

# Minimal Invasive Corrective Osteotomy with the Ilizarov Mini-Fixator for Malunited Fractures of Proximal Phalanges in Adolescence: Report of Three Cases and a Review of the Literature

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Posttraumatic malunion with combination of angular, rotational, and shortening deformity of the proximal phalanx may cause scissoring of a finger and impairment of hand function. Cosmetic disfigurement and severe dysfunction of fingers require surgical correction, most often via open corrective osteotomies and rigid fixation with a plate or screws. However, such an approach requires a longer incision, inevitably results in a scar, and has a higher potential for extensor tendon adhesion. Also, abruption of the periosteum and plating of the phalange requires longer bone healing time. Thus, we devised a technique of minimally invasive correction of phalangeal malunion using an external mini-fixator. We presented representative three cases of malunited fractures of phalanges treated with the Ilizarov mini-fixator in adolescence and review reports of similar cases. The usage of Ilizarov mini-fixator provided excellent outcomes for posttraumatic malunion of three fingers. (J Nippon Med Sch 2023; 90: 141–148)

**Key words:** finger, proximal phalange, malunion, corrective osteotomy, external fixator

## Introduction

Most fractures of the proximal phalanx can be treated non-surgically and obtain the bone union uneventfully<sup>1</sup>. Some of the deformations due to malunion of the fracture also are minor and acceptable to the patient. However, the deformation of the fingers occasionally causes cosmetic deformation or functional impairment, which includes scissoring of the fingers, disturbance in tendon balance, and reduction of grasp strength<sup>2-4</sup>. When cosmetic and functional disability is not acceptable for patients, surgical intervention required to correct the malunion of phalanx to restore the anatomical alignment<sup>2-4</sup>. Since a combination of angular, rotational, and shortening deformity occurs in malunion of phalanx, the surgical correction of the malunion of the phalanx are challenging and technically demanding<sup>1,4</sup>. Limited number of studies for corrective osteotomy for the malunion of phalanges have been published and, most of cases have been treated with open surgical correction<sup>1,4</sup>. However, the major issue for the surgical correction of malunion of phalanx is that open surgical correction of the phalangeal

malunion inevitably leads a scar formation and arouse a risk of extensor tendon adhesions, two results in the extensor lag of the finger<sup>1,4</sup>. In addition, the exfoliation of the periosteum and the internal fixation with screw or plate of the phalange have a risk of inadvertent intraoperative injury to the extensor tendon and require more time for bone healing, which would deteriorate the range of motion (ROM) of fingers<sup>3-5</sup>.

We devised a technique of minimally invasive correction of phalangeal malunion using an external mini-fixator<sup>6</sup>. In the current report, we present representative three cases of malunited fractures of phalanges treated with the Ilizarov mini-fixator in adolescence and review reports of similar cases.

## Patients and Methods

### Patients

We followed the Helsinki Declaration throughout this study. We obtained approval from our Institutional Review Board (539-2-4). Between April 2017 and March 2019, three patients, all of whom were adolescents with

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scissoring finger deformity due to the malunion of the finger, were referred to our hospital. They had no pain of fingers and no restriction of ROM of fingers but complained that the cosmetic disturbance of the fingers and disturbance of the ADL. All these patients had a history of trauma on the proximal fingers. After the initial trauma on their fingers, nonsurgical treatment with the application of volar splint. The application of splint was performed for three to six weeks, but the residual deformity of the fingers was persistent. Written informed consent for treatment and publication was obtained from all patients and their parents.

#### Devise

The Ilizarov mini-fixator, developed by the Russian Ilizarov Scientific Center, was used. This fixator is a multiplanar fixator that is able to link with all other units three-dimensionally by combining the rod, hinge, and posts; it can also be used for bone elongation<sup>6,7</sup>. Four 1.5-mm-diameter dedicated pins were used for the proximal phalanges.

