reviewed the symptomatic implant removal rates and perioperative factors of plate fixation for midshaft clavicle fractures. Our aims in this study were to compare the symptomatic implant removal rates between 2 different positions of plating for midshaft clavicle fractures and to evaluate the independent factors associated with implant removal using multivariate analyses.

2. Materials and Methods

2.1. Study Design

This retrospective cohort study was conducted after obtaining approval from the institutional review board. Data were collected from a longitudinal database of midshaft clavicle fractures in our institution. The surgery was performed for patients with Robinson type 2A2, 2B1, and 2B2 fractures. For patients with Robinson type 2A2 fractures, the surgery was performed when the fracture was complete, when the angular deformity was 20 degrees or more, or when patients preferred surgery to alternative options, including conservative treatment. Eighty-seven patients were diagnosed with midshaft clavicle fractures and underwent open reduction and plate fixation between April 2016 and March 2020. We included an aggregate of 71 patients 16 years or older and followed up at least 6 months after plate fixation.

The 71 patients were divided into 2 groups: 39 and 32 in group "superior plate" (Group SP) and in group "anteroinferior plate" (Group AIP), respectively (Fig. 1). The rate of symptomatic implant removal was investigated as the primary outcome in both groups. After the bone union was confirmed on x-ray, the implant was removed according to the same protocol in Groups SP and AIP. It was conducted for the patients who complained of symptoms, such as discomfort, pain, and prominence, and agreed to the removal. We did not conduct the removal for patients without any symptoms, except for those who strongly requested it. These exceptional cases were excluded from the symptomatic implant removal reported here. Postoperative follow-up was handled by the orthopaedic surgeon responsible for the primary surgery.

2.2. Surgical Procedures

All cases during the study period were supervised by the same chief surgeon (H.S), and 11 orthopaedic surgeons participated in the surgeries as assistants. Assistant surgeons who performed surgeries between April 2016 and March 2018 used SP, while other assistants who performed surgeries between April 2018 and March 2020 used AIP.

2.3. Superior Plate Fixation

The patient was placed in a modified beach chair position. The skin incision was centered over the fracture site according to the bone axis. We attempted to preserve the supraclavicular nerve for all cases to reduce the postoperative risk of paresthesia in front of the clavicles (Fig. 2).[16] After subcutaneous dissection and minimal dissection of the clavicle periosteum to expose the fracture, temporal reduction was conducted. Lag screws were set in applicable cases, and a superior plate of the HOMS Anodized Implant clavicle locking plate (HOMS, Chino, Japan) was used as the neutralization plate. In patients with comminuted fractures, locking plates were used as bridging plates.

2.4. Anteroinferior Plate Fixation

Patients undergoing AIP fixation were placed in a modified beach chair position. As performed in the superior plate positioning, the skin incision was centered over the fracture and made parallel to the clavicle line. In subcutaneous dissection, an attempt was made to preserve the supraclavicular nerve (Fig. 3). Around the proximal side of the clavicle, the pectoralis major muscle was detached. On the other hand, the deltoid muscle was detached at

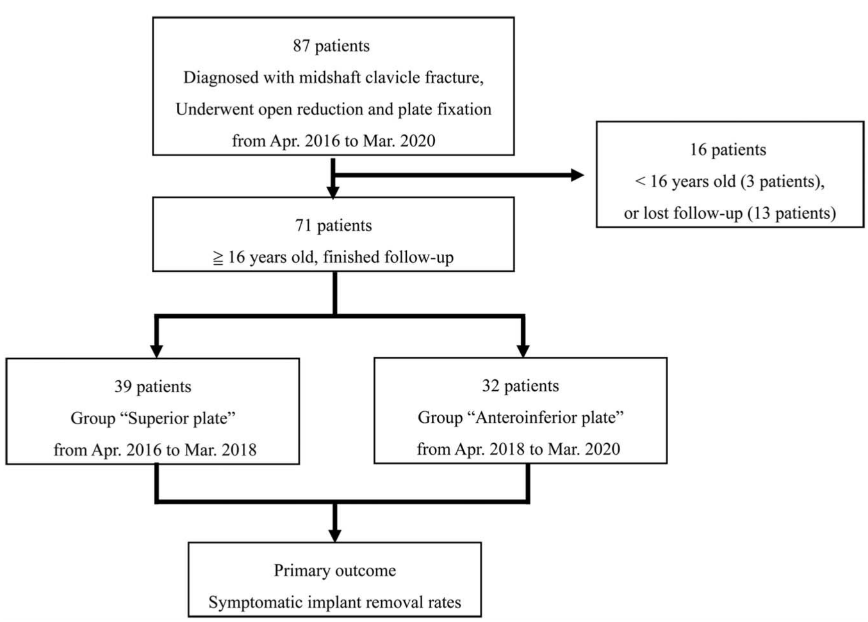

Figure 1. Selection of patients.

