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Kirschner Wire Migration and Complete Dislodgement After Locked Versus Nonlocked Percutaneous Fixation for Hand and Distal Forearm Fractures: A Retrospective Observational Cohort Study

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Background: Percutaneous K-wire fixation is commonly used for hand and distal forearm fractures, often with adjunctive splint immobilization. A locking technique that links the exposed proximal ends of adjacent K-wires may provide an alternative fixation strategy without postoperative splinting. However, comparative clinical evidence regarding K-wire migration and complete dislodgement remains limited.

Purpose: To compare Kirschner wire (K-wire) migration and complete dislodgement between locked fixation without splinting and nonlocked fixation with splinting for hand and distal forearm fractures.

Methods: This retrospective cohort study included 99 patients treated between January 2017 and April 2025 (locked, n=45; nonlocked, n=54). Outcomes included migration, complete dislodgement, and pin tract infection. Crude risk ratios (RRs) and adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were calculated. Firth's penalized logistic regression adjusted for age, sex, fracture site, and injury mechanism.

Results: In the locked and nonlocked groups, respectively, migration occurred in 1 (2.2%) and 21 (38.9%) patients (RR, 0.057; 95% CI, 0.008–0.408; p<0.001), and complete dislodgement occurred in 1 (2.2%) and 16 (29.6%) patients (RR, 0.075; 95% CI, 0.010–0.544; p<0.001). Adjusted odds were lower for migration (aOR, 0.064; 95% CI, 0.011–0.384; p=0.003) and complete dislodgement (aOR, 0.080; 95% CI, 0.011–0.561; p=0.011). Infections occurred in 1 (2.2%) and 10 (18.5%) patients, respectively (RR, 0.120; 95% CI, 0.016–0.902; p=0.011); the adjusted association was imprecise and nonsignificant (aOR, 0.165; 95% CI, 0.024–1.125; p=0.066).

Conclusions: Locked fixation without splinting was associated with lower adjusted odds of migration and complete dislodgement than nonlocked fixation with splinting. Because fixation strategy, splint use, and treatment period were linked, these associations cannot be attributed to locking alone.

Keywords: K-wire, locked K-wire, hand fracture, distal forearm fracture, K-wire migration, K-wire dislodgement

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Hand fractures account for approximately 20% of all fractures, with a global incidence of 179 per 100,000 population. They are more common in males than in females. The highest incidence of hand fractures occurs in individuals aged 15–40 and 70–80 years[1]. The reported overall incidence of adult distal forearm fractures was 207.7 per 100,000

population per year, with incidences of 323.4 and 93.3 per 100,000 population per year in females and males, respectively. A marked increase in the incidence with increasing age was observed in women older than 50 years. The incidences of distal radius fractures and isolated ulnar fractures were 203.0 and 3.8 per 100,000 population per year, respectively. The most common fracture type was extra-articular AO type 2R3A (69%), and the most common mechanism of injury was a fall from standing height (76%)[2].

According to the medical records at Sakon Nakhon Hospital, 5,533 patients with hand and wrist fractures underwent surgery between 2017 and 2025. Treatment options include conservative management and surgical fixation, depending on fracture characteristics and patient factors. Conservative treatment may include fracture reduction followed by cast immobilization[3].

Fixation options include percutaneous Kirschner wires (K-wires) and metal plates. For selected distal radius fractures, plate fixation may provide earlier functional recovery than percutaneous K-wire fixation[4,5]. However, plate fixation generally requires a more invasive surgical approach. K-wires are versatile, easy to use, inexpensive, easily removed, less invasive, and relatively quick to apply[6,7,10]. The disadvantages and complications of percutaneous K-wire fixation include pin tract infection, wire loosening, migration, accidental dislodgement, loss of reduction, and, less commonly, nonunion or osteomyelitis[8,9]. To minimize these complications, adjunctive splint immobilization is commonly used to provide external protection after percutaneous K-wire fixation. However, prolonged immobilization may contribute to joint stiffness and the need for subsequent rehabilitation[17-21]. Therefore, several techniques have been described to link the exposed K-wire ends into a unified construct. These approaches include the use of locked-wire fixators, metal clamps, and cemented K-wire frames. Biomechanical and small clinical studies suggest that linked K-wire constructs may improve resistance to wire loosening or migration; however, clinical evidence remains limited[12-15].

At Sakon Nakhon Hospital, specialized K-wire locking devices were not routinely available. Therefore, we developed a technique using readily available materials in which the exposed proximal ends of adjacent K-wires are bent, interlocked, and wrapped with an elastic adhesive bandage to create a linked construct after fracture reduction and percutaneous fixation.

This study aimed to compare the incidence of K-wire migration and complete dislodgement between patients treated with locked K-wire fixation without splinting and those treated with conventional nonlocked K-wire fixation with splinting for hand and distal forearm fractures. Pin tract infection was evaluated as a clinical outcome.

METHODS

This retrospective comparative cohort study included patients who underwent percutaneous K-wire fixation for hand and distal forearm fractures at Sakon Nakhon Hospital from January 2017 to April 2025. The conventional nonlocked K-wire technique with splint immobilization was used from January 2017 to October 2019, whereas the locked K-wire technique without splint immobilization was used from October 2019 to April 2025. Medical records and radiographs were reviewed from initial treatment through K-wire removal and completion of treatment. All procedures were performed by the same surgeon.

