



Factors affecting healing following percutaneous intramedullary fixation of metacarpal fractures

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Abstract

Although percutaneous intramedullary nailing of metacarpal fractures is a straightforward and reliable technique, it is not without complications, and patients experience different outcomes. This study analyzed factors affecting fracture healing time and complication rates in patients who underwent percutaneous intramedullary fixation of metacarpal fractures.

This study was a retrospective review of the 25 patients who underwent retrograde percutaneous Kirschner wire (K-wire) nailing for fracture of the metacarpal shaft or neck at a military hospital between May 2016 and October 2018. Correlation study and multiple regression analysis were performed to evaluate variables (age, smoking history in pack-years, body-mass index, fracture site, number of K-wires used) that affect time to bone union. Clinical features of patients with metacarpal neck fractures and those with metacarpal shaft fractures were also compared.

The metacarpal shaft fractures (as opposed to metacarpal neck fractures) and higher number of K-wire used were associated with longer time to bone union. Mean union time was significantly longer for metacarpal shaft fracture (8.6 weeks) than for metacarpal neck fracture (6.1 weeks) and for patients who received more K-wires than for those who received less (regression coefficient 1.307). One patient suffered fixation failure and required revision operation, and another experienced superficial infection which was treated with intravenous antibiotics.

Percutaneous intramedullary nailing is an effective technique for metacarpal fractures, but fracture site and number of K-wire used affect time to achieve bone union.

Abbreviations: BMI = body mass index, K-wire = kirschner wire.

Keywords: fracture, intramedullary fracture fixation, metacarpal bone

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1. Introduction

Metacarpal fracture is one of the most common types of hand fracture, especially in young, active persons.^[1] These fractures sometimes require surgical treatment, and various surgical techniques have been shown to be successful in treating metacarpal bone fractures. One of the intramedullary fixation techniques in metacarpal fractures, was first introduced in the 1950s.^[2] This method, which was shown to be easy and reliable, has led to the development of many modified nailing techniques to treat metacarpal bone fractures.^[3,4]

Although the locking plate technique has also been used to treat metacarpal bone fractures, the intramedullary nailing technique is largely preferred, because of decreased concern for soft tissue injuries, scarring, and tendon adhesion or stiffness.^[5,6] Percutaneous intramedullary pinning has shown success for various types of metacarpal fractures, especially fractures of the metacarpal neck and shaft, including their proximal parts.^[7,8] Less is known, however, about factors associated with fracture healing time and complication rates after these procedures. This study therefore evaluated clinical outcomes in patients with metacarpal bone fractures who underwent retrograde percutaneous intramedullary multiple Kirschner wire (K-wire) fixation and assessed factors associated with fracture healing time and complication rates.

2. Materials & methods

2.1. Patient selection

We retrospectively reviewed all patients with metacarpal fractures who had undergone retrograde intramedullary K-wire

fixation from May 2016 to October 2018 at our military hospital. The inclusion criteria for study was diagnosis of fracture of the metacarpal neck or shaft based on radiographic examination and subsequent treatment with retrograde percutaneous intramedullary multiple K-wire fixation. Patients with combined carpal bone fracture ($n=1$) and multiple metacarpal bone fractures ($n=1$) were excluded, as were those lost to follow-up ($n=3$). After these exclusions, 25 patients with metacarpal fractures remained for retrospective cohort analysis. We obtained approval for this study from the institutional review board of our center (approval number: AFMC-19-IRB-003).

2.2. Surgical technique

All procedures were performed by 2 orthopedic surgeons (DHK, CHK) at a single center. Indications for surgical treatment of metacarpal fractures included >30 degrees of angulation, rotational deformity, and shortening >5 mm after closed reduction attempt. Surgery was performed under local anesthesia (WALANT technique, 1% lidocaine is used with 1:100,000 epinephrine),^[9] using previously described intramedullary fixation technique.^[8] Under C-arm guidance, fracture reduction was performed using the Jahss maneuver.^[10] After confirming fracture reduction and while maintaining reduction with the Jahss maneuver, a 1.2 mm K-wire was inserted from the metacarpal head to the metacarpal base, in the retrograde direction. After checking the location of the wire, its distal tip was cut, and the wire was hammered gently to advance it across the fracture site. After achieving acceptable reduction, the wire was advanced proximally, taking care that the distal tip did not violate the joint space and fracture reduction was maintained. The proximal end of the wire was allowed to protrude through dorsal skin and flexed with pliers. At least 3 wires were inserted to achieve sufficient stability and fit the intramedullary space (Fig. 1). Postoperatively, the arms of all patients were placed in

dorsal short arm splints in the intrinsic-plus position. If pain was tolerable, patients were instructed to start active motion exercises within the splint. The splint was replaced by a short arm brace 3 weeks after surgery. The short arm brace and K-wires were removed after radiographic evaluation.

