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ARTICLE

Comparison of surgical outcomes between single versus dual K-wire fixation for unstable distal phalanx fractures

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ABSTRACT

Distal phalanx fractures are the most common injuries of the hand, and K-wire fixation is commonly performed for unstable fractures. However, there is no consensus regarding the number of K-wires to use in bone fixation. We aimed to compare the results between single and dual K-wire pinning. This retrospective study enrolled patients who underwent K-wire pinning for unstable distal phalanx fractures, including the shaft and tuft, from June 2016 through April 2020. We divided patients into two groups based on the number of K-wires used for bone fixation (single vs. dual). Clinical and radiographic data were measured and compared between the two groups. Additionally, multivariable logistic analysis was performed to identify the risk factors for nonunion. A total of 80 patients were enrolled. Among them, 27 were managed with a single K-wire and 53 with a dual K-wire. There was no significant difference in the union rate between the single and dual K-wire groups (77.7% vs. 84.9%, respectively), but time to union was significantly longer in the single K-wire group (11.3 vs. 8.4 weeks; $p = .003$). The presence of a bone gap after fixation was a risk factor for nonunion. Our study showed that the union rate was comparable between single and dual K-wire pinning in distal phalanx fractures. However, dual K-wire pinning shortened the union time.

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Introduction

Distal phalanx (DP) fractures are the most common hand fractures [1,2]. Closed and nondisplaced DP fractures are usually treated with conservative management including a period of protective splinting. For cases of DP fractures displaced or accompanied by soft tissue injury, surgical treatment is usually recommended [3–5].

Several studies have addressed surgical methods for DP fracture treatment, including K-wire fixation as well as techniques involving hypodermic needles and screws. Senesi et al. demonstrated satisfactory outcomes with a surgical technique using 23-gauge hypodermic needles for DP fracture treatment. They concluded that the technique could result in substantial cost savings and provide a safe alternative to K-wire fixation for selected patients [6]. Hay et al. reported the outcomes of cortical screw fixation for DP fractures and concluded that union incidence and time to union were comparable to K-wire fixation [7].

K-wire fixation is still the most frequently used method for DP fracture management. Nevertheless, few studies have specifically focused on K-wire fixation of DP fractures. Though Wang et al. reported that using two crossed K-wires afforded significantly more stability than a single K-wire in a biomechanical study, there have been no further clinical studies to confirm their outcomes [8]. The number of K-wires used for DP fractures appears to be mainly determined by the operator's preference or the fracture pattern, but it remains unclear how the number of K-wires affects clinical results.

We hypothesized that dual K-wire fixation affords more satisfactory surgical outcomes in terms of fracture union. Therefore, to determine whether the number of pins affects the results, we compared surgical outcomes, including union incidence, time to union, and range of motion (ROM), between single and dual K-wire fixation for patients with unstable DP fractures. Additionally, we investigated the risk factors for nonunion of DP fractures after K-wire fixation.

Materials and methods

Patient selection

This study was approved by our institutional review board (GNAH 2020-09-009). We retrospectively reviewed the medical records of patients who underwent K-wire fixation for DP fractures from 2016 June through 2020 April. One of our coauthors, an experienced hand surgeon (J.Y.B.), performed all surgical procedures.

Eligible patients were those with unstable DP fractures who underwent surgical fixation with K-wires. We excluded patients with DP fractures involving the joint surface, including those with bony mallet fingers; we also excluded patients with concomitant injuries in the same hand.

We divided our patients into two groups based on the number of K-wires used (Group A: single K-wire; Group B: dual K-wire).

Clinical data

Clinical data included demographic characteristics, injury laterality, injury type (opened or closed fracture), range of motion (ROM), and complications. Patients were meticulously assessed for any complications, including fingertip pain, deformity, and instability,

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during postoperative outpatient clinical assessments. The range of motion of the distal interphalangeal (DIP) joint was measured using a goniometer at the final outpatient follow-up assessment. We also investigated the history of diabetes mellitus and smoking status.