#### Surgical Procedure

The corrective osteotomy of the proximal phalanges is performed under digital block or general anesthesia without an air tourniquet in a supine position. Preoperatively, the site of previous fracture, which is the malunion site, is confirmed under a fluoroscope and marks the location of both the lateral ends of the original fracture line. When the site of the malunion is unclear, the area between the epiphysis and diaphysis of the phalanx is marked. The surgical procedure followed the corrective osteotomy technique published in 2021<sup>6</sup>. Briefly, the dedicated pins are inserted into the proximal and distal parts of the presumptive site of the osteotomy. The rod of the fixator is adjusted to make it parallel to the axis of the proximal and distal parts of the proximal phalanx. The rod of the fixator is attached to the Ilizarov mini-fixator units. A 10-mm incision is made at the presumptive site of the osteotomy, and the lateral band is retracted dorsally and protected. The osteotomy is performed through the skin incision with a 5-mm osteotome. The malunited phalange is resected with lighter tapping with a hummer. The phalange should be resected completely, but the opposite site of the periosteum of the skin incision is still continuously attached to phalange. Since the deformity of the phalange is corrected when all the fingers are fully flexed, the mini-fixator is adjusted according to the fully flexed position of the fingers, and each fixator unit is fixed in a position in which the alignment of the finger is corrected. Bone engraftment is not required. When the

correction of the shortening of the phalange is required, the distraction osteogenesis would be performed<sup>7</sup>. After the well-organized alignment of the fingers is obtained, a skin incision is sutured, and the dedicated pins are disinfected with 0.05% chlorhexidine gluconate solution and covered sterilized gauze.

#### Rehabilitation

The ROM exercise is encouraged immediately after the surgery. The insertion sites of the dedicated pins are disinfected with a 0.05% chlorhexidine gluconate solution once a week. If a superficial infection of the insertion sites of the dedicated pins occurs, oral antibiotics are given to the patients. The dedicated pins are removed at out-patient clinics after six weeks, and a knuckle splint is then applied for several weeks. Follow-up radiographs are taken every two weeks for eight weeks after the surgery. After that, the radiographs are taken every month until rigid consolidation of the osteotomized site is observed. Twelve weeks postoperatively, patients are allowed to grasp with full strength and to return to full performance in the sport.

#### Postoperative Assessments

The clinical evaluation included ROM of fingers, grasp strength, and evaluation score was investigated. Pre- and postoperative grasp strength measured with a dynamometer (Jamar; Baran/Tec, Clifton, NJ) and evaluation score, the Disabilities of the Arm, Shoulder and Hand questionnaire, and the Hand20 questionnaire<sup>8</sup> were investigated. These scores evaluate many types of activities of daily living related to hand, wrist, and arm function. The Disabilities of the Arm, Shoulder and Hand, and Hand20 questionnaire were used for patients with musculoskeletal diseases or with injuries to the hand, wrist, or arm, and tasks that require two hands in daily life were rated. A score of 100 indicated the worst hand function, and a score of 0 indicated the best hand function.

#### Results

Detailed data is shown in **Table 1**. No patient underwent bone grafting and bone elongation at the osteotomized site. In a patient (Case 3), he had the instability of the osteotomized site and an additional temporary fixation with a Kirschner wire was applied at the osteotomized site.

All the patients obtained the bone union of the osteotomized site, and no interruption of the application of the fixator. A patient (Case 3) had a pin track infection of a temporary Kirschner wire at three weeks after surgery, and the wire was removed. The patient took oral antibi-

Table 1 Pre- and Post-operative demographic data of the patients with malunion of the fingers

	Case 1		Case 2		Case 3	
Age/sex	12/male		15/male		17/male	
Affected finger (dominant)	ring finger, Left		middle finger, Left		ring finger, Right	
History of trauma	Be forced to twist the finger (11 y)		Fell from the top of a desk (15 y)		Fell at the game of Rugby (15 y)	
Duration from the injury to surgery (mo)	12		3		24	
Deformity of fingers (degrees)	Radial deviation (26 degrees)		Radial deviation (25 degrees)		Ulnar deviation (30 degrees)	
Follow-up period (mo)	7		24		18	
Postoperative complications	none		none		Pin tract infection	
Evaluation of grasp strength and clinical outcomes	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Grasp strength (kg)	30	29	20	22	33	32
The ratio of the grasp strength* (%)	98%	99%	67%	76%	110%	97%
DASH	1.7 Sports: 12.5 Work: 12.5	0 Sports: 0 Work: 0	6.9 Sports: 12.5- Work: 6.25	0 Sports: 0 Work: 0	10.83 Sports: 12.5 Work: 12.5	0 Sports: 0 Work: 0
Hand20	3	0	4	0	4.5	0

DASH, Disabilities of the Arm, Shoulder and Hand

\* The ratio of grasp strength of the affected wrist compared with that of the unaffected wrist.

otics for three days, and the infection was mitigated and allowed to maintain the application of the fixator.