2.3. Data collection

Demographic data collected included patient age, sex, body mass index (BMI), and smoking habits. Surgical details collected included the injured digit, fracture location (metacarpal neck versus shaft), and number of K-wires used. Patients were followed up until fracture union. Since the patients belonged to the military of Korea, they were hospitalized until rehabilitation was complete. Radiographs of the affected hand were taken at admission and every week after surgery regularly to evaluate postoperative bone healing status. The primary outcome was the time to achieve bone union on simple radiographs. Bone union was defined as the presence of bone-bridging calluses in at least 3 cortices in 2 planes. Postoperative complication evaluation included fixation failure, pin-site infection, any discomfort due to rotational deformity, and postoperative joint stiffness. All data analyzed during this study were shown in supplementary information file (Supplemental Digital Content, <http://links.lww.com/MD/G545>).

2.4. Statistical analysis

Correlation analysis was used to find which variables are related to each other. Multiple regression analysis was performed to evaluate which factors affect time to union. As fracture site was found to affect healing time, we also compared the characteristics of metacarpal neck fracture group and the metacarpal shaft fracture group. Demographic and clinical outcome data were analyzed. Continuous variables were evaluated using the Mann–Whitney *U* test, and categorical variables were evaluated using



Figure 1. (A) Preoperative simple radiograph of a fifth metacarpal shaft fracture in a 19-year-old man. (B) Postoperative radiograph which maintained reduction with 3 K-wires inserted. (C) Radiograph at final follow-up period showing fracture union.

Table 1
Patient demographic characteristics.

Variables	N = 25
Age, years	23.0 ± 3.4 (20–35)
Male	28 (100%)
BMI, kg/m ²	22.8 ± 2.6 (18.0–29.4)
Smoking data	
Smokers	16 (64.0%)
Years of smoking	5.4 ± 3.4 (1–15)
Cigarettes per day	11.2 ± 6.0 (2–30)
Pack-years	5.3 ± 6.9 (0.5–24)
Non-smokers	9 (36.0%)

Results are presented as mean ± standard deviation (range) or as n (%).

the Chi-Squared test or Fisher exact test, as applicable. All statistical analyses were performed using PASW Statistics version 18.0 (IBM Corp., Armonk, NY). Statistical significance was defined as a *P* value < .05.

Based on the evaluation of factors influencing time to bone union, a post hoc power analysis of the outcome measures showed a power of 81.2% to yield a statistically significant result, assuming a 2-sided error rate of 5% for the sample size of each group.

3. Results

3.1. Demographic characteristic and operative outcomes of the patients

All patients involved in this study were young men in their twenties, and all fracture were due to traumatic incidents because this study was conducted at a military hospital. The average age of patients was 23.0 years (range, 20–35 years). And 16 patients were current smokers (Table 1). Injury to the fifth metacarpal bone was most common (84.0%), and the most common fracture location was the neck of the metacarpal bone (72.0%). The average number of K-wires used for fixation was 3.4 (range, 3–5). Fracture union was achieved in all patients, with a mean time to union of 6.8 weeks (range, 5–12 weeks). Operative details and results are summarized in Table 2.

3.2. Correlation and multiple regression of factors associated with healing time

Age, smoking history (in pack-years), BMI, fracture site (metacarpal shaft versus neck), number of K-wire used, and complication rates were evaluated by correlation analysis. Age was correlated with smoking in pack-years (*P* = .029); but BMI,

Table 2
Operative details and results.

Variables	N = 25
Injured digit	
Fourth metacarpal bone	4 (16.0%)
Fifth metacarpal bone	21 (84.0%)
Fracture location	
Metacarpal Neck	18 (72.0%)
Metacarpal Shaft	7 (28.0%)
No. of Kirschner wires used	
3	20 (80.0%)
4	4 (16.0%)
5	1 (4.0%)
Time to union, weeks	6.8 ± 1.9 (5–12)
Postoperative complications	
Fixation failure	1 (4.0%)
Pin-site infection	1 (4.0%)

Results are presented as n (%) or as mean ± standard deviation (range). No = number.

fracture site, number of K-wire used, and complication rates were independent of one another (Table 3). Multiple regression analysis revealed that fracture site (*P* = .002) and the number of K-wires used (*P* = .025) were positively correlated with healing time that is, fractures in the metacarpal shaft tended to take longer to union than fractures in the metacarpal neck; and usage of more K-wires for fixation led to longer times to bone union. (Table 4)

3.3. Comparison between fracture of the metacarpal neck and shaft

No clinical or surgical features were significantly different between patients with metacarpal neck and shaft fractures excepts healing time (Table 5) (*P* < .05). Fracture healing time of metacarpal shaft group was significantly longer than that of metacarpal neck group (8.6 weeks vs 6.1 weeks).

