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Original Research

Results of an Adjustable Traction Method Using Surgical Gloves and K-Wires for the Treatment of Proximal Interphalangeal Joint Fracture Dislocation

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Purpose: This study aimed to evaluate an adjustable traction method using surgical gloves and Kirschner wires (K-wires) for proximal interphalangeal (PIP) fracture dislocations and examine the association between a reduction pin and range of motion (ROM), and between subluxation immediately after removal and ROM.

Methods: Patients who underwent this surgical method for PIP joint dislocation fractures between 2003 and 2017 were included. We retrospectively investigated the postoperative results. We defined patients having surgery within 4 weeks after an injury as fresh cases and after 4 weeks as chronic cases. K-wires were inserted at the center of the proximal phalangeal head and the distal part of the middle phalanx to create a frame, and the finger of the surgical glove was used as a traction-force generator. We analyzed the association of ROM with each finger, age, presence of a reduction pin, and subluxation immediately after frame removal.

Results: Overall, 37 fingers were included (27 acute and 10 chronic). The mean age of the participants was 40.0 years (range: 13–72 years). The mean follow-up period was 10.5 months (3–47 months). The final active ROM was −4.6°/94.6° (extension/flexion) for acute cases and −27.0°/73.5° for chronic ones. Active ROM was significantly better in patients with a reduction pin than in those without it. Subluxation immediately after frame removal was not associated with postoperative active ROM. Additionally, all PIP joints with subluxation that occurred immediately after frame removal achieved good joint congruity.

Conclusions: The results of the adjustable traction method using surgical gloves and K-wires were satisfactory. Postoperative ROM did not decrease because of the additional reduction pin. Subluxation occurring immediately after frame removal did not affect the ROM, ultimately resulting in good joint congruity.

Type of study/level of evidence: Therapeutic IV.

Although various traction methods have been proposed for proximal interphalangeal (PIP) joint dislocations,[1–8] no consensus exists on the best device. In the early 2000s, Kuroshima reported an adjustable traction method using surgical gloves and Kirchner wires (K-wires) called the wire-frame traction method.[9] This method offers several advantages. First, only K-wires and surgical gloves are required; hence, it can be performed anytime and anywhere, even during emergencies. Furthermore, these materials are inexpensive compared with commercially available external fixators or dynamic distraction devices. Third, seamless fine-tuning of the traction force is possible by changing the amount of glove-stretching. By contrast, other methods adjust the force by adding rubber bands, which does not allow seamless fine-force tuning. For example, although it was reported that overdistraction leads to vascular compromise in the case of dynamic pins and rubber systems for acute PIP joint injuries,[10] the wire-frame traction method allows for delicate adjustments, which helps avoid such complications. Moreover, adjustments can be made to the radial and ulnar sides. Finally,