Inclusion Criteria

Patients were eligible if they had extra-articular or simple articular fractures of the hand, distal ulna, or distal radius, classified according to the AO Foundation and Orthopedic Trauma Association (AO/OTA) classification; underwent percutaneous K-wire fixation; had complete preoperative and postoperative radiographs; had a minimum follow-up period of 6 weeks; and had sufficient medical records for analysis. The AO/OTA fracture classifications were recorded for each patient, and their distributions were compared between the locked and nonlocked groups.

Exclusion Criteria

Patients with Gustilo type II or higher open fractures or pathological fractures; open wounds or active infection at the planned K-wire insertion site; preoperative neurovascular compromise; incomplete medical records or loss to follow-up before 6 weeks; combined fixation methods (e.g., K-wires with a plate or external fixator) in the same affected bone; or clothing-related accidental partial K-wire pullout during postoperative follow-up were excluded.

Sample Size

No a priori sample size calculation was performed because of the retrospective nature of the study. This study included patients who met the eligibility criteria during the study period. A total of 114 patients were initially identified, with 45 and 69 patients in the locked and nonlocked groups, respectively. Fifteen patients in the nonlocked group experienced clothing-related partial K-wire pullout approximately 2 weeks postoperatively. These patients were excluded from the primary analysis because the events were initially considered to be externally induced rather than spontaneous fixation failures. After applying the original eligibility criteria, the final analytical cohort comprised 99 patients, with 45 and 54 in the locked and nonlocked groups.

Patients were divided into either the locked K-wire group or the conventional nonlocked group according to the fixation strategy used during the respective treatment period, rather than through randomization. The nonlocked group (nonlocked K-wire fixation with splinting) was treated from January 2017 to October 2019, followed by the locked group (locked K-wire fixation without splinting) from October 2019 to April 2025.

Prophylactic antibiotics were administered to all patients: adults received 1 g of intravenous cefazolin preoperatively, whereas pediatric patients received 30 mg/kg of intravenous cefazolin preoperatively. This was followed by a 5-day course of oral dicloxacillin with the dose prescribed according to age and body weight. The same antibiotic regimen was used in both treatment groups as part of routine clinical practice and was not specific to the fixation strategy.

Postoperative anteroposterior and lateral radiographs were obtained for reference and comparison. Serial postoperative radiographs were reviewed by the operating surgeon, who was also an investigator in this study. K-wire migration and complete dislodgement were assessed by comparison with the immediate postoperative radiographs, according to the study outcome definitions. Because the fixation construct was identifiable on the radiographs, the reviewer was not blinded to the treatment group. No independent radiographic adjudication was performed. Follow-up appointments and radiography were scheduled at 2, 4, and 6 weeks. The follow-up dates varied by several days, according to routine outpatient scheduling. K-wire removal was typically performed as part of routine clinical practice, with a mean time to removal of 4±1 weeks for hand fractures and 6±1 weeks for distal radius and ulnar fractures.

The baseline data collected included age, sex, fracture location, and cause of fracture. The clinical outcomes included K-wire migration, complete K-wire dislodgement, and pin tract infection. K-wire migration was defined as any change in wire position relative to the immediate postoperative radiograph, including proximal backing out or distal progression into the bone or soft tissue without complete loss of fixation. Complete K-wire dislodgement was defined as total extrusion of the K-wire from its original placement within both the bone and soft tissue. Pin tract infection was defined clinically as the presence of inflammation or swelling of the skin and/or serous or purulent discharge around the K-wire insertion site. Pin sites were assessed clinically by the treating surgeon at each scheduled follow-up visit. When patients reported that discharge had been present before the visit, the diagnosis was recorded during the visit when the treating surgeon clinically confirmed the infection. Patients diagnosed with a pin tract infection were treated with oral dicloxacillin and reassessed after approximately 1 week. The K-wires were retained if the fracture union was considered insufficient for removal. If radiographic union was considered adequate when infection was identified, the K-

wires were removed, and oral antibiotic treatment was initiated, with wound reassessment approximately 1 week later. For descriptive analysis, each patient with complications was classified into a mutually exclusive category: K-wire migration only, complete K-wire dislodgement only, K-wire migration with pin tract infection, pin tract infection only, or complete K-wire dislodgement with pin tract infection. Patients with more than one complication component were counted once in the corresponding combined categories. For the analyses of individual clinical outcomes, any K-wire migration, any complete K-wire dislodgement, and any pin tract infection were analyzed separately; therefore, a patient with more than one complication could contribute to more than one individual clinical outcome.

All statistical analyses were performed using Stata version 19.5 (StataCorp LLC, College Station, TX, USA). Continuous variables were summarized as means and standard deviations and compared between groups using independent-samples t-tests. Categorical variables were summarized as frequencies and percentages and compared using Pearson's chi-square test or two-sided Fisher's exact test, as appropriate. Crude associations between fixation strategy and clinical outcomes were expressed as risk ratios (RRs) with 95% confidence intervals (CIs). Because of sparse outcome events and small cell counts, adjusted associations were estimated using Firth's penalized logistic regression to reduce small-sample and separation-related bias. Separate models were fitted for K-wire migration, complete K-wire dislodgement, and pin tract infection. Each model included the fixation strategy as the exposure of interest and was adjusted for age as a continuous variable, sex, fracture site, and mechanism of injury. Adjusted odds ratios (aORs) with 95% CIs were reported. These covariates were selected a priori based on their clinical relevance and the potential for baseline case-mix differences between treatment groups, rather than solely on statistical significance in univariable analyses. Calendar period was not included as a separate covariate because the fixation strategy was completely determined by the treatment period in the analyzed cohort, precluding the estimation of an independent calendar period effect. Any complication was additionally evaluated as a secondary composite outcome. Age-stratified analyses were additionally performed for pediatric (<18 years) and adult (≥18 years) patients. Because of the small sample size and sparse outcome events within the strata, these analyses were considered exploratory and were performed using two-sided Fisher's exact tests without multivariable adjustment. A sensitivity analysis was performed by including the 15 patients with clothing-related partial K-wire pullout in the original cohort. These events were classified as K-wire migration rather than complete dislodgement, consistent with the predefined outcome definitions. Because individual-level baseline characteristics were unavailable for these patients, the sensitivity analysis was restricted to crude comparisons of event proportions and RRs with 95% CIs. Two-sided Fisher's exact tests were used to compare event rates between the treatment groups. A two-sided p-value <0.05 was considered statistically significant.