Radiographic data

Radiographic data included fracture type (simple or comminuted), fracture location (tuft or mid-shaft or proximal metaphysis), number of K-wires, bone gap size after K-wire fixation, DIP joint involvement of the K-wires (transarticular or non-transarticular), and radiographic union. The mean time to union was calculated after excluding patients with nonunion. The bone gap after K-wire fixation was measured in 0.1 mm increments using immediate post-operative posteroanterior (PA) and lateral finger plain radiographs. Two orthopedic surgeons (S.W.C, J.Y.B) independently measured the fracture gap of each radiograph at maximum magnification (258%) using a picture archiving and communication system (PACS) program (New Version 2.0, Asan Medical Center, Seoul, Korea). If the results of the two observers did not match, a consensus was reached by collaborative remeasurement.

Radiographs in the PA and lateral views were taken at each outpatient visit after surgery (2, 4, 6, 8, 12, and 16 weeks after surgery) to verify bone union. Bone union was defined as restoration of the continuity of the fractured fragment with the bridging callus [9]. Radiological nonunion was defined as no sign of bone healing for a minimum of 4 months after surgery [7,10,11].

Operative technique

All procedures were performed in an operating room under local, regional, or general anesthesia with the patient in the supine position.

Displaced fragments were reduced under fluoroscopy and stabilized using a single 1.0 mm K-wire or dual 0.8 mm K-wire (Figures 1 and 2). Each K-wire was inserted until the tip of the K-wire just reached the subchondral bone of the DIP joint. However, if the proximal bone fragment was insufficient because of fracture location (Figure 3), or if the fracture was unstable because of severe soft tissue injuries, the K-wire was extended to the middle phalanx across the DIP joint for additional stability. To allow for easy removal in the outpatient clinic, the K-wires were not buried underneath the skin.

K-wires were removed at outpatient clinic visits 4 to 6 weeks after surgery depending on the patient's radiographic union status. For patients without visible bridging callus, the K-wires were left in place until 8 postoperative weeks.

For patients with non-transarticular K-wires, we applied a finger splint immediately after surgery for 4 weeks, after which the splint was replaced by a removable splint for another 4 weeks. ROM exercises were started at the time of finger splint removal at 4 postoperative weeks. For patients with transarticular pinning, ROM exercises were initiated after the transarticular pins were removed. Heavy labor and sporting activities were allowed 3 months after surgery except for among patients with a delayed union, which was defined as union later than 3 months after surgery.

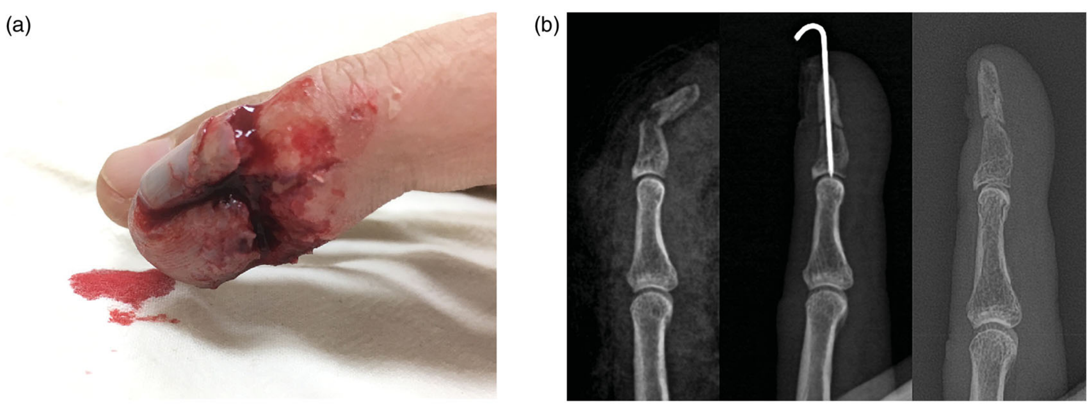

Figure 1. A 50-year-old man who had an unstable distal phalangeal fracture of the left fifth finger treated with single K-wire fixation. (a) Clinical image and (b) radiographs taken preoperatively, postoperatively, and after pin removal.