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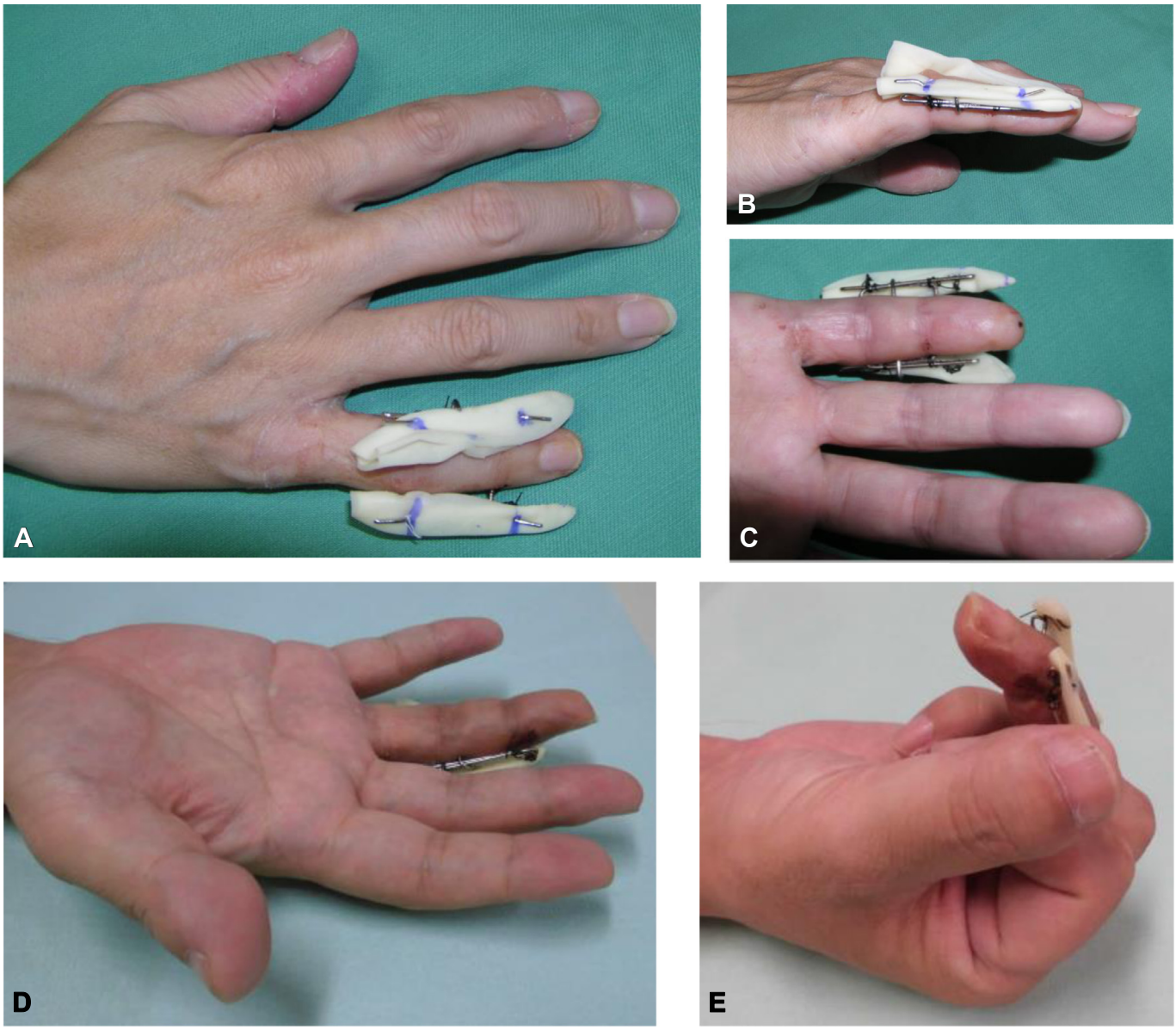

Figure 1. The wire-frame traction method. **A** Dorsal side. **B** Ulnar side. **C** Palmar side. **D** and **E** The appearance during active exercise after surgery.

this frame is smaller than those of the other devices because the K-wires face each other (Figs. 1 and 2).

Kobayashi has applied this method to two patients with dorsal fracture dislocation of the distal interphalangeal joint;[11] they initiated early ROM exercises and obtained satisfactory results. Although these are not dynamic devices, Kimura et al[12] modified this method and applied it to fractures of the distal radius, distal ulna, and diaphyses of the radius and ulna.

However, no reports have shown the results of the adjustable traction method using surgical gloves and K-wires for PIP joint fracture dislocation in a relatively large number of patients. Based on the aforementioned advantages, we hypothesized that this method would be beneficial in patients with PIP fracture dislocations, with no specific complications. Additionally, we asked the following two clinical questions (based on our experience) that few reports have addressed: the first question was whether a reduction pin insertion reduces ROM owing to friction and the second was whether subluxation immediately after frame removal affects the final postoperative ROM and results in good joint congruity.