There was no deep infection or secondary displacement of the fixation. All the patients were satisfied with the outcomes and had no residual extension lag and pain. The grasp strength and evaluation scores for the wrist improved remarkably in all 3 patients. At the time of the final follow-up evaluation, all 3 patients had fully recovered their performance and radiographs showed a well corrected rotational deformity. They had no functional deficits without discernible incision scars and reported full activity without pain or limitations.

**Cases Report**

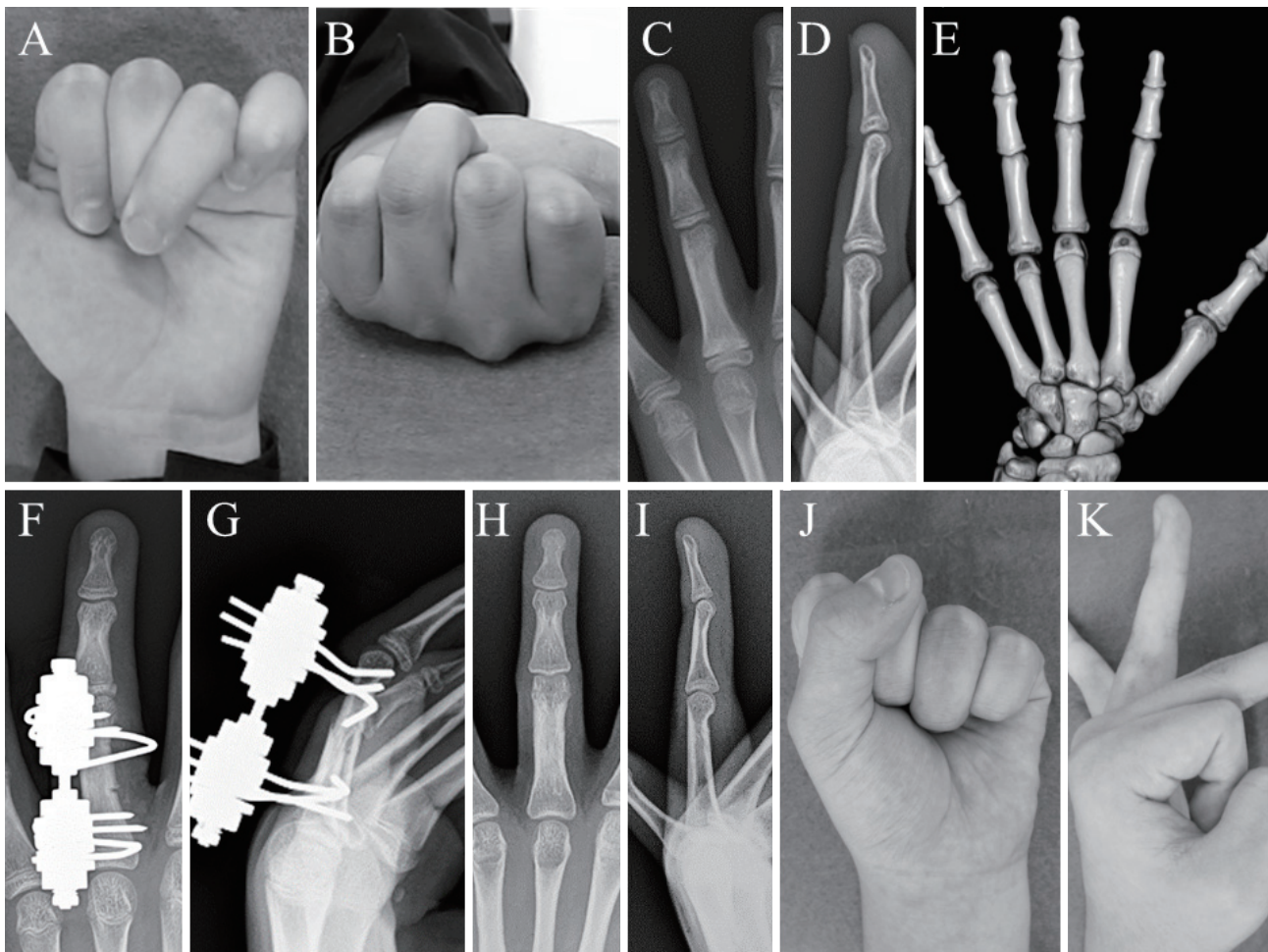
Case 1

A 12-year-old right-handed male presented with post-traumatic phalangeal malunion. He had a quarrel with his senior brother and injured while his brother held and severely twisted the patient’s left ring finger at 11-year-old. He referred to a clinic and diagnosed fracture of the proximal phalange of the left ring finger. He was treated with a volar splint that included the interphalangeal and metacarpophalangeal joint for 4 weeks. Bone union of the fracture was obtained but scissoring of the finger was appeared. Due to the cosmetic disfigurement and functional dysfunction of the finger, he referred to our hospital. Physical examination showed radial rotation and scissor-

ing of the ring finger over the middle finger was seen on grasping (Fig. 1A, B). Radiographs and computed tomography revealed malunion of the left fourth proximal phalange (Fig. 1C, D, and E). Minimally invasive corrective osteotomy in a malunited phalange was performed at the proximal site of the phalange followed by the external fixation (Fig. 1F, G). After the application of the external fixator for six weeks, he has applied a knuckle splint for two weeks after the removal of the fixator. Follow-up radiographs taken two months after correction showed the union of the osteotomy. He progressed in activities over the next four weeks and returned to full activity without limitations at three months. At the latest follow-up 7 months after surgery, radiographs showed a well-corrected rotational deformity (Fig. 1H, I). He had no functional deficits and barely discernible incision scars (Fig. 1J, K).

Case 2