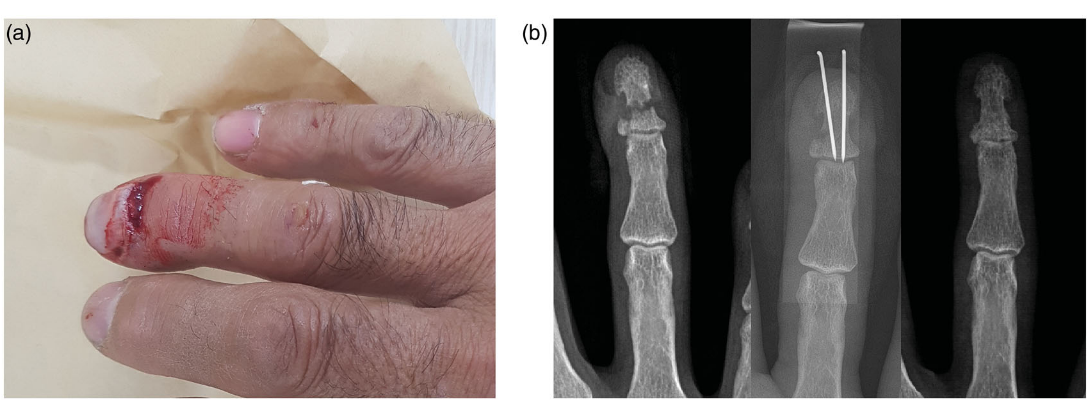

Figure 2. A 67-year-old man who had an unstable distal phalangeal fracture of the right fourth finger treated with dual K-wire fixation. (a) Clinical image and (b) radiographs taken preoperatively, postoperatively, and after pin removal.

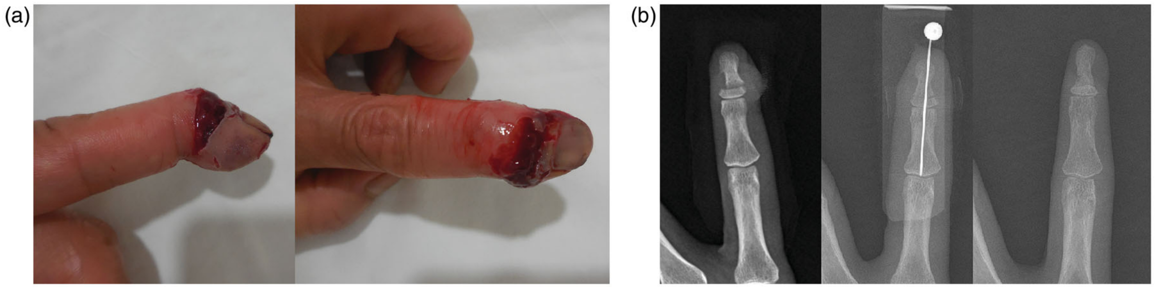

Figure 3. A 63-year-old woman who had a basal distal phalangeal fracture of the left second finger treated with transarticular single K-wire fixation. (a) Clinical image and (b) radiographs taken preoperatively, postoperatively, and after pin removal.

Statistical analysis

We used the Shapiro-Wilk test to determine the normality of distributions among data within a given variable. Clinical data and radiographic data were compared between Group A and B using Student's *t*-test and the chi-square test. Additionally, ROM was compared between patients with transarticular and non-transarticular pinning. A multivariable logistic analysis, including age, sex, injury type, fracture type, fracture location, gap after fixation, number of K-wires, and joint involvement by pinning, was performed to identify the risk factors for the nonunion of DP fractures (binary logistic regression with the forward conditional method). Statistical significance was declared when *p*-values were $<.05$. All the statistical analyses were performed using SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY, USA).

Results

Clinical data

From 2016 June through 2020 April, 663 patients visited our emergency department with a diagnosis of DP fracture. Of these, 510 patients were treated conservatively, and 153 patients underwent surgery, of whom 33 were excluded because they had fractures extending into the DIP joint, and 40 were excluded because they had concomitant ipsilateral hand injuries. Finally, 80 patients were involved in this study. Of these, 36 patients were current smokers or being treated for diabetes mellitus. Twenty-seven patients were treated with single K-wires (Group A), and 53 patients were treated with dual K-wires (Group B). The mean follow-up period was 8.5 months (range, 4 to 26).

There were no significant differences between the two groups in terms of the clinical data and demographic data (Table 1).

Table 1. Clinical data of Group A and B.