This study aimed to evaluate the adjustable traction method using surgical gloves and K-wires. Our results might encourage surgeons to use this method in various settings, especially when urgently needed. Additionally, we aimed to investigate the association between reduction pins and ROM, and between subluxation immediately after removal and final ROM. This information may also be beneficial in deciding whether to add a reduction pin, predicting future prognoses and encouraging patients to continue ROM exercises.

Materials and Methods

This study was approved by the institutional review board at our institution. This single-center retrospective study was performed at a municipal hospital located in a city center. We defined patients who underwent surgery within 4 weeks after

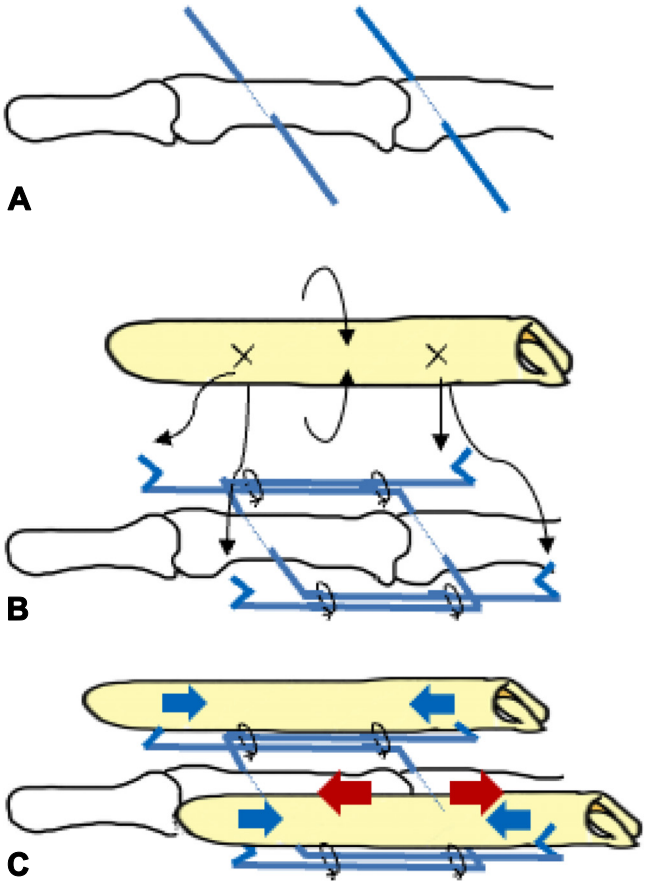

Figure 2. Overall flow of operating procedures. **A** Insertion of two Kirschner wires (K-wires). **B** Process of making a sliding mechanism and frame structure, and surgical finger gloves folded in three longitudinally. **C** Gloves are typically stretched 20%–40% and used as traction-force generators.

injury as acute cases and those who underwent surgery after 4 weeks as chronic cases, as defined by Ruland.[13] We treated acute unstable PIP joint fracture dislocations with surgery according to Kiefhaber.[14] We excluded the following injuries or patients for the following acute cases: incomplete amputation, multiple PIP joint fracture dislocations, coexisting tendon rupture, and patients who cannot perform therapy exercises reliably (such as those younger than 10 years and elderly persons with dementia). We operated on patients with chronic PIP joint fracture dislocations who had poor joint congruity and wanted improved ROM, in addition to preventing the development of osteoarthritis. We excluded patients with osteoarthritis and coexisting tendon rupture at the time of the injury. Patients who underwent surgery for acute or chronic unstable PIP joint dislocation fractures between 2003 and 2017 and were regularly followed up for >3 months were included in this study. All patients were diagnosed with unstable PIP joint fracture dislocation by hand surgeons.