A 15-year-old right-handed male presented with post-traumatic phalangeal malunion. He fell from the top of a desk and was broken his left third proximal phalange three months previously. He was treated with a volar splint that included the interphalangeal and metacarpophalangeal joint for four weeks. At the first visit our hospital, physical examination showed radial rotation and scissoring of the middle finger over index finger was



**Fig. 1** A photograph of a 12-year-old right-handed male patient with posttraumatic malunion of left ring proximal phalanx. Preoperative scissoring deformity of the left ring finger from malunion of a proximal phalanx fracture. Scissoring deformity of the left ring finger over the middle finger on grasping (A, B). Radiographs did not reveal remarkable malunion of the left forth proximal phalanx (C: posteroanterior, D: lateral view), but three-dimensional CT showed the malunion of the left ring proximal phalanx with rotational deformity (E). Postoperative radiographs, showing the osteotomy line and oblique insertion of the dedicated pins (F: posteroanterior, G: lateral view). Follow-up radiographs taken 2 months after the correction surgery showed union of the osteotomy. At the latest follow-up, 7 months after surgery, radiographs showed a well-corrected rotational deformity (H: posteroanterior, I: lateral view). Photographs of the left hand with fingers in flexion (J) and in extension (K) without restriction of ROM.

seen on grasping (**Fig. 2A, B**). Radiographs revealed malunion of the left third proximal phalanx at the proximal part (**Fig. 2C, D**). The minimally invasive corrective osteotomy was performed at the malunited site of the phalanx, followed an application for Ilizarov external fixator (**Fig. 2E, F**). The external fixation was removed at six weeks postoperatively followed the application for a knuckle splint for four weeks. Follow-up radiographs taken 2 months after correction showed the union of the osteotomy. He progressed in activities over the next six weeks and resumed full activities without pain at three months. At the latest follow-up, 24 months after surgery, radiographs showed a residual deformity, but well-corrected rotational deformity (**Fig. 2G, H**). He had no

functional deficits and no restriction of ROM of the finger. There were barely discernible incision scars (**Fig. 2I, J**).