	Group A	Group B	*p*-value
Number of patients	27	53	
Male (%)	74.1	79.2	.600
Mean age (years)	53.74	50.64	.367
Right hand (%)	59.3	62.3	.794
Finger			.201
1	3	12	
2	5	7	
3	6	15	
4	8	14	
5	5	5	
Injury type (open, %)	77.8	67.9	.357

Radiographic data: union incidence and time to union

Table 2 shows intergroup comparisons of radiographic data, including fracture characteristics.

The mean time to union was significantly longer in Group A than in Group B ($p = 0.003$). In Group A, the mean time to union was 11.3 weeks (range, 6 to 22), and six patients (22.2%) had DP fracture nonunion. In Group B, the mean time to union was 8.4 weeks (range, 4 to 20), and nonunion of DP fractures occurred in seven patients (13.2%). The overall nonunion incidence was 16.2%. There was no significant difference between smoker/diabetic patients and the remaining patients in terms of bone healing ($p = .148$ and $p = .976$, respectively, for time to union and union incidence).

Table 2. Radiographic data of Group A and B.

	Group A	Group B	*p*-value
Fracture type (%)			.388
Simple (transverse or oblique)	63.0	52.8	
Comminuted	37.0	47.2	
Fracture location (%)			.284
Tuft	48.1	30.2	
Mid-shaft	29.6	41.5	
Proximal metaphysis	22.2	28.3	
Transarticular pinning (%)	7 (25.9)	8 (15.1)	.241
Bone gap after fixation (mm)	0.3	0.25	.208
Time to union (weeks)	11.30	8.42	.003*
Union incidence (%)	21 (77.7)	45 (84.9)	.169

*$p < .05$.

Range of motion

Overall, the mean ROM of the DIP joint at the final follow-up was 53°. Between Group A and B, there was no significant difference in the mean ROM (Table 3). However, among patients treated with transarticular pinning, the mean ROM was 45°, which was significantly different from the mean ROM among patients treated with non-transarticular pinning ($p = .029$).

Risk factor for nonunion

Among the variables, including age, sex, injury type, fracture type, fracture location, number of K-wires, and joint involvement, a larger bone gap after K-wire fixation was found to be a significant risk factor for nonunion of DP fractures (OR, 18.11; 95% CI, 3.58-91.67; $p < .001$).

Among patients who had DP fracture nonunion, the mean gap size was 0.71 mm (range, 0.2 to 1.8 mm) after K-wire fixation, while patients with united DP fractures had a mean gap size of 0.2 mm (range, 0 to 1.0 mm, $p = .002$).

Table 3. Mean range of motion for Group A and B, and for patients who underwent transarticular and non-transarticular fixation.

	Group A	Group B	*p*-value
ROM (°)	54	53	.784
	Transarticular	Non-transarticular	
ROM (°)	45	55	.029*

ROM: range of motion.
*$p < 0.05$.

Complications

One patient in Group B developed osteomyelitis caused by methicillin-resistant *Staphylococcus aureus* in a DP fracture fragment after 3 postoperative months; this patient underwent diffuse debridement, including excision of the bone fragment. This patient was excluded from the analysis of union incidence and time to union.

All patients with united distal phalanges had stable, pain-free fingers without any complications.

Discussion

This study revealed that dual K-wire fixation of unstable DP fractures was associated with a faster bony union time than single K-wire fixation. Additionally, a larger bone gap after K-wire fixation was a risk factor for DP fractures nonunion.

To our knowledge, the number of K wire used in distal phalanx fracture generally depends on surgeon's preference, because there had been very few research for the issue. In our clinic, the choice was mainly depends on the comminution of injured finger. As shown in Table 2, there were more simple fractures in the single K-wire group (63.0 vs 52.8%, $p = .388$). Another important factor was the size of bone fragment. Because of size constraints of small finger, proportion of small finger was higher in the single K-wire group (18.5 vs 9.5%, $p = .201$, shown in Table 1). When a single K-wire fixation was performed, it is important to take several PA, lateral, and oblique views to ensure that the fracture is synthesized well without a gap. And it is also important to insert a K wire perpendicular to the fracture line as much as possible. After fixation, soft tissue injury was managed appropriately and the fingernail was repositioned to provide additional external stability.