The surgical procedure was the same as that described in the by Kuroshima[9] and similar to that reported by Kobayashi.[11] K-wires (1.0 mm in diameter) were inserted at the center of the proximal phalangeal head and the distal part of the middle phalanx to create a frame (Fig. 2A). Both the K-wires were bent at right angles bilaterally near the skin and formed hooks that aligned next to each other. The K-wires were tied using 2–0 nylon threads to provide a sliding mechanism and frame structure. We folded the finger of the surgical glove thrice and used it as a traction-force generator (Fig. 2B). The gloves were typically stretched by 20%–40%. The traction force was adjusted by altering the extent of glove-stretching (Fig. 2C). After setting up the traction device, we confirmed the reduction, concentric motion, and smooth movement. Many PIP joint fractures can be reduced using simple traction. Some cases required additional reduction pins (described later) to achieve smooth motion. In such cases, the subluxated middle phalanx was manually reduced, and an additional K-wire (1 mm in diameter) was inserted transversely at the base of the middle phalanx just below or above the other K-wires, forming the frame as a buttress reduction pin. During this procedure, an assistant surgeon guided the K-wire to ensure that it passed immediately above or below the wire frame (Fig. 3). Open reduction was not generally performed during the acute phase. By contrast, we generally resected the collateral ligaments in chronic cases. Active and passive ROM exercises were permitted from the first postoperative day. The patients were examined weekly before frame removal at the outpatient clinic. We performed pin care and instructed the patients to perform ROM exercises as aggressively as they could tolerate. Formal physical therapy was not performed with a hand therapist. The K-wires were removed 6 weeks after surgery.

Postoperative active ROM of the PIP joint was the primary outcome. We also investigated the association between active ROM and the specific finger, age of the patient, presence of a buttress reduction pin, and presence of subluxation immediately after frame removal. Additionally, we investigated whether joints with subluxation that occurred immediately after frame removal would achieve good ROM and joint congruity during mid-to-long-term follow-up.

Statistical analysis was performed using the Steel–Dwass test for each finger and the Mann–Whitney U test for the others. Statistical significance was set at $P < .05$.

Results

Overall, 37 fingers were included (27 acute and 10 chronic—8 index, 7 middle, 15 ring, and 7 little fingers). The mean age was 40.0 years (range: 13–72 years). The mean follow-up period was 10.5 months (3–47 months). The mean degree of articular involvement was 45.4%.

The final mean active ROM (Table 1) was −4.6°/94.6° (extension/flexion) for the acute cases; the final mean active arcs was 90°. The final mean active ROM was −27.0°/73.5° for the chronic cases; the final mean active arc was 46.5°. A significant difference was observed between the mean arcs in the acute and chronic cases ($P = .015$).

Table 2 presents the results of the association between ROM and each factor. No significant differences were observed between the fingers. Nonetheless, ROM was significantly better in cases with a reduction pin than in those without it ($P < .05$). Subluxation occurred immediately after frame removal and was not associated with the postoperative ROM.

Furthermore, all PIP joints with subluxation that occurred immediately after removal of the frame were remodeled and ultimately obtained good joint congruity (Fig. 4).

No patients with septic arthritis or osteomyelitis required hospitalization for intravenous antibiotics or surgical debridement.

Discussion

This study investigated the results of an adjustable traction method using surgical gloves and K-wires called the “wire-frame traction method,” as well as the association between reduction pin and ROM and between subluxation immediately after removal and