### Case 3

A 17-year-old right-handed male presented with post-traumatic phalangeal malunion. He fell and twisted his right ring finger at the game of Rugby at 15-year-old. He referred to a clinic and diagnosed a fracture of the proximal phalanx of the right ring finger. He was treated with a volar splint that included the interphalangeal and metacarpophalangeal joint for four weeks. Bone union of the fracture was obtained, but the scissoring of the finger has appeared. Due to the cosmetic disfigurement and functional dysfunction of the finger, he referred to our



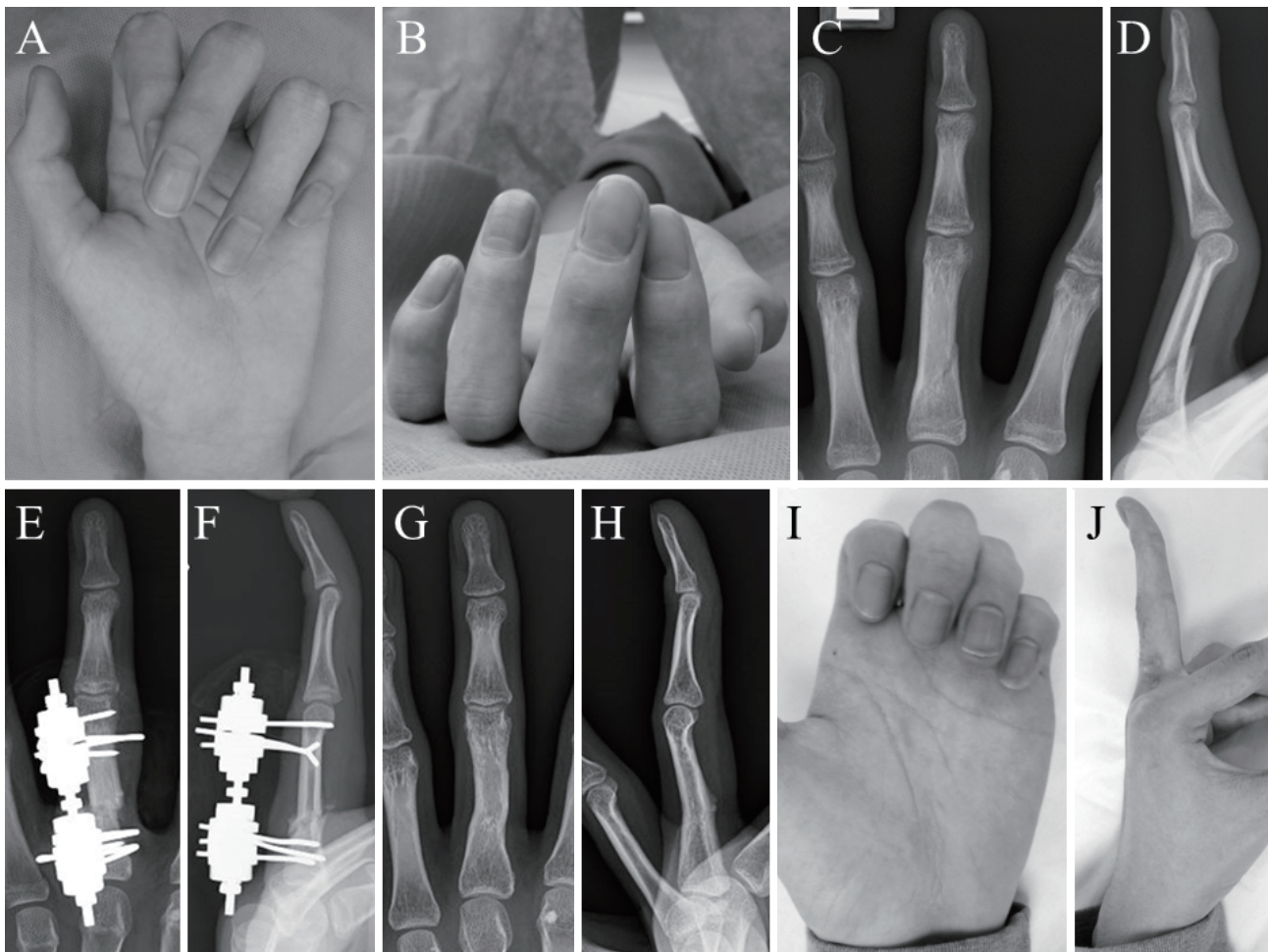


Fig. 2 A photograph of a 15-year-old right-handed male patient with posttraumatic malunion of left third proximal phalanx. Preoperative scissoring deformity of the left middle finger from malunion of a proximal phalanx fracture. Scissoring deformity of the left middle finger over the index finger on grasping (A, B). Radiographs revealed malunion with angular and rotational deformity of the left third proximal phalanx at proximal third of the proximal phalanx (C: posteroanterior, D: lateral view). Postoperative radiographs, showing the osteotomy line and oblique insertion of the dedicated pins (E: posteroanterior, F: lateral view). Follow-up radiographs taken 2 months after the correction surgery showed union of the osteotomy. At the latest follow-up, 24 months after surgery, radiographs showed residual deformity (G: posteroanterior, H: lateral view). Photographs of the left hand with fingers in flexion (I) and in extension (J) without restriction of ROM.