Several studies focusing on DP fractures nonunion have found that the stability of fixation is a critical factor in the treatment of such fractures [12–14]. However, few studies have specifically addressed the stability of fixation of acute DP fractures. When unstable DP fractures occur, single K-wire fixation is usually performed because of constraints associated with fragment size [1,4]. For unstable fractures with soft tissue damage, including nail bed injuries, a single K-wire may not provide sufficient stability. Wang et al. performed a biomechanical study investigating the effects of K-wire fixation on comminuted DP fractures of amputated finger stumps and concluded that fixation using two crossed K-wires can provide significantly more stability than fixation using a single K-wire [8]. Regardless of the state of the nail, the mean peak bending and torsion forces were significantly larger among the group treated with two K-wires than among the group treated with a single K-wire. Our study findings strongly support the results of Wang's research. In our study, single K-wire fixation significantly delayed the union time (11.3 vs. 8.4 weeks, $p = .003$), and it was associated with a higher nonunion incidence, although the difference between single and dual K-wire fixation was not statistically significant (22.2 vs. 13.2%, $p = .169$).

One of the most common complications after the treatment of DP fractures is DIP joint stiffness. In this study, the mean ROM of the DIP joint at the final follow-up was 53°. Hay et al. reported a mean DIP joint ROM of 45° among 12 patients who underwent K-wire fixation and a mean DIP joint ROM of 60° among 21 patients who underwent screw fixation; 4 of the 12 patients who were treated with K-wires underwent transarticular pinning [7]. The small number of patients who underwent K-wire fixation precluded robust analysis and the drawing of definitive conclusions regarding this specific outcome, however. Senesi et al. reported only a 40° mean DIP joint ROM among 28 patients treated with crossed K-wires and a mean ROM of 60° among 32 patients treated with 23 G needles [6]. In their study, transarticular pinning was performed for articular DP fractures; however, they did not specify how many patients underwent transarticular pinning. According to our findings, transarticular pinning significantly affected the final ROM of the DIP joint. Soft tissue injury can also affect the ROM. Duncan et al. reported that a reduction of total active finger ROM correlated with the severity of soft tissue damage [15]. Furthermore, patient compliance and cooperation with protocols is imperative for achieving optimal results [4,16]. We believe that enthusiastic education and encouragement provided by surgeons to patients is a key factor that improves patient cooperation.

There are several published reports of studies investigating the nonunion of phalangeal fractures. In 1988, DaCruz et al. performed a prospective study of 110 consecutive patients with DP fractures managed conservatively [17]. They found that over half of the patients had DP fracture nonunion after 6 months, and these were associated with a variety of problems significantly affecting daily life. Van Oosterom et al. performed a retrospective study of 666 phalangeal fractures treated operatively [18]. They reported that 6% of phalangeal fracture operations were associated with postoperative nonunion; infection, segmental bone loss, and vascular injury were the risk factors for nonunion. In another study, technical problems, such as inadequate fixation of phalangeal fractures, were reported as the major factors causing nonunion after internal fixation surgery [19]. However, the subjects of those studies were not limited to DP fracture patients treated with K-wire fixation. Our study found a nonunion incidence of 16% after K-wire fixation of unstable DP fractures; we also observed that a larger bone gap after fixation was associated with nonunion. Because K-wires do not provide compression to fracture sites, surgeons should try not to complete the fixation in a distracted position. If there is an irreducible gap between bones after K-wire pinning, other surgical methods, such as screw fixation, may lead to more favorable outcomes.

There were some limitations in our study. First, this was a retrospective study involving a small number of patients at a single center. Second, the follow-up period was short, because many patients had achieved union within 4 postoperative months, and their symptoms had resolved by that time. Finally, this study only involved the surgical technique with K-wire, so there is a lack of comparison with other surgical methods including the hypodermic needle technique. Performing simple surgery using a hypodermic needle in an emergency room with a surgical setup may reduce the healthcare cost comparing with hospitalization [6]. In the future, additional studies with larger patient samples will be needed to evaluate the surgical outcomes including cost savings among the various surgical techniques.