The research protocol was approved by the Institutional Review Board (IRB)/Human Research Ethics Committee of Sakon Nakhon Hospital (no. 062/2568).

K-Wire Locking Technique

Two-Wire K-wire Locking Method

After the induction of anesthesia, the surgical site was prepared with chlorhexidine and Betadine solutions following standard sterile protocols. Fracture reduction was achieved under fluoroscopic guidance, followed by percutaneous fixation using K-wires. The wire diameter was selected based on the fracture site: 1.2 mm for hand fractures and either 1.4 or 1.6 mm for distal radius fractures.

The fixation construct used two K-wires inserted obliquely to cross the fracture site, ensuring that the tips engaged the opposite cortex. After insertion, the wires were bent perpendicular to the skin. At a distance of 2–3 cm from the skin exit site, the wires were bent toward each other using a needle holder or pliers until their proximal ends were parallel and adjacent.

The locking mechanism was performed sequentially as follows: the first K-wire was wrapped tightly around the shaft of the second wire, followed by the second wire being wrapped tightly around the shaft of the first wire. Excess wire was trimmed. To reinforce the construct and protect the skin from sharp edges, two layers of a 1-inch (2.54 cm) elastic adhesive bandage (Nexcare Coban; 3M, St Paul, MN, USA) were applied around the locked junction. In the nonlocked group, K-wires were bent and trimmed conventionally, followed by immobilization in a supportive short-arm slab (Figure 1).

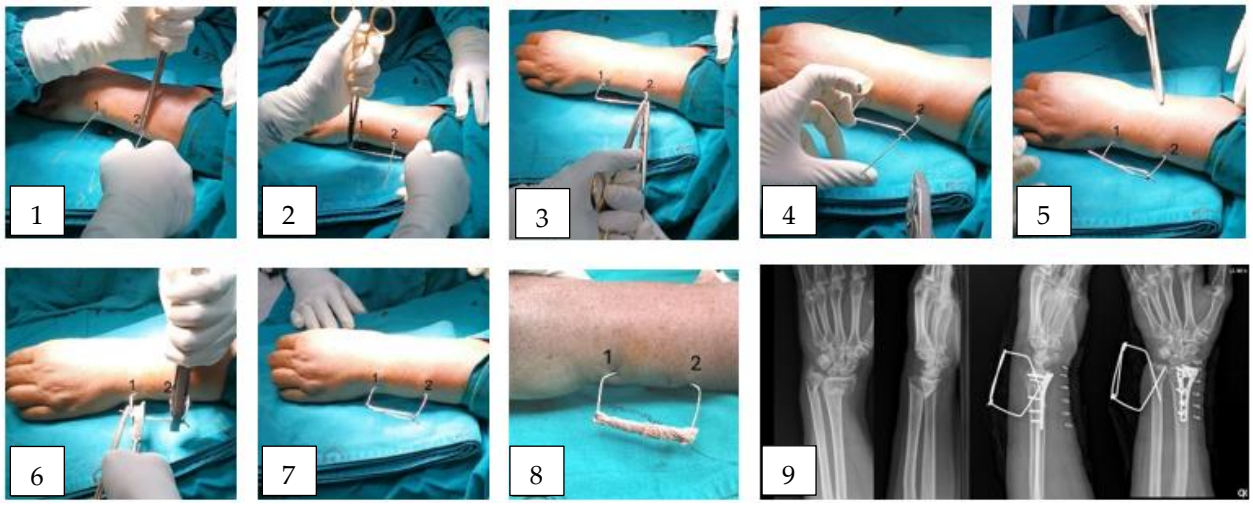


Fig. 1 **Locking technique for two Kirschner wires (K-wires).** (1) Bend both K-wires perpendicular to the skin using a needle holder or pliers. (2) Bend the first K-wire toward the second K-wire. (3) Securely wrap the end of the first K-wire around the shaft of the second K-wire. (4) Firmly grasp the interlocking junction with pliers to ensure stable fixation. (5) Bend the second K-wire toward the first K-wire. (6) Securely wrap the end of the second K-wire around the shaft of the first K-wire. (7) Trim the excess ends of both wires. (8) Apply an elastic adhesive bandage over the K-wires to reinforce the fixation and cover any sharp edges. (9) Postoperative radiographs.

Three-Wire K-wire Locking Method

For distal radius fracture fixation, three 1.6-mm K-wires were used. The first K-wire was driven obliquely through the radial styloid process to cross the fracture line. The second wire was inserted adjacent to the first and aimed toward the midpoint between the first and third wires. The third wire was placed lateral to Lister's tubercle, with a dorsal-to-volar penetration depth not exceeding 5 mm.

