

A novel dynamic distraction external fixator for proximal interphalangeal joint fracture dislocation

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Abstract

Objective: To evaluate the efficacy of a novel dynamic distraction external fixator for proximal interphalangeal joint (PIPJ) fracture-dislocation.

Methods: From March 2005 to March 2014, 20 patients with PIPJ fracture-dislocation were treated with our technique. Function scores according to the Michigan Hand Outcome Questionnaire (MHQ) score, union time, grip strength, and range of motion (ROM) were recorded before and after treatment.

Results: All patients completed a mean follow-up of 22 months (range, 12–60 months). All patients achieved fracture union and joint reduction. The mean union time was 3 months (range, 2–6 months). The mean postoperative MHQ score was 88.00 ± 3.42 (range, 84.00–92.00). Postoperative grip strength of the affected sides was 92% of the contralateral sides. X-rays showed that the fracture line disappeared completely with a good joint contour. The range of extension in the PIPJ was -5° (range, $-10^\circ-0^\circ$). The range of flexion in the PIPJ was $89.40^\circ \pm 9.79^\circ$ (range, $75^\circ-100^\circ$). Postoperatively, four patients had slight narrowing of the joint space and two had an uneven articular surface. Pin breakage, loosening, and tract infection were not observed.

Conclusions: The novel dynamic distraction external fixator is a promising option for PIPJ fracture-dislocation.

Keywords

Dislocation, dynamic distraction external fixator, fracture-dislocation, proximal interphalangeal joint, Michigan Hand Outcome Questionnaire, range of motion

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Introduction

When fracture-dislocations to the proximal interphalangeal joint (PIPJ)^{1,2} are damaged and overstretched and axial load is experienced, this causes loss of hand function and subsequent disability. PIPJ fracture-dislocation often causes many complications, such as ankylosis, joint instability, post-traumatic arthritis, and flexion contracture. If PIPJ fracture-dislocation is suboptimally treated, this injury complex can be potentially debilitating secondary to subsequent stiffness, pain, development of arthritis, and limited function of the affected digit. This has always been a difficult problem in hand surgery.³ Traditional internal fixation instruments, such as the Kirschner wire (K-wire) and steel screws, are not capable of dissecting reset and strong internal fixation of a fracture, and they do not allow the joint to exercise early. A dynamic distraction external fixator (DDEF) is a favorable effective device for treating an unstable PIPJ fracture-dislocation.⁴⁻⁶ However, the DDEF device cannot be fully realized because of loose joints surrounding soft tissue and solid fixation of joints after reduction of joints. Therefore, how to effectively guarantee the stability of joints and make joints move in advance are important.

On the basis of a static traction external fixator in 1946,⁷ Schenck et al.⁸ treated 10 patients with comminuted intra-articular fractures of the PIPJ by dynamic distal traction splinting and early mobilization in 1986. However, Schenck ring traction splinting has the disadvantages of a large appearance and non-joint active activity.

Several operative and non-operative techniques and approaches have been devised, but consensus is still lacking as to the indication of each or the best approach for treatment of fracture-dislocation. Suzuki et al.⁹ designed a compact and dynamic traction external fixator device to

solve this problem. However, the Suzuki fixator cannot prevent secondary fracture displacement. Therefore, we further modified this device, which can prevent secondary fracture and displacement of the joint, as well as allowing exercise earlier to achieve better results. This study aimed to describe this modified device and verify its clinical results and safety.

Materials and methods

Patients

The study was approved by the Ethics Committee of Cangzhou Hospital of Integrated Traditional and Western Medicine of Hebei Province and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients. We performed a retrospective study on 20 patients with old PIPJ fracture-dislocation who were treated with the novel DDEF device from March 2005 to March 2014 in our hospital.

We evaluated active motion of the affected fingers with a goniometer. The grip strength was measured with the Jamar dynamometer (Sammons Preston, Mississauga, Ontario, Canada) and compared with the contralateral hand. The Michigan Hand Outcome Questionnaire (MHQ) was used for assessing hand function.