For unstable DP fractures without joint extension, dual K-wire pinning achieved bony union significantly faster than single K-wire pinning. Inadequate fracture fixation in a distracted position was associated with nonunion.

Ethical statement

This study was approved by the institutional review board of the Gangneung Asan Hospital (project no.: 2020-09-009).

Informed consent

Written informed consent was obtained from the patients for their anonymized information to be published in this article.

Author contributions

Shin Woo Choi: Study design, data analysis and writing.

Joo-Yul Bae: Acquisition of data and critical revision.

Sang Young Kim and Jin Kyung Kim: Data collection and analysis.

Jae-Seok Song: Study design, editing paper, and final approval.

Disclosure statement

The authors declared no potential conflicts of interest with respect to the research, authorship, or publication of this article.

References

[1] Carpenter S, Rohde RS. Treatment of phalangeal fractures. Hand Clin. 2013;29(4):519–534.
[2] Yoong P, Goodwin RW, Chojnowski A. Phalangeal fractures of the hand. Clin Radiol. 2010;65(10):773–780.
[3] Prunieres G, Gouzou S, Facca S, et al. Treatment of unstable distal phalanx fractures by extra-articular DIP pinning: a series of 12 cases. Hand Surg Rehabil. 2016;35(5):330–334.
[4] Gregory S, Lalonde DH, Fung Leung LT. Minimally invasive finger fracture management: wide-awake closed reduction, K-wire fixation, and early protected movement. Hand Clin. 2014;30(1):7–15.
[5] Chen F, Schneider LH. Fractures of the distal phalanx. Operat Tech Orthopaed. 1997;7(2):107–115.
[6] Senesi L, Marchesini A, Pangrazi PP, et al. K-wire fixation vs 23-gauge percutaneous hand- crossed hypodermic needle for the treatment of distal phalangeal fractures. BMC Musculoskelet Disord. 2020;21(1):590
[7] Hay RA, Tay SC. A comparison of K-wire versus screw fixation on the outcomes of distal phalanx fractures. J Hand Surg Am. 2015;40(11):2160–2167.
[8] Wang W, Yu J, Fan CY, et al. Stability of the distal phalanx fracture – a biomechanical study on the importance of the nail and the influence of fixation by crossing Kirschner wires. Clin Biomech (Bristol, Avon)). 2016;37:137–140.
[9] Fisher JS, Kazam JJ, Fufa D, et al. Radiologic evaluation of fracture healing. Skeletal Radiol. 2019;48(3):349–361.
[10] Jupiter JB, Koniuch MP, Smith RJ. The management of delayed union and nonunion of the metacarpals and phalanges. J Hand Surg Am. 1985;10(4):457–466.
[11] Ozçelik IB, Kabakas F, Mersa B, et al. Treatment of nonunions of the distal phalanx with olecranon bone graft. J Hand Surg Eur Vol. 2009;34(5):638–642.
[12] Chim H, Teoh LC, Yong FC. Open reduction and interfragmentary screw fixation for symptomatic nonunion of distal phalangeal fractures. J Hand Surg Eur Vol. 2008;33(1):71–76.
[13] Kim J, Ki SH, Cho Y. Correction of distal phalangeal nonunion using peg bone graft. J Hand Surg Am. 2014;39(2):249–255.
[14] Meijs CM, Verhofstad MH. Symptomatic nonunion of a distal phalanx fracture: treatment with a percutaneous compression screw. J Hand Surg Am. 2009;34(6):1127–1129.
[15] Duncan RW, Freeland AE, Jabaley ME, et al. Open hand fractures: an analysis of the recovery of active motion and of complications. J Hand Surg Am. 1993;18(3):387–394.
[16] Cannon NM. Rehabilitation approaches for distal and middle phalanx fractures of the hand. J Hand Ther. 2003;16(2):105–116.
[17] DaCruz DJ, Slade RJ, Malone W. Fractures of the distal phalanges. J Hand Surg Br. 1988;13(3):350–352.
[18] Van Oosterom FJ, Brete GJ, Ozdemir C, et al. Treatment of phalangeal fractures in severely injured hands. J Hand Surg Br. 2001;26(2):108–111.
[19] Ring D. Malunion and nonunion of the metacarpals and phalanges. Instr Course Lect. 2006;55:121–128.