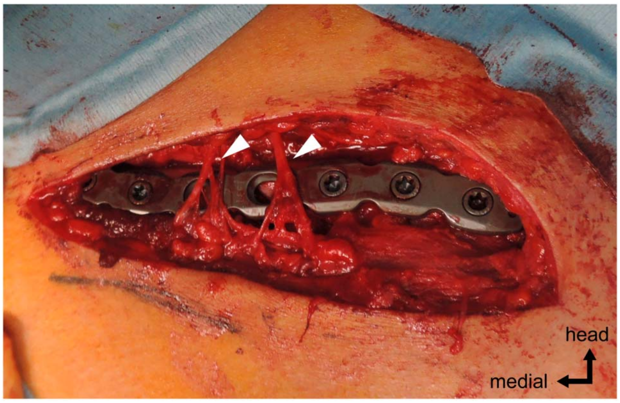

Figure 2. Superior plating. The image illustrates the superior plate below the preserved supraclavicular nerves (white arrowheads).

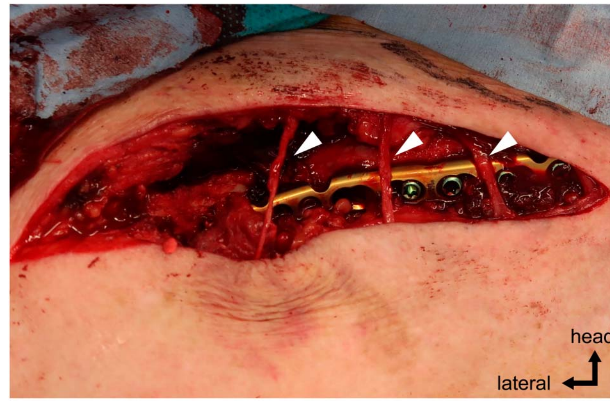

Figure 3. Anteroinferior plating. The image shows the anteroinferior plate positioned below the preserved supraclavicular nerves (white arrowheads).

the distal side of the clavicle to secure space for attaching the plate. After minimal dissection of the clavicle periosteum to expose the fracture, anatomic reduction was performed using lag screws in applicable cases, and a variable angle-locking compression plate (VA-LCP) anterior clavicular plate (DePuy Synthes, West Chester, PA) was used as the neutralization plate. For comminuted fractures, locking plates were used as bridging plates. The anteromedial to superolateral VA-LCP was not used in our institution.

3. Outcome Assessment

The electronic medical records were reviewed for baseline patient characteristics, complications, and implant removal during follow-up. The detailed reasons for implant removal were examined, whether the patient wanted to remove the plate for specific reasons including pain and prominence or patients' request. We also examined the radiographs taken at 1, 3, and 6 months after surgery to ensure that the plate was correctly positioned. Bone union was defined when the fracture line disappeared. The bone union was evaluated independently by 2 orthopaedic surgeons (A.A. and H.S.), and the average time for the bone union was calculated and shown as the days from the primary surgery. The symptomatic implant removal rates and the bone union in each group were set as the primary and secondary outcome parameters, respectively.

3.1. Statistical Analysis

Statistical analyses were conducted using R (manova; R ver. 4.0.2). Differences between groups were compared using the Mann–Whitney *U* test for continuous data and the Fisher exact test for categorical data. Based on the previous report[17] of a high rate of implant removal in patients with low body mass index (BMI) and age after fracture surgery, we suspected that BMI and age could independently be predictive variables in the SP and AIP groups. Therefore, surgical technique, age, sex, and BMI were assessed as relative factors for implant removal rates. These factors were evaluated using multivariate logistic regression. BMI was classified according to the World Health Organization classification, in which BMI $\geq$25 kg/m^2 is defined "preobese." The difference was considered statistically significant when $P < 0.05$.