Following insertion, all the wires were bent perpendicular to the skin. At a distance of 2–3 cm from the skin exit site, the wires were bent toward one another using small pliers until their proximal ends were parallel and adjacent. The locking sequence was performed as follows: the proximal end of the first K-wire was wrapped securely around the shaft of the second K-wire. Subsequently, the third K-wire was wrapped around the shaft of the second wire, and the end of the second K-wire was wrapped around the shaft of the third K-wire. The excess wire ends were trimmed, and the interlocking construct was wrapped with an elastic adhesive bandage to provide reinforcement and cover the sharp edges. The sequence of wire locking may be modified according to the surgeon's preference (Figure 2).

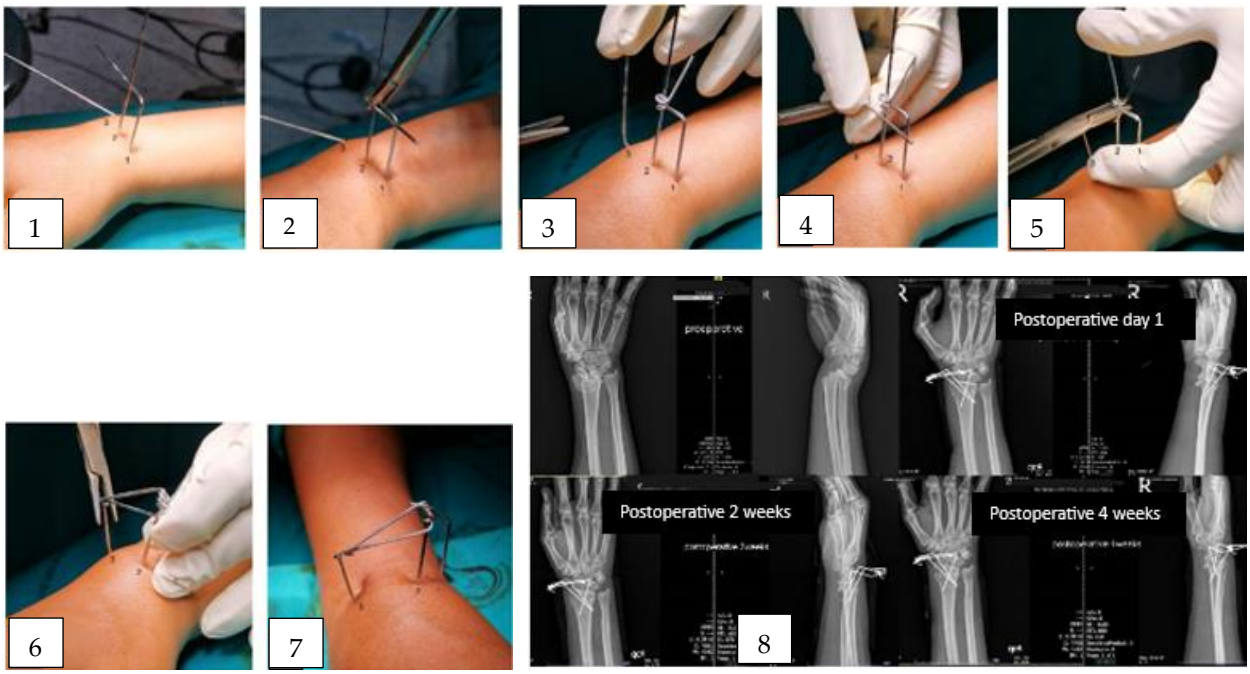


Fig. 2 Locking technique for three Kirschner wires (K-wires). (1) Bend all K-wires perpendicular to the skin using pliers. Subsequently, bend the first K-wire toward the second wire. (2) While holding the wires close together with pliers, wrap the first K-wire securely around the shaft of the second wire. (3) Ensure the third K-wire is bent perpendicular to the skin and directed toward the second K-wire. (4) Wrap the third K-wire tightly around the shaft of the second K-wire. (5) Stabilize the construct with pliers, then bend the second K-wire toward the third K-wire. (6) Securely wrap the second K-wire around the shaft of the third K-wire to complete the interlocking mechanism. (7) Trim any excess wire and apply an elastic adhesive bandage over the K-wires to reinforce the fixation and cover any sharp edges. (8) Representative radiographs for an AO Foundation and Orthopaedic Trauma Association 23-A3 fracture.

RESULTS

The study included 99 patients: 45 in the locked group and 54 in the nonlocked group. There were no statistically significant differences in mean age (37.40±19.68 vs. 35.02±20.80 years; p=0.562), age-group distribution (p=0.564), or affected side (p=0.607). However, the mechanism of injury differed significantly between the groups (p=0.035), with traffic accidents being the most common mechanism (55.6%) in the locked group and accounting for 33.3% of the injuries in the nonlocked group. A significant difference was observed in sex distribution (p=0.017), with a higher proportion of males in the nonlocked group than in the locked group (83.3% vs. 62.2%) (Table 1).

Fracture-site distributions differed significantly between the groups (p=0.004; Table 1). The most common fracture site in the locked group was the metacarpal bone (n=18; 40.0%), followed by the proximal phalanx (n=12; 26.7%). Compared with the locked group, the nonlocked group had higher proportions of distal phalanx fractures (n=16; 29.6%) and distal forearm fractures (n=17; 31.5%). The distribution of the AO/OTA fracture classifications by treatment group is presented in Table 2. No statistically significant overall difference in the AO/OTA classification was observed between the locked and nonlocked groups (Fisher's exact test, p=0.176).

Table 1 Baseline demographic and clinical characteristics of patients by treatment group (n=99).