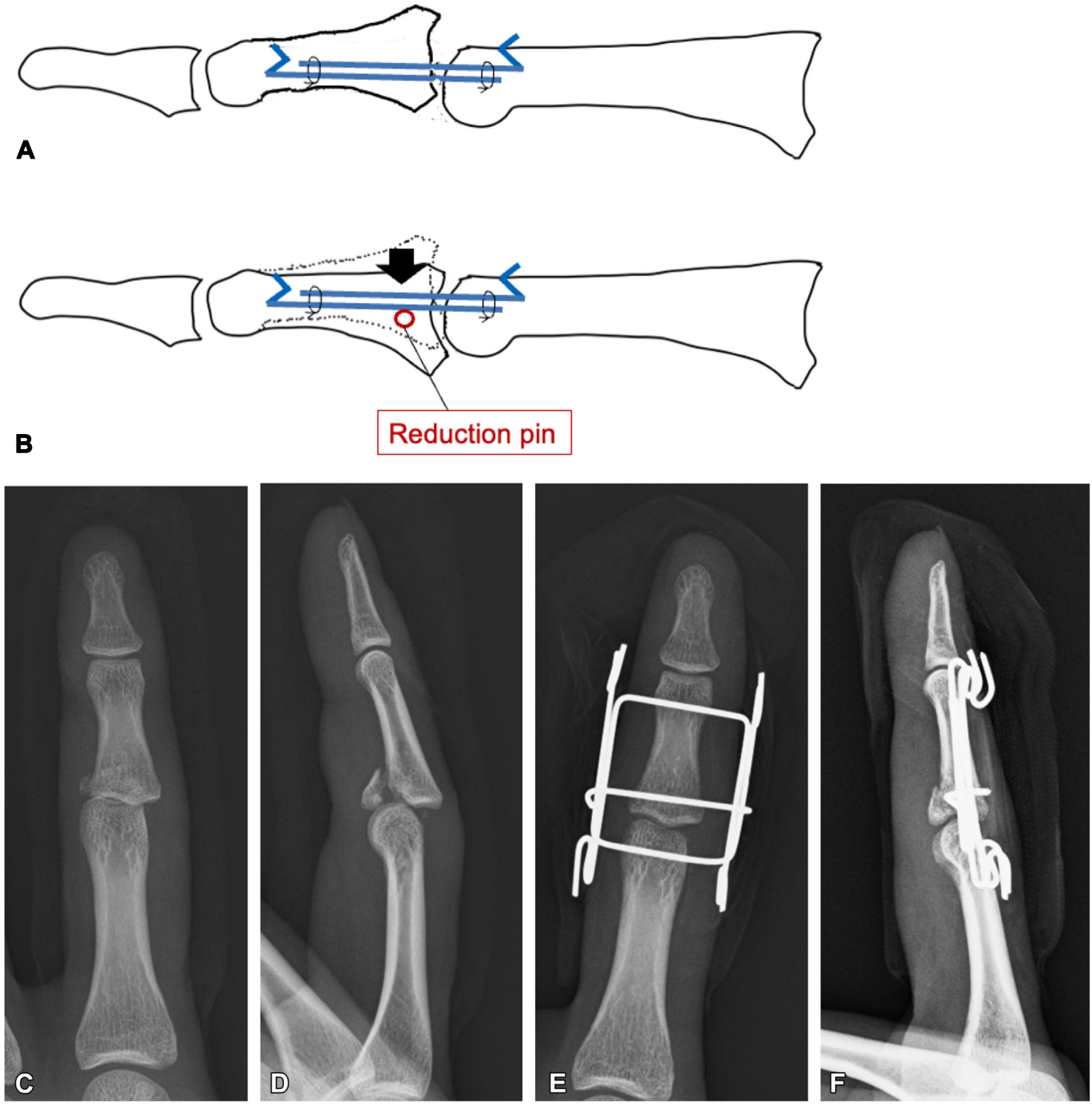

Figure 3. **A** Subluxated middle phalanx before insertion of an additional reduction pin. **B** Reduced middle phalanx after insertion of an additional reduction pin. **C** and **D** Posteroanterior and lateral preoperative radiographs of the proximal interphalangeal (PIP) joint. **E** and **F** Postoperative radiographs with the wire-frame traction method and a reduction pin.