4. Results

4.1. Baseline Characteristics

Table 1 presents the demographic data of the patients. There was no significant difference between Groups SP and AIP for age, sex,

TABLE 1

Baseline Characteristics of Patients

	Group SP (n = 39)	Group AIP (n = 32)	*P*
Mean age (yr)	47.4 ± 14.9	47.8 ± 17.1	0.922*
Sex, n (%)			
Female	7 (17.9)	7 (21.9)	0.768†
Male	32 (82.1)	25 (78.1)	
BMI (kg/m^2)	23.5 ± 3.9	24.7 ± 3.2	0.194*
Mean time from injury to surgery (days)	6.6 ± 3.3	9.2 ± 8.5	0.056*
Mean time from primary surgery to implant removal (days)	310 ± 70.9	313 ± 64.0	0.773*
Mean follow-up (days)	327 ± 97.9	389 ± 160	0.600*
Fracture side, n (%)			
Right	20 (51.3)	17 (53.1)	1.00†
Left	19 (48.7)	15 (46.9)	
Dominant hand, n (%)			
Right	38 (97.4)	32 (100)	1.00†
Left	1 (2.6)	0 (0)	
Robinson classification, n (%)			
2A2	2 (5.1)	2 (6.3)	1.00†
2B1	15 (38.5)	16 (50.0)	0.348†
2B2	22 (56.4)	14 (43.8)	0.344†
Mechanism of injury, n (%)			
Car accident	3 (7.7)	1 (3.1)	1.00†
Motorcycle accident	14 (35.9)	14 (43.8)	0.626†
Bicycle accident	4 (10.3)	69 (18.8)	1.00†
Fall from standing height	11 (28.2)	8 (25.0)	1.00†
Sports injury	7 (17.9)	3 (9.4)	0.495†
Multiple injury, n (%)			
Yes	13 (33.3)	10 (31.3)	1.00†
No	26 (66.7)	22 (68.8)	
American Society of Anesthesiologists physical status, n (%)			
1	20 (51.3)	18 (56.3)	0.812†
2	19 (48.7)	12 (37.5)	0.471†
3	0 (0)	2 (6.3)	0.200†

Data are shown as mean ± SD or numbers. $P < 0.05$ indicates statistical significance.
* Mann–Whitney *U* test.
† Fisher exact test.

TABLE 2

Implant Removal Rates

	Group SP (n = 39)	Group AIP (n = 32)	P
Symptomatic, n (%)	21 (53.8)	9 (28.1)	0.033
Patients' request, n (%)	5 (12.8)	4 (12.5)	1.00

Differences between groups were compared using the Fisher exact test. $P < 0.05$ indicates statistical significance.

BMI, time from injury to surgery, time to evaluation, fracture side, the dominant hand, Robinson classification, mechanism of injury, multiple injuries, and American Society of Anesthesiologists physical status.

4.2. Symptomatic Implant Removal Rates

As presented in Table 2, the rate of symptomatic implant removal was significantly lower in patients in Group AIP than in patients in Group SP ($P = 0.033$). A similar number of patients in the 2 groups requested removal despite no implant-related symptoms ($P = 1.00$).

4.3. Bone Union

Table 3 presents every patient in both Groups SP and AIP that achieved bone union. The mean time to bone union was not significantly different between the 2 groups ($P = 0.694$).

4.4. Intraoperative Factors

Table 4 presents a comparison of the intraoperative factors between Groups SP and AIP. The duration of the operation ($P = 0.083$) and anesthesia ($P = 0.201$) was not different between the 2 groups.

4.5. Independent Factors for Decreasing the Symptomatic Implant Removal Rates

As presented in Table 5, the multivariate analyses revealed that anteroinferior plating ($P = 0.037$), 45 years or older ($P = 0.029$), and BMI ≥25 kg/m^2 ($P = 0.034$) were independently associated with significantly low implant removal rates.

5. Discussion

Baltes et al reported that anteroinferior plating resulted in a low implant removal rate. However, neither control groups nor statistical analyses were described in their report.[18] Serrano et al[12] also demonstrated that anteroinferior plating required a significantly lower number of secondary surgeries than superior plating, but they did not mention the risk factors for those ratios. By contrast, Hulsmans et al[13] reported no significant difference in the symptomatic plate removal rate between superior and anteroinferior plating techniques. Hence, the factors that significantly and independently affect the implant removal rates after plate fixation for midshaft clavicle fractures remained controversial. What is novel about this study is that multivariate analyses were applied and demonstrated, for the first time in the literature, that the anteroinferior plating significantly and independently decreased the rates of symptomatic implant removal.