Characteristic	Locked (n=45)	Nonlocked (n=54)	p-Value
Age (years)	37.40±19.68	35.02±20.80	0.562
Age group			0.564
Pediatric (<18 years)	11 (24.4)	16 (29.6)	
Adult (≥18 years)	34 (75.6)	38 (70.4)	
Sex			0.017
Male	28 (62.2)	45 (83.3)	
Female	17 (37.8)	9 (16.7)	
Affected side			0.607
Left	21 (46.7)	28 (51.9)	
Right	24 (53.3)	26 (48.1)	
Mechanism of injury			0.035
Traffic accident	25 (55.6)	18 (33.3)	
Fall	10 (22.2)	8 (14.8)	
Crush/entrapment injury	4 (8.9)	15 (27.8)	
Sharp/cutting injury	3 (6.7)	9 (16.7)	
Blunt/impact injury	3 (6.7)	4 (7.4)	
Fracture site			0.004
Distal forearm	10 (22.2)	17 (31.5)	
Distal phalanx	4 (8.9)	16 (29.6)	
Metacarpal bone	18 (40.0)	9 (16.7)	
Middle phalanx	1 (2.2)	5 (9.3)	
Proximal phalanx	12 (26.7)	7 (13.0)	

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

Age was compared using the independent-samples t-test. Sex, age group, and affected side were compared using Pearson's chi-square test. Injury mechanism and fracture site were compared using Fisher's exact test because of small cell counts. A two-sided p-value <0.05 was considered statistically significant.

Table 2 Distribution of AO/OTA fracture classification by treatment group (n=99).

AO/OTA classification	Locked (n=45)	Nonlocked (n=54)
23-A1	1 (2.2)	1 (1.9)
23-A2	6 (13.3)	12 (22.2)
23-A3	2 (4.4)	3 (5.6)
23-B1	1 (2.2)	1 (1.9)
77.1.1A	1 (2.2)	0 (0.0)
77.1.1B	3 (6.7)	0 (0.0)
77.1.2A	1 (2.2)	2 (3.7)
77.2-5.1A	1 (2.2)	0 (0.0)
77.2-5.2A	12 (26.7)	7 (13.0)
78.1.1.1A	0 (0.0)	1 (1.9)
78.1.2A	1 (2.2)	0 (0.0)
78.2-5.1.1A	0 (0.0)	2 (3.7)
78.2-5.1.2A	7 (15.6)	2 (3.7)
78.2-5.1.2B	1 (2.2)	2 (3.7)

AO/OTA classification	Locked (n=45)	Nonlocked (n=54)
78.2-5.1.3A	1 (2.2)	2 (3.7)
78.2-5.2.1A	1 (2.2)	1 (1.9)
78.2-5.2.2A	2 (4.4)	3 (5.6)
78.2-5.3.1A	0 (0.0)	1 (1.9)
78.2-5.3.2A	2 (4.4)	6 (11.1)
78.2-5.3.3A	2 (4.4)	8 (14.8)
Total	**45 (100.0)**	**54 (100.0)**

Data are presented as n (%).
The distribution of the AO/OTA fracture classifications between the locked and nonlocked groups was compared using Fisher's exact test because of the small cell counts.
Overall, Fisher's exact test was used (p=0.176).
AO/OTA, AO Foundation and Orthopedic Trauma Association.

The postoperative complication patterns are summarized in Table 3. Complication patterns were classified into mutually exclusive categories to avoid double counting of patients who experienced more than one complication. Overall, 3 patients (6.7%) in the locked group and 43 patients (79.6%) in the nonlocked group experienced at least one complication (p<0.001). The overall distribution of complication patterns also differed significantly between the two groups (Fisher's exact test, p<0.001). In the nonlocked group, the most frequent patterns were K-wire migration only (n=18, 33.3%) and complete K-wire dislodgement only (n=15, 27.8%), but each of these patterns occurred in 1 patient (2.2%) in the locked group. Combined complication patterns involving pin tract infections occurred only in the nonlocked group.

Table 3 Comparison of postoperative complication patterns between treatment groups.

Complication pattern	Locked (n=45)	Nonlocked (n=54)	p-Value
No complication	42 (93.3)	11 (20.4)	<0.001[a]
K-wire migration only	1 (2.2)	18 (33.3)	
Complete K-wire dislodgement only	1 (2.2)	15 (27.8)	
K-wire migration with pin tract infection	0 (0.0)	3 (5.6)	
Pin tract infection only	1 (2.2)	6 (11.1)	
Complete K-wire dislodgement with pin tract infection	0 (0.0)	1 (1.9)	
Any complication (≥1)	3 (6.7)	43 (79.6)	<0.001[b]

Values are presented as n (%).
[a]Overall comparison of the mutually exclusive complication pattern distribution using Fisher's exact test.
[b]Comparison of patients with any complication versus no complication using Fisher's exact test. Each patient was assigned to one mutually exclusive category; "any complication" summarizes all complication categories. Fifteen patients in the nonlocked group who experienced clothing-related partial K-wire pullout were excluded from the primary analysis but were included in a separate sensitivity analysis.
K-wire, Kirschner wire.

As individual clinical outcomes could occur concurrently, K-wire migration, complete K-wire dislodgement, and pin tract infection were analyzed separately (Table 4). K-wire migration occurred in 1 patient (2.2%) in the locked group compared with 21 patients (38.9%) in the nonlocked group (RR, 0.057; 95% CI, 0.008–0.408; p<0.001). Complete K-wire dislodgement occurred in 1

patient (2.2%) and 16 patients (29.6%), respectively (RR, 0.075; 95% CI, 0.010–0.544; p<0.001). Pin tract infection occurred in 1 patient (2.2%) in the locked group and in 10 patients (18.5%) in the nonlocked group (RR, 0.120; 95% CI, 0.016–0.902; p=0.011).