Surgical technique with the modified DDEF

The modified DDEF apparatus consisted of one externally-fixed traction bow, three K-wires, and rubber bands (Figure 1). Under a local anesthetic and X-ray screening, three 1.2-mm K-wires were inserted transversely through the lateral center of the proximal phalanx (Figure 1e), the middle phalanx (Figure 1c), and the middle phalanx base (Figure 1d). These three wires were called the anti-traction

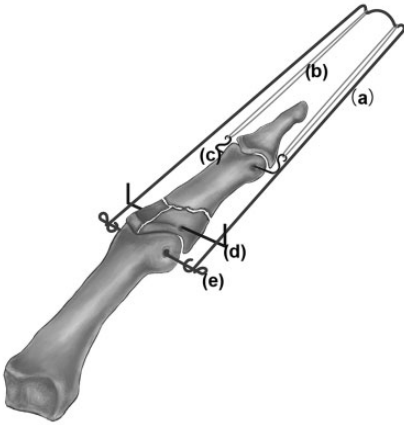


Figure 1. The modified distraction dynamic external fixator. (a) External-fixed traction bow, (b) rubber band, (c) traction Kirschner wire, (d) reduction Kirschner wire, (e) anti-traction Kirschner wire.

K-wire (AW), traction K-wire (TW), and reduction K-wire (RW), respectively. A long 1.2-mm K-wire (20 cm in length) was folded into a U-shape with two grooves (Figure 1a) to be used as the externally-fixed traction bow. Each end of the wire was folded into a ring shape to enclose both ends of the RW. We next attached the RW to the external fixation traction bow in a hinge form. Finally, rubber bands were used to connect the TW to the two grooves of the traction bow. According to fracture dislocation under intraoperative X-ray fluoroscopy, the traction force was controlled by adjusting the amount of rubber bands to pull the joint space to approximately 1 to 2 mm.

Statistical analysis

Qualitative data are described by number or percentage. Quantitative data are expressed as mean \pm standard deviation (SD). The Student's *t*-test was used to evaluate differences before and after surgery. Statistical analysis was performed by IBM SPSS Statistics

Version 20.0 (IBM Corp., Armonk, NY, USA). All statistical tests were two-sided, and significance was set at $P < 0.05$ along with the 95% confidence interval (CI).

Results

Among the 20 patients studied, there were five women and 15 men, with a mean age of 25.2 years (range, 16–58 years). The mean interval time between injury and surgery was 15 days (range, 2–90 days). The right hand was affected in 16 patients and the left hand was affected in four patients. The middle finger was involved in 14 patients and the ring finger was involved in the remaining six patients. The etiologies of the injuries were from sport injuries ($n = 13$), traffic accident injuries ($n = 6$), and a sprain ($n = 1$). According to the Schenck Classification of fracture and dislocation of PIPJ,¹⁰ there was type I in six cases, type II in 10 cases, and type III in four cases. The mean preoperative MHQ score was 56.00 ± 3.63 (range, 50.00–60.00). The preoperative active motion of PIPJ was 0° . The preoperative average grip strength was 70% (range, 60%–80%) of the contralateral hand.

The mean follow-up period was 22 months (range, 12–60 months). No patient was lost to follow-up. After the operation, the device remained for 4 to 6 weeks. All patients achieved fracture union and joint reduction. The mean union time was 3 months (range, 2–6 months). At the end of the follow-up period, the mean MHQ score was significantly improved from 56.00 ± 3.63 (range, 50.00–60.00) preoperatively to 88.00 ± 3.42 (range, 84.00–92.00) postoperatively ($P < 0.001$, Table 1). Postoperative grip strength attained $91.75\% \pm 4.71\%$ (85%–100%) of the contralateral hand ($P < 0.001$). The range of extension in the PIPJ was -5° (range, -10° – 0°), and the range of flexion in the PIPJ was $89.40^\circ \pm 9.79^\circ$ (range, 75°–100°).

Table 1. Comparison of MHQ scores, grip strength, and range of motion before and after treatment.

	MHQ scores	Grip strength	Range of motion
Before the operation	56.00 ± 3.63	70.00 ± 6.55	0.00 ± 0.00
After the operation	88.00 ± 3.42	91.75 ± 4.71	84.38 ± 9.79
T value	18.15	7.66	24.37
P value	<0.001	<0.001	<0.001

MHQ, Michigan Hand Outcome Questionnaire.