3.4. Postoperative complications

One patient with metacarpal neck fracture experienced fixation failure. This patient underwent successful revision surgery, consisting of open reduction and internal fixation with a plate and headless screw. One patient experienced pin-site infection without evidence of osteomyelitis. This patient required wire removal and changing of the short arm cast and recovered completely after treatment with intravenous antibiotics for 2 weeks. No patients experienced postoperative malrotation or stiffness.

Table 3
Correlation between clinical features of metacarpal fractures.

	Age	Smoking (PY)	BMI	Fracture site	No. of K-wire	Complication rate
Age	1					
Smoking (PY)	0.4357*	1				
BMI	0.2289	0.2451	1			
Fracture site	−0.1154	−0.1095	−0.0352	1		
No. of K-wire used	−0.1711	−0.1472	−0.2093	0.2296	1	
Complication rate	−0.2267	−0.1396	−0.2046	−0.0352	−0.2093	1

* *P* < .05.

No. = number, PY = pack-year.

Table 4
Multiple regression analysis of factors that affect healing time for metacarpal fractures.

	Coefficients	SD	T value	P value
Age			-0.362	.721
Smoking PY			-0.521	.608
BMI			-0.630	.535
Fracture site	2.174	0.617	3.806	.001
No. of K-wire used	1.307	0.541	2.414	.025
Complication rate			0.291	.774

PY = pack-year, SD = standard deviation.

4. Discussion

Multiple regression analysis revealed that fracture site and quantity of K-wires used affect time to achieve bone union after percutaneous intramedullary fixation. Fracture of the metacarpal shaft takes longer to achieve union than fracture of the metacarpal neck, and patients who receive more K-wires for fixation take longer to heal. Comparison analysis between fractures of the metacarpal shaft and neck reaffirmed that the healing time of metacarpal shaft fracture is statistically significantly longer than that of neck fracture but did not reveal any differences in the clinical or surgical characteristics of the patients in the 2 groups. Such comparison between fractures of the metacarpal shaft and neck has not been reported yet; it is a novel comparison that may reveal implications about the pathophysiology of metacarpal fractures based on the affected location that should be investigated further in future studies. Additionally, it is necessary to control the confounding variable for comparison between the 2 groups.

The healing time for metacarpal fractures after intramedullary fixation has been reported to be between 5 to 8 weeks.^[3,8,11,12] The healing time in our study also falls within this previously published range of healing time. Blood supply and stability of the fracture site affect time to achieve bone union.^[13] Both the metacarpal neck and shaft are supplied by the dorsal metacarpal artery from small periosteal branches,^[14] and the same procedure is used in both fractures. The difference in the time to bone union despite this fact suggests that percutaneous intramedullary K-wire fixation may not be able to provide sufficient stabilization to

Table 5
Comparison between metacarpal neck and shaft fractures.

Variables	Total (N=25)		P value
	Neck (n=18)	Shaft (n=7)	
Age (yrs)	23.3±3.9	22.4±1.3	.976
BMI, kg/m ²	22.8±2.8	22.6±2.3	.836
Smokers	10 (55.6%)	6 (85.7%)	.355
Injured digit			.053
Fourth metacarpal bone	1 (5.6%)	3 (42.9%)	
Fifth metacarpal bone	17 (94.4%)	4 (57.1%)	
No. of K-wires			.323
3	15 (83.3%)	5 (71.4%)	
4	3 (16.7%)	1 (14.3%)	
5	0 (0%)	1 (14.3%)	
Time to union (weeks)	6.1±0.8	8.6±2.6	.041
Fixation failure	1 (5.6%)	0 (0%)	
Pin site Infection	1 (5.6%)	0 (0%)	

Values are presented as mean ± standard deviation or n (%).

metacarpal shaft fractures as K-wires have been shown to have enough strength against physiological loading for treatment of metacarpal neck fractures in the past^[15] while the fixation strength of K-wires were shown to be significantly weaker than plates for the treatment of metacarpal shaft fractures.^[16,17] Otherwise, K-wire fixation showed shorter surgery time, less postoperative stiffness, and less skin problem, compared to plate fixation. Furthermore, in this study, early rehabilitation exercises were encouraged in patients, and it is possible that this early exercise may have put a load beyond the physiological loading for patients of metacarpal shaft fractures. Pursuit of more rigid stabilization, either through method of surgical fixation or reduction of load after operation, should be considered in the treatment of metacarpal shaft fractures.