Table 4 Comparison of clinical outcomes between treatment groups.

Clinical outcome	Locked (n=45)	Nonlocked (n=54)	RR (95% CI)	p-Value
Any complication	3 (6.7)	43 (79.6)	0.084 (0.028–0.252)	<0.001
Any K-wire migration	1 (2.2)	21 (38.9)	0.057 (0.008–0.408)	<0.001
Any complete K-wire dislodgement	1 (2.2)	16 (29.6)	0.075 (0.010–0.544)	<0.001
Any pin tract infection	1 (2.2)	10 (18.5)	0.120 (0.016–0.902)	0.011

Values are presented as n (%).
p-Values were calculated using two-sided Fisher's exact tests.
RR, risk ratio; CI, confidence interval; K-wire, Kirschner wire.

The adjusted associations between the fixation strategy and individual clinical outcomes are presented in Table 5. In Firth's penalized logistic regression models adjusted for age, sex, fracture site, and mechanism of injury, the locked group had lower odds of K-wire migration than the nonlocked group (adjusted OR [aOR], 0.064; 95% CI, 0.011–0.384; p=0.003). A similar association was observed for complete K-wire dislodgement (aOR, 0.080; 95% CI, 0.011–0.561; p=0.011). For pin tract infection, the adjusted estimate was imprecise, and the 95% CI included 1.0 (aOR, 0.165; 95% CI, 0.024–1.125; p=0.066).

Table 5 Adjusted association between fixation technique and clinical outcomes.

Outcome	Adjusted OR	95% CI	p-Value
Any K-wire migration	0.064	0.011–0.384	0.003
Any complete K-wire dislodgement	0.080	0.011–0.561	0.011
Any pin tract infection	0.165	0.024–1.125	0.066

Adjusted ORs compare the locked group with the nonlocked group. Estimates were obtained using Firth's penalized logistic regression adjusted for age (continuous), sex, fracture site, and mechanism of injury.
OR, odds ratio; CI, confidence interval; K-wire, Kirschner wire.

In a secondary analysis of the composite outcome of any complication, Firth's penalized logistic regression using the same adjustment set also showed lower adjusted odds in the locked group compared with the nonlocked group (aOR, 0.011; 95% CI, 0.001–0.089; p<0.001).

A sensitivity analysis was conducted by including the 15 patients with clothing-related partial K-wire pullout and increasing the cohort size to 114 patients (45 locked and 69 nonlocked). When these events were classified as K-wire migration, migration occurred in 1 patient (2.2%) in the locked group and in 36 patients (52.2%) in the nonlocked group (crude RR, 0.043; 95% CI, 0.006–0.300; p<0.001).

The corresponding rates of complete K-wire dislodgement were 1/45 (2.2%) and 16/69 (23.2%), respectively (crude RR, 0.096; 95% CI, 0.013–0.698; p=0.002).

Both outcomes remained statistically significant in the crude sensitivity analysis with associations in the same direction as those observed in the primary analysis. Adjusted sensitivity analyses could not be performed because individual-level baseline covariate data were unavailable for the 15 additional patients.

Age-stratified exploratory analyses are presented in Table 6. Among pediatric patients (aged <18 years), the differences between the locked and nonlocked groups did not reach statistical significance for K-wire migration (9.1% vs. 37.5%; p=0.183), complete K-wire dislodgement (0.0% vs. 31.3%; p=0.060), or pin tract infection (0.0% vs. 37.5%; p=0.054). Among adults (≥18 years), K-wire migration (0.0% vs. 39.5%; p<0.001) and complete K-wire dislodgement (2.9% vs. 29.0%; p=0.004) differed between groups, whereas pin tract infection did not (2.9% vs. 10.5%; p=0.361). Figure 3 shows serial follow-up radiographs of a representative pediatric case treated with locked fixation. Figure 4 presents corresponding radiographs of a representative adult hand fracture treated with locked fixation.

Table 6 Age-stratified clinical outcomes by treatment group.

Clinical outcome	Locked	Nonlocked	p-Value
Pediatric (<18 years)			
Any K-wire migration	1/11 (9.1)	6/16 (37.5)	0.183
Any complete K-wire dislodgement	0/11 (0.0)	5/16 (31.3)	0.060
Any pin tract infection	0/11 (0.0)	6/16 (37.5)	0.054
Adult (≥18 years)			
Any K-wire migration	0/34 (0.0)	15/38 (39.5)	<0.001
Any complete K-wire dislodgement	1/34 (2.9)	11/38 (29.0)	0.004
Any pin tract infection	1/34 (2.9)	4/38 (10.5)	0.361

Data are presented as n/N (%).

p-Values were calculated using two-sided Fisher's exact tests. Because of the small sample size and sparse event counts, particularly in the pediatric subgroup, these analyses were considered exploratory and should be interpreted cautiously.