In the multivariate analyses, anteroinferior plating, 45 years or older, and BMI ≥25 kg/m^2 were found to be independent factors for decreasing the implant removal rates after plate fixation for midshaft clavicle fractures. Among these independent factors, age and BMI are unalterable patients' background characteristics from a medical viewpoint. However, the plating technique is the only factor that can be altered by medical institutions. In other words, we could decrease the rate of postoperative implant-related irritation, including pain and prominence by means of plating technique. Furthermore, no significant difference of bone union between Groups SP and AIP was noted. These are substantial reasons for recommending anteroinferior plating for midshaft clavicle fractures.

This study also analyzed the intraoperative factors in addition to patients' characteristics and postoperative implant removal rates. Both operation and anesthesia time were comparable between Groups SP and AIP, although anteroinferior plating requires additional steps of surgical technique in which we detach the major pectoral and the deltoid muscle from the clavicle, while superior plating involves separation of only the soft tissue above the clavicle.

In our analyses, the symptomatic implant removal rates were 53.8% for superior plating and 28.1% for anteroinferior plating. These rates were much higher than those reported in previous studies, which ranged from 0% to 20.3% for superior plating[1,19–27] and from 0% to 8.1% for anteroinferior plating.[9,28–31]

TABLE 3

Bone Union and Intraoperative Data

	Group SP (n = 39)	Group AIP (n = 32)	P
Bone union, n (%)			
Yes	39 (100)	32 (100)	1.00*
No	0 (0)	0 (0)	
Mean time to bone union (days)	89.2 ± 21.7	95.2 ± 30.8	0.694†

Data are shown as mean ± SD or numbers. $P < 0.05$ indicates statistical significance.
* Fisher exact test.
† Mann–Whitney U test.

TABLE 4

Intraoperative Data

	Group SP (n = 39)	Group AIP (n = 32)	P
Operation time (min)	96 ± 0.016	103 ± 0.011	0.083
Anesthesia time (min)	141 ± 0.017	147 ± 0.016	0.201

Differences between groups were compared using the Mann–Whitney U test. $P < 0.05$ indicates statistical significance.

TABLE 5

Risk Factors for Symptomatic Implant Removal

	Multivariate Analysis	
	Odds Ratio [95% Confidence Interval]	P
Plate		
Superior plate	1 (base)	0.037
Anteroinferior plate	0.323 [0.111, 0.935]	
Age		
≥45 years	0.312 [0.110, 0.888]	0.029
<45 years	1 (base)	
Sex		
Male	2.960 [0.693, 12.60]	0.143
Female	1 (base)	
BMI		
≥25	0.117 [0.016, 0.846]	0.034
<25	1 (base)	

The factors were evaluated using multivariate logistic regression. $P < 0.05$ indicates statistical significance.

This difference might be related to BMI, whose average value tends to be lower for Japanese people than that in other countries. Subcutaneous tissue might prevent implant irritation or prominence, and our study subjects had relatively thin subcutaneous tissue compared with subjects from western countries, the major study subjects in previous studies. Moreover, there might be a mismatch in plate size and contour with the Japanese population.

This study has several limitations to be addressed. First, it was a retrospective cohort study conducted with a relatively small number of patients in a single center. Second, the mean follow-up period was relatively short. However, during the follow-up period in this study, we identified bone unions in all cases in both groups, confirming a request for symptomatic plate removal. In cases where patients requested implant removal at other institutions, we provided them with detailed information about their implants. In Japan, when removing the implants operated in other institutions, we always contact the previous doctor to confirm the details of the surgery and implant type. Therefore, it is unlikely that the patients treated in our institute undergo plate removal without our awareness. Third, there was ambiguity in the decision for implant removal in this study. Although we conducted implant removal for only patients who complained of symptoms, it would be undeniable that orthopaedic surgeons have contributed some subjective factors to the decision of the implant removal. Moreover, patient-based evaluation was not reviewed. Further studies with larger numbers of patients and a longer follow-up period are required. Although this study was not randomized, we standardized the plating technique by the period but not by the characteristics of the patients or clavicle fractures, which allowed us to discuss the clinical outcomes mostly from the viewpoint of different plating positions.

6. Conclusions

Anteroinferior plating, ≥45 years or older, and BMI ≥25 kg/m^2 were the independent factors for decreasing the symptomatic implant removal rates after plate fixation for midshaft clavicle fractures in our multivariate analyses. Plating technique is the only factor that can be altered by medical institutions. Therefore, we recommend anteroinferior plating for displaced midshaft clavicle fractures to reduce a second surgery such as symptomatic implant removal.

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