Table 1
Results of Active ROM

Active ROM	Acute	Chronic
	27	10
PIP Joint ROM	Mean (SD)	Mean (SD)
Extension	−4.6 (7.6)	−27.0 (28.6)
Flexion	94.6 (14.1)	73.5 (32.9)
Arc	90.0 (18.7)	46.5 (47.0)

ROM in relatively large number of patients. Our results are comparable with those of previous studies. Moreover, we demonstrated two important points that few studies have reported. First, postoperative ROM did not decrease despite the additional reduction pin. Second, subluxation occurring immediately after frame removal did not affect ROM exercise. Finally, good joint congruity was obtained.

Various studies on dynamic external fixation and similar devices have shown relatively good results for PIP joint fracture dislocations.[1–8] Representative previous reports in which more than

Table 2
Results of the Association Between ROM and Each Factor

Factors	Active ROM		*P* Value
	N	Average ± SD	
Reduction pin			
Yes	18	92.5 ± 18.6	< .05
No	19	64.7 ± 40.6	
Subluxation occurred just after frame removal			
Yes	5	94.0 ± 21.6	.23
No	32	75.8 ± 35.7	
Finger			
Index	8	81.9 ± 38.0	*
Middle	7	81.4 ± 22.9	
Ring	15	85.0 ± 37.8	
Little	7	56.4 ± 11.2	
Sex			
Male	31	80.2 ± 34.0	.45
Female	6	68.3 ± 38.2	

* No significant difference among each group.

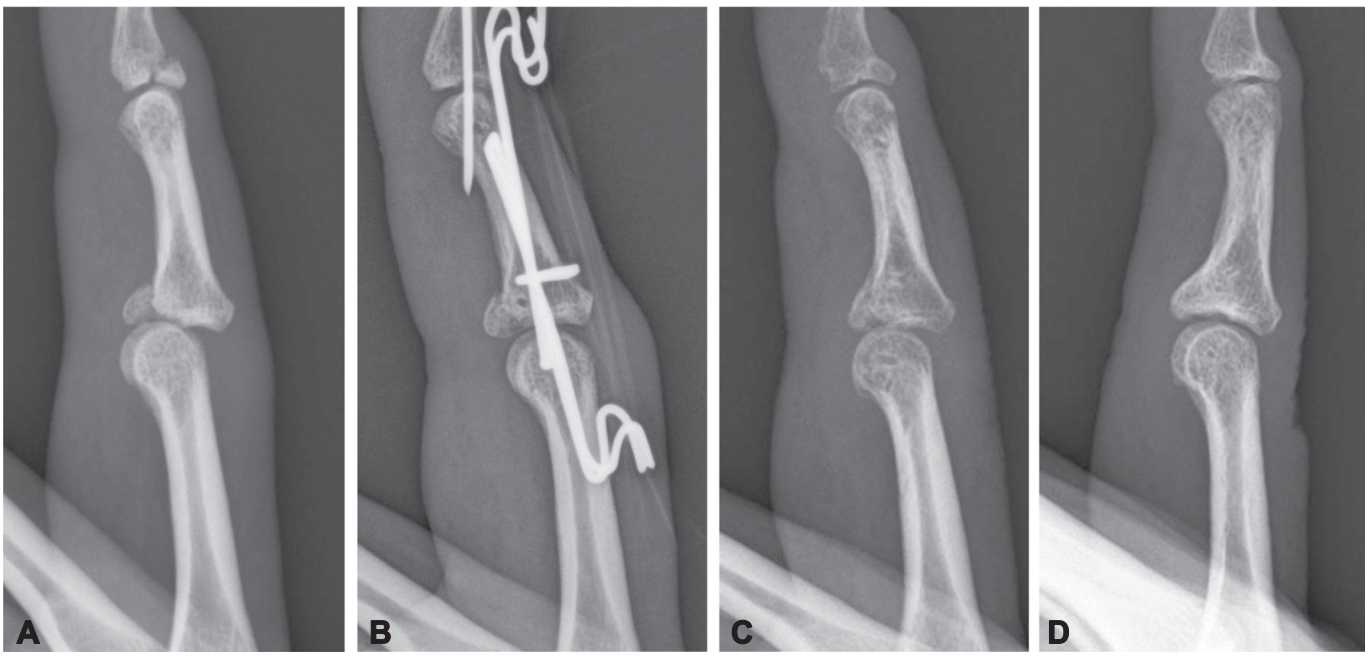

Figure 4. Lateral radiographs of proximal interphalangeal (PIP) joint. **A** Preoperatively. **B** Immediately after surgery. **C** Immediately after the removal of the frame. **D** 2 years after surgery.