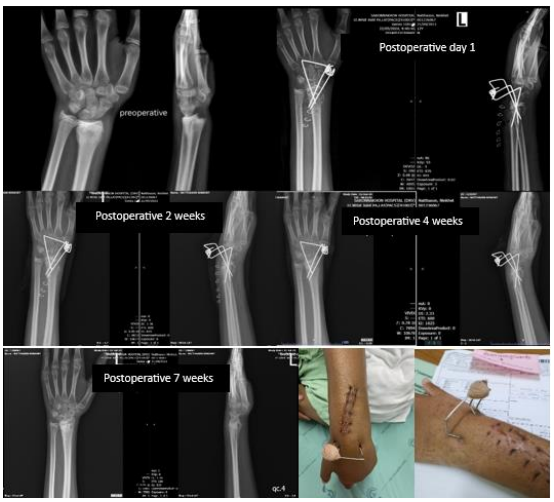


Fig. 3 Representative pediatric case: a 12-year-old boy with a closed distal radius fracture treated with the locked K-wire technique. The serial radiographs were obtained preoperatively, on postoperative day 1, and at 2, 4, and 7 weeks of follow-up. K-wires were removed after satisfactory fracture union was observed.



Fig. 4 Representative adult hand fracture case: a 49-year-old woman with a Bennett fracture treated with the locked K-wire technique. The serial radiographs were obtained preoperatively, on postoperative day 1, and at 2, 4, and 8 weeks of follow-up.

In the nonlocked group, K-wire migration occurred in 21 patients, complete K-wire dislodgement occurred in 16 patients, and pin tract infection occurred in 10 patients (Tables 3 and 4). Among the 10 patients with pin tract infection, 3 had concurrent K-wire migration, 1 had concurrent complete K-wire dislodgement, and 6 had pin tract infection without either migration or complete dislodgement. Patients were followed up until fracture union and K-wire removal were achieved.

In the locked group, K-wire migration, complete K-wire dislodgement, and pin tract infection occurred in 1 patient each. Complete dislodgement occurred 5 weeks postoperatively in a patient with a fifth metacarpal fracture following a fall onto the operated hand. Subsequently, radiographs demonstrated satisfactory fracture union, and the remaining K-wire was removed without further complications (Figure 5).

A single pin tract infection in the locked group was documented at the 4-week follow-up visit. Radiography revealed satisfactory fracture union without any evidence of osteomyelitis. The K-wires were removed, and the infection resolved after a 1-week course of oral dicloxacillin.

Representative follow-up images demonstrating joint motion in selected patients treated with the locked strategy are presented in Figure 6; these images are illustrative and were not included in the formal functional outcome analysis.



Fig. 5 Representative clinical and radiographic images from the locked group. A 31-year-old woman who fell 5 weeks postoperatively, resulting in the extrusion of one K-wire; subsequent radiographs demonstrated fracture union.



Fig. 6 Representative range-of-motion images during follow-up. These images are illustrative and were not part of a formal functional outcome assessment.

DISCUSSION

This study compared the incidence of K-wire migration and complete dislodgement between locked K-wire fixation without splinting and nonlocked fixation with splinting for hand and distal forearm fractures. The study identified substantial differences in the K-wire-related outcomes between the two treatment strategies. Crude analyses showed that K-wire migration and complete dislodgement were less frequent in the locked group than in the nonlocked group. These associations remained after adjustment for age, sex, fracture site, and mechanism of injury using Firth's penalized logistic regression. In contrast, although pin tract infections were less frequent in the locked group in the crude comparison, the adjusted estimate was imprecise and did not reach statistical significance. Therefore, these findings should be interpreted as associations between the two treatment strategies rather than as evidence of an independent causal effect of the locking mechanism.

Previous studies have explored strategies to improve the stability of percutaneous K-wire constructs. Naito et al. reported the use of a locked-wire fixator without postoperative immobilization in a small pediatric series, whereas De Spirito described linking external K-wires with a metal clamp and demonstrated greater resistance to loosening than conventional unlinked K-wires in mechanical testing[12,13]. Meng et al. reported a cemented K-wire frame for distal radius fractures, with no K-wire migration or fixation failure observed in their series[14]. Biomechanical evidence also suggests that the K-wire configuration and number can influence construct stiffness[15]. However, the differences in patient populations, fracture patterns, fixation constructs, and study designs limit direct comparisons with the present cohort.

A significant limitation of this study is its retrospective design, which relied on medical records and radiographic reviews. The treatment strategy was determined by treatment period rather than by randomization, and baseline differences in sex, fracture site, and mechanism of injury were observed between the groups. Although these measured factors were addressed in the adjusted analyses, residual confounding from unmeasured differences in the case mix cannot be excluded. Functional outcomes and time to return to work were not evaluated and warrant further investigation. An additional limitation is that the fixation strategy, postoperative splint use, and treatment period were linked. All nonlocked cases were treated with splint immobilization during the earlier study period, whereas locked cases were treated without splint immobilization during the later period. Consequently, the observed differences cannot be attributed to the locking mechanism alone, and the potential temporal effects, including changes in clinical practice and surgeon experience over time, cannot be separated from the treatment strategy. An additional methodological consideration is the exclusion of 15 patients from the nonlocked group who experienced clothing-related partial K-wire pullout. Although these events were initially considered externally induced, their exclusion may have introduced selection bias because partial pullout represents a clinically relevant form of K-wire migration. In the sensitivity analysis, inclusion of these patients did not change the direction or statistical significance of the crude associations for K-wire migration and complete dislodgement. However, as individual-level baseline characteristics were unavailable for these patients, an adjusted sensitivity analysis could not be performed. Therefore, the sensitivity findings should be interpreted with caution.

Quantitative radiographic measures of the maintenance of fracture reduction, including changes in angulation, shortening, articular step-off, and secondary displacement, were not systematically assessed. Therefore, this study cannot determine whether either treatment strategy provided superior maintenance of fracture reduction. In addition, the radiographic outcomes were assessed by the operating surgeon, who was also a study investigator and was not blinded to the treatment group; no independent radiographic adjudication was performed. This may have introduced observer bias.