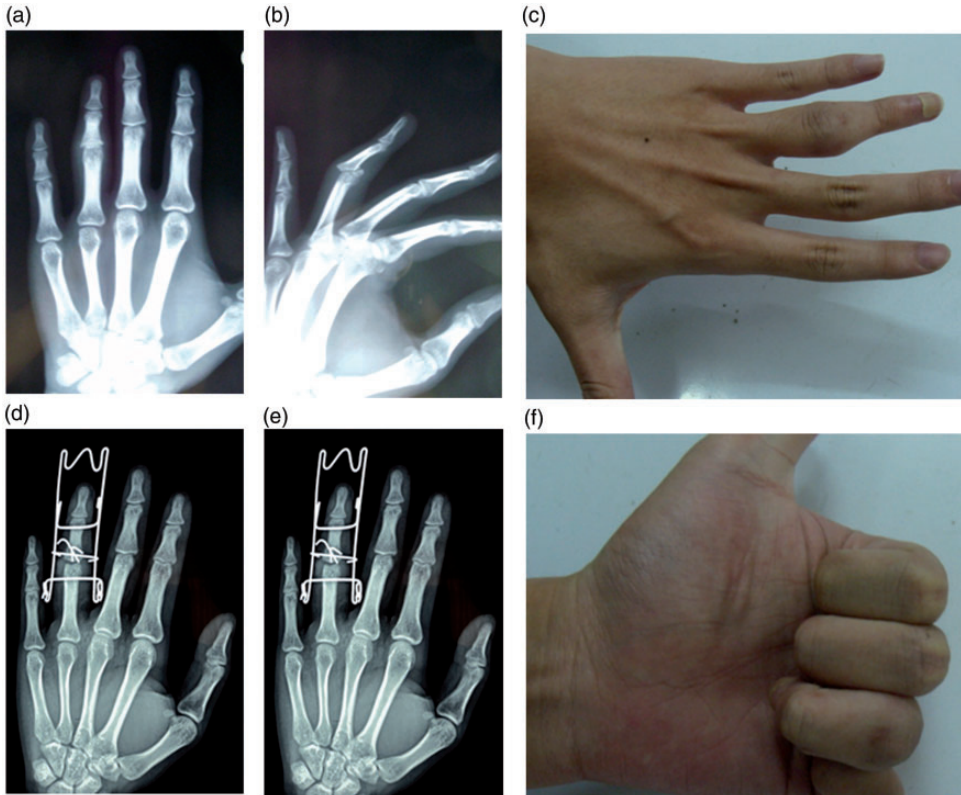


Figure 2. Images of a 19-year-old man with a left ring finger proximal interphalangeal joint fracture-dislocation for 55 days. (a, b) Preoperative radiographs show malunion of a fracture of the fundus of the middle phalanx and dorsal dislocation of the proximal interphalangeal joint. (c, d) Postoperative radiographs show joint congruity and the joint space has returned to normal after fixation with a pin-rubber band distraction external fixator for 3 weeks. (e, f) Finger function photographs show functional recovery (extension, 0°; flexion, 100°) at 24 weeks postoperatively.

The range of motion was significantly increased after the operation compared with before the operation ($P < 0.001$). An X-ray at the end of follow-up showed that

the fracture line had disappeared completely with a good joint contour (Figure 2).

Postoperatively, there were 14 cases of a normal joint space, four cases of slight

narrowing of the joint space, and two cases of an uneven articular surface. All patients returned to their prior activity levels and achieved a good level of functional activity. Good lateral stability of the joint was achieved without rotation, angular deformity, and distinct swelling. Malunion, pin-track infection, pin breakage, loosening, and osteomyelitis were not observed in any patients. All patients were satisfied with the therapeutic effects.

Discussion

There are various methods to treat PIPJ fracture-dislocation, such as closed reduction,¹¹ K-wire fixation,^{11,12} open reduction,¹³ and internal fixation.^{13,14} Although internal and external fixation has been a common treatment for fractures in recent years, these surgical methods still have some disadvantages. Traditional internal fixation devices, such as K-wire fixation, cannot achieve anatomical reduction and strong internal fixation for comminuted fractures.¹⁵ Moreover, early joint movement is not allowed when an external fixator is used to treat intra-articular fractures.¹⁶ Therefore, how to maintain stability of the joint and fracture reduction while performing active joint activity has become an urgent technical problem in this field.

In our study, we describe a modified device and verified its clinical results and safety. We found that PIPJ fracture-dislocation was successfully treated by our modified device with a good curative effect. All patients returned to their prior activity levels and achieved a good level of functional activity. In our study, postoperative grip strength was significantly higher than that in Körting et al.'s study¹⁷ and the range of motion of the joint was significantly higher than that of Shen et al.'s study.¹⁸ According to our experience, the following problems should be noted during the operation. First, the three K-wires should be kept

parallel and in the same plane. Second, the AW should be located at the flexion and extension center of the PIPJ so that the traction force of the joint can be uniform at any angle. Third, the traction force should be appropriate, and the joint space of the adjacent proximal fingers and the position of the fractures should be properly corrected by altering tension in the rubber bands. Four, the width of the traction bow should be greater than the widest part of the finger by 3 to 5 mm, so as to not affect movement of the adjacent fingers. Fifth, to place the proximal pin at the exact center, fluoroscopic control is essential. Additionally, weekly fluoroscopy is required after the operation, and tension of the rubber band should be adjusted according to the joint reduction.