Table 3
Findings in Previous Representative Reports

Type of Dynamic Distraction External Fixation	Author	Year	Number of Fingers (Acute Case in Our Definition)	Number of K-wires	Time Until Surgery	Device Removal time	PIP ROM (Degree)	Reduction Pin
Suzuki	Duteille	2003	20	2	3.25 d	3.6 d	85.9	
	Nilsson	2014	42	2 or 3	7 d	5.1 wk	TAM 66%	○
	Nanno	2019	24	2 or 3	within 3 wk	6.4 wk	74.6	○
Modified Suzuki	Abou	2017	36	3	11 d	33–42 d	90	○
	Wang	2019	20	3	15 d	4–6 wk	84.4	
Slade	Ruland	2008	34	3		6 wk	88	○
Ligamentotaxor	MacFarlane	2015	28	2	7 d	4–6 wk	85	
	Pélissier	2015	88	3	<8 d	36 d	70	
S-Quattro	Khan	2006	81	2	7.1 d	4–6 wk	92	
	Bouvet	2022	26	2	6 d	5.5 wk	82	
Other	Kastenberger	2020	21	2	2.8 d	35.2 d	76	
Our study	Nishimura	2023	27	2 or 3	9.8 d	6 wk	90	○

20 fingers were affected in acute cases are shown in Table 3.[13,15–24] In acute cases, ROM in this study was comparable with that reported in previous studies. For chronic cases, the number of patients in each study was small, and the time to surgery after injury varied significantly. Additionally, factors related to joint contracture were included in the older cases. Therefore, we believe that it is difficult to compare these results. No cases of severe complications, such as septic arthritis or osteomyelitis that required hospitalization for intravenous antibiotics or surgical debridement were noted. This method appeared to have no specific complications. This knowledge may encourage surgeons to use this method in various settings, particularly when they must perform it emergently or want to reduce medical costs.

Few studies have shown an association between reduction pin insertion and postoperative ROM. In this study, the postoperative ROM did not decrease because of the additional reduction pin, as hypothesized. Although the insertion of a reduction pin suggests that the injury is more severe and causes an increase in friction during postoperative ROM exercise, we showed that not underestimating the remaining subluxation and reducing it anatomically as much as possible during the surgery is more important than concerns regarding friction.

In addition, few reports have mentioned an association between subluxation immediately after removal and ROM. In this study, subluxations occurring immediately after frame removal did not seem to affect ROM, and good joint congruity was obtained ultimately. This result indicates that if the subluxation is within the range in which patients can perform concentric motion, joint remodeling may be expected with continued ROM in the mid-to-long term. Theoretically, the same phenomenon can be expected with other dynamic distraction devices. This information may be beneficial in predicting future prognoses and encouraging patients to continue performing ROM exercises.

Our study had several limitations. First, this study was retrospective and therefore subject to bias associated with the study design. Second, the results of our study were analyzed using a univariate analysis. Third, the follow-up period could have been longer. Therefore, the long-term incidence of traumatic osteoarthritis remains unknown. Finally, we did not evaluate patient-reported outcomes. Further prospective studies addressing these limitations are required to generalize our results.

In conclusion, our study demonstrated that the results of the adjustable traction method using surgical gloves and K-wires, called the wire-frame traction method, were satisfactory. The postoperative active ROM did not decrease with the reduction pin. Subluxation occurring immediately after frame removal did not affect ROM, and good joint congruity was achieved.

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