Pin tract infection, pin loosening, loss of reduction, and K-wire migration are recognized

complications of percutaneous K-wire fixation[8,9]. The relationship between K-wire migration and pin tract infection should be interpreted with caution. In the nonlocked group, 3 of the 10 patients with pin tract infection had concurrent K-wire migration, whereas 6 had pin tract infection without migration or complete dislodgement and 1 had concurrent complete dislodgement. Although mechanical irritation from wire movement may plausibly contribute to local pin site complications, the present data do not establish a causal relationship between K-wire migration and infection.

Our locking technique uses the exposed proximal ends of K-wires, which are bent and interlocked with adjacent wires and subsequently wrapped with an elastic adhesive bandage. Unlike previously described methods that use specialized metal clamps[13] or bone cement[14], the present technique uses exposed K-wire ends to create a linked construct. This may offer a technically simple approach using readily available materials.

However, the present study was not designed to establish biomechanical superiority, functional benefits, or equivalence in the maintenance of fracture reduction, and these outcomes require prospective evaluation.

CONCLUSION

In this retrospective comparative cohort, the locked K-wire strategy without splinting was associated with lower odds of K-wire migration and complete dislodgement than the nonlocked K-wire strategy with splinting, after adjustment for age, sex, fracture site, and mechanism of injury. Although pin tract infections were less frequent in the locked group in the crude analysis, the adjusted association was imprecise and did not reach statistical significance. Because fixation strategy, splint use, and treatment period were linked, these findings cannot be attributed to the locking mechanism alone. This technique represents a practical method for linking exposed K-wire ends using readily available materials. Prospective studies incorporating standardized radiographic and functional outcomes are required to further evaluate its clinical performance.

REFERENCES

1. Colmers-Gray IN, Louison H, Kadar A. Assessment and management of common hand fractures in adults. BMJ 2025;388:e075436.
2. Soerensen S, Larsen P, Korup LR, et al. Epidemiology of distal forearm fracture: a population-based study of 5426 fractures. Hand (N Y) 2024;19:24-9.
3. Chan YH, Foo TL, Yeo CJ, et al. Comparison between cast immobilization versus volar locking plate fixation of distal radius fractures in active elderly patients, the Asian perspective. Hand Surg 2014;19:19-23.
4. Rozental TD, Blazar PE, Franko OI, et al. Functional outcomes for unstable distal radial fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation. A prospective randomized trial. J Bone Joint Surg Am 2009;91:1837-46.
5. Franceschi F, Franceschetti E, Paciotti M, et al. Volar locking plates versus K-wire/pin fixation for the treatment of distal radial fractures: a systematic review and quantitative synthesis. Br Med Bull 2015;115:91-110.
6. Day CS, Stern PJ. Fractures of metacarpals and phalanges. In: Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, editors. Green's Operative Hand Surgery. 6th ed. Philadelphia, PA: Elsevier Churchill Livingstone; 2011. p. 239-90.
7. Klein DM, Belsole RJ. Percutaneous treatment of carpal, metacarpal, and phalangeal injuries. Clin Orthop Relat Res 2000;(375):116-25.
8. Botte MJ, Davis JL, Rose BA, et al. Complications of smooth pin fixation of fractures and dislocations in the hand and wrist. Clin Orthop Relat Res 1992;(276):194-201.
9. Subramanian P, Kantharuban S, Shilston S, et al. Complications of Kirschner-wire fixation in distal radius fractures. Tech Hand Up Extrem Surg 2012;16:120-3.

10. Stern PJ. Management of fractures of the hand over the last 25 years. J Hand Surg Am 2000;25:817-23.
11. Jaroenporn W, Rerksanan W, Phiphobmongkol V, et al. Biochemical finite element analysis of the locked Kirschner wire system versus volar plate fixation of distal radius fracture. J Southeast Asian Med Res 2021;5:91-8.
12. Naito K, Kawakita S, Nagura N, et al. Locked wires fixator for fractures of the distal third of the radius and ulna in children. Eur J Orthop Surg Traumatol 2020;30:1193-7.
13. De Spirito D. Percutaneous fixation of hand fractures using locked K-wires: mechanical analysis and clinical application. Tech Hand Up Extrem Surg 2013;17:134-43.
14. Meng H, Xu B, Xu Y, et al. Treatment of distal radius fractures using a cemented K-wire frame. BMC Musculoskelet Disord 2022;23:591.
15. Sanders L, Johnson N, Dias JJ. Kirschner wire fixation in dorsally displaced distal radius fractures: a biomechanical evaluation. J Wrist Surg 2022;11:21-7.
16. Chia B, Catalano LW 3rd, Glickel SZ, et al. Percutaneous pinning of distal radius fractures: an anatomic study demonstrating the proximity of K-wires to structures at risk. J Hand Surg Am 2009;34:1014-20.
17. Tubiana R. Early mobilization of fractures of the metacarpals and phalanges. Ann Chir Main 1983;2:293-7.
18. Wehbé MA. Early motion after hand and wrist reconstruction. Hand Clin 1996;12:25-9.
19. Bryan BK, Kohnke EN. Therapy after skeletal fixation in the hand and wrist. Hand Clin 1997; 13:761-76.
20. Crosby CA, Wehbé MA. Early motion protocols in hand and wrist rehabilitation. Hand Clin 1996;12:31-41.
21. Putnam MD. Posttraumatic stiffness in the hand. Clin Orthop Relat Res 1996;(327):182-90.