The number of K-wires used was also shown to be associated with healing time of metacarpal fractures. Two or 3 K-wires are commonly used in percutaneous intramedullary K-wire fixation.^[8] However, the effect of the number of K-wires used on bone union has been rarely reported. Kwak et al did report that comparison between 2 and 3 K-wires for multiple retrograde intramedullary fixation did not show significant differences in clinical and radiologic outcomes except for pin migration, but usage of 3 K-wires is preferred to prevent metacarpal head perforation.^[18] In our study, 3 to 5 K-wires were used, and no case of pin migration was observed. For intramedullary nailing, fixation instruments with larger diameters provide more strength and stability for fixation^[19]; thus it was expected that using as many K-wire as possible would provide enough stabilization for metacarpal fracture. Indeed, Hiatt et al reported that strength of reduced bone increases as the number of K-wire used increases, and sufficient strength to withstand physiological load was obtained with 3 K-wires.^[20]

Despite this evidence, regression analysis demonstrated that usage of more K-wires for fixation led to longer times to achieve union. Two possible explanations can be hypothesized:

1. excessive reaming and introduction of too many K-wires could cause damage to the medulla and therefore compromise the blood supply of the bone, delaying union^[19];
2. the requirement of a higher number of K-wires for stabilization usually means high energy trauma and complicated fracture that are difficult to reduce and fixate.

The delayed union seen in patients with more K-wires stems from the degree of the initial trauma itself rather than the effect of the K-wires. Considering that the reported that average minimum isthmus of the ring finger metacarpal bone is 2.2 mm and average minimum isthmus of the small finger metacarpal bone is 3.8 mm,^[21] we recommend using 2 to 3 K-wires (1.2 mm or 1.6 mm in diameter) for retrograde percutaneous intramedullary K-wire fixation based on the results of this study.

One patient with metacarpal neck fracture experienced fixation failure. Preoperative radiograph was initially assessed as a simple metacarpal neck fracture. Slippage of the metacarpal head fragment occurred 3 days after retrograde intramedullary fixation (Fig. 2). A three-dimensional computed tomography scan revealed combined metacarpal head fracture which was not observed preoperatively.^[5] This case serves as an example in which a plain radiograph is not sufficient for diagnosis of nondisplaced metacarpal fracture. Because accurate understanding of the fracture pattern is essential for any preoperative plan, CT evaluation should be considered in high energy trauma patients. Another patient experienced superficial pin-site infec-



Figure 2. (A) Preoperative simple radiograph of a fifth metacarpal fracture in a 21-year-old man. (B) Postoperative C-arm images showed the acceptable reduction status of fracture. (C) Radiograph 3 days after surgery showing fixation failure. (D) Postoperative computed tomography scan images showing a hidden metacarpal head fracture pattern.

tion which was adequately treated with intravenous antibiotics. Statistical analysis did not identify any statistically significant risk factors for pin-site infection. No other complications were observed in this study. With early rehabilitation exercises, all patients returned to normal range of hand movement 6 weeks after surgery, and no patient complained of stiffness. Feedback from each patient during the operation under local anesthesia also allowed for confirmation that enough strength against physiological load was obtained and that the axis of the metacarpal was correct without muscle relaxation. Early rehabilitation and feedback under WALANT technique are considered important components of retrograde percutaneous intramedullary K-wire fixation.

Another notable aspect of this study was that all participants were Korean soldiers. This is a homogenous group of individuals as Korean soldiers consist of men with similar level of health and activity conscripted for long periods of time. This is expected to reduce confounding as many variables will be naturally controlled due to homogeneity of the study population. However, this may also be the reason for different findings from previous studies, raising the concern of generalizability of the results of this study to other populations.

This study is limited by its small sample size and retrospective design. Nevertheless, this study had certain strengths: the homogenous population enabled relatively low risk of confounding bias, and good patient compliance and long follow-up within the military hospital with standardized operative and postoperative management allowed for accurate recording and interpretation of results.

5. Conclusion

Our study demonstrated that fracture location and number of K-wires used can affect time to achieve bone union in metacarpal

fractures. The healing time of metacarpal shaft fracture were longer than those of metacarpal neck fractures, and more K-wires used led to longer healing times. Further biomechanical studies are necessary to characterize the properties of each fracture site and how it affects healing time.

Author contributions

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