Several similar dynamic external fixators have been reported previously^{17,19–23} (Table 2), but these devices still have some disadvantages. Suzuki et al.⁹ and De Smet et al.¹⁹ reported excellent results with the use of a DDEF that was originally described by Suzuki et al. for comminuted intra-articular fractures of the PIPJ. However, the Suzuki device cannot avoid friction at the bone–pin interface, and is prone to causing inflammation around the pin sites. Körting et al.¹⁷ reported a dynamic external fixator, but severe secondary fracture displacement easily occurs with that system. Hynes et al.²⁰ and Abou Elatta et al.²¹ used an improved Suzuki's device to treat pilon fractures of the inter-phalangeal joint. However, their patients experienced proximal pin tract sepsis because of movement of the proximal pin during proximal inter-phalangeal joint motion. Therefore, a reduction in K-wires was performed in our modified device to reduce dorsal displacement of the middle phalanx. Furthermore, we attached the RW to the external fixation traction bow in a hinge form so that movement occurred at the hinge between the two parts. This eventually

Table 2. Summary of comparable published series.

	Cases (no.)	Mean age (years)	Devices	Mean follow-up (months)	Mean active ROM	Mean MHQ score	Grip strength	Complications
Suzuki et al. ⁹	7	40 (range, 16–61)	Suzuki DEF (two or three K-wires and two rubber bands)	13 (range, 5–20)	80	N/A	N/A	1 case of pain
De Smet and Boone ¹⁹	8	35 (range, 19–59)	Suzuki DEF (two K-wires and two rubber bands)	6 (range, 6–36)	82 (range, 42–125)	N/A	N/A	None
Hynes and Giddens ²⁰	8	36 (range, 16–57)	DEF (two K-wires)	N/A	88 (range, 80–95)	N/A	N/A	2 PTSs
Körting et al. ¹⁷	15	47 (range, 19–76)	DEF with the Ligamentotaxor system	10 (range, 6–21)	76.4 (range, 50–120)	N/A	85.7%	1 PTS
Duteille et al. ²²	20	30 (range, 12–74)	Suzuki DEF (two K-wires and two rubber bands)	18	85.9 (range, 70–100)	N/A	N/A	2 failures
Damert et al. ²³	16	52 (range, 28–79)	Ligamentotaxor system	15	73 (range, 60–100)	N/A	N/A	2PTIs; 1 RS
Shen et al. ¹⁸	10	48 (range, 24–79)	Modified DEF (two K-wires and two rubber bands)	24 (range, 10–36)	83.9 (range, 52–100)	97.3 ± 3.0	N/A	1 case of mild pain
Abou Elatta et al. ²¹	36	37 (range, 18–58)	Modified DEF (three K-wires and two cerclage wires)	12 (range, 4–22)	86 (range, 60–100)	N/A	N/A	5 PTIs; 4 RSs
Our study	20	25 (range, 16–58)	Modified DEF (three K-wires and two rubber bands)	22 (range, 12–60)	89 (range, 75–100)	88.0 ± 3.4	92%	4 RSs; 2 uneven articular surfaces

K-wire, Kirschner wire; ROM, range of motion; MHQ, Michigan Hand Outcome Questionnaire; DEF, dynamic external fixator; N/A, not available; PTS, pin tract sepsis; PTI, pin tract infection; RS, reduction of joint space.

eliminates damage and secondary fracture displacement to the greatest extent.

The modified DDEF device has three advantages. First, this device is simple, minimally invasive, and compact, and requires only two widely available components, K-wires and rubber bands. Second, reduced K-wires can adjust the direction of traction, and maintain reduction of the joint and fracture block pressure stability to avoid secondary fracture displacement. Third, the RW and external fixation traction bow are linked in a hinge form. This allows the device to not exert any extension or bending force, and eventually avoids pin tract infection because of friction at the bone–pin interface.

There are several limitations in our study. First, because of the small number of patients with PIPJ fracture-dislocation in our hospital, only a few patients were enrolled in this study. Second, this was a retrospective study, which did not have sufficient evidence to evaluate the long-term efficacy of our device. Further studies with a larger number of samples are still required to verify our device.

Conclusions

The pin–rubber band DDEF can maintain stability of fractures and central reduction of the joint. However, most importantly, this device can achieve early active joint movement with the advantages of being minimally invasive, a reliable fixator, and having a good curative effect. Our modified DDEF is an effective method of treatment for restoring function of PIPJ fracture-dislocations. Further studies with a larger number of samples are still required to verify our device. Additionally, further technical improvements are required.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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