hospital. Physical examination showed ulnar rotation and scissoring of the ring finger over little finger was seen on grasping (Fig. 3A). Radiographs and computed tomography revealed malunion with a remarkable rotational deformity of the right fourth proximal phalangeal bone (Fig. 3B, C, D). The minimally invasive corrective osteotomy was performed at the proximal site of the finger, followed by the application for Ilizarov external fixator (Fig. 3E, F). Because he had the instability of the osteotomized site, an additional temporary fixation with a Kirschner wire was applied at the osteotomized site. He had a pin track infection of a temporary Kirschner wire at three weeks after surgery and the wire was removed. The patient took oral antibiotics for three days and the

infection was mitigated and allowed to maintain the application of the fixator. After the application for the external fixation for six weeks, the patient has applied a knuckle splint for four weeks. Follow-up radiographs taken 9 weeks after correction showed the union of the osteotomy (Fig. 3G, H). He progressed in activities over the next six weeks and returned to the Rugby at the full activity without limitations at three months. At the latest follow-up 18 months after surgery, radiographs showed a residual deformity of the fourth proximal phalange, but well-corrected rotational deformity (Fig. 3G, H). He had no functional deficits without restriction of finger ROM and barely discernible incision scars (Fig. 3I, J). He returned to the Rugby and reported full activity without



Fig. 3 A photograph of a 17-year-old right-handed male patient with posttraumatic malunion of right fourth proximal phalanx. Preoperative scissoring deformity of the ring finger from malunion of a proximal phalanx fracture. Scissoring deformity of the right ring finger over the little finger (A). Radiographs revealed malunion of the right fourth proximal phalanx (B: posteroanterior, C: lateral view). Three-dimensional CT showed the malunion of the left ring proximal phalanx with a remarkable rotational deformity (D). Postoperative radiographs, showing the osteotomy line and oblique insertion of the dedicated pins (E: posteroanterior, F: lateral view). Follow-up radiographs taken 2 months after the correction surgery showed union of the osteotomy. At the latest follow-up, 24 months after surgery, radiographs showed residual deformity (G: posteroanterior, H: lateral view). Photographs of the right hand with fingers in flexion (I) and in extension (J) without restriction of ROM.

pain or limitations.

### Discussion

Various techniques for osteotomy methods, site of osteotomy and the procedures for the fixation of the osteotomized site have been reported for the years<sup>1,4</sup>. However, there is no consensus for the appropriate site of osteotomy, methods of osteotomy, and optimal method and apparatus for the fixation technique<sup>1,4</sup>. In most case reports, a closing or opening wedge osteotomy at the malunion of fracture site was used for correction<sup>3-5</sup>. A cohort study of reviewed 90 corrective phalangeal osteotomies performed over twenty years for posttraumatic malunion showed that the best method to correct lateral angula-

tion, flexion, or extension deformities to be an incomplete opening-wedge osteotomy<sup>3</sup>. To obtain an anatomical correction, many researcher described that a corrective osteotomy of phalanx should be undergone at the site of the fracture. However, the internal fixation after the osteotomy on the site of the original fracture could limit the range of motion of fingers because of producing additional adhesions of the flexor and extensor on the phalanx. Moreover, the development of adhesions in the flexor or extensor systems and shortening of the phalanges could result in the extension lag<sup>1,4,9,10</sup>. Some have advocated correction at the base of the metacarpal of the affected finger<sup>11-13</sup>. They described that metacarpal osteotomy of the affected finger could provide correction of ro-

tation without potential adhesions<sup>13</sup>. However, a physical limitation to the extent of metacarpal derotation reported in a cadaveric study<sup>14</sup>. Thus, the corrective osteotomy for the malunion of phalange should be performed at the site of the malunited phalange.

According to previously reported research, most surgeons consider that a corrective osteotomy should be performed at the site of the fracture. As for the procedure of the fixation for the osteotomized site, several researchers have been reported open correction with osteotomies followed by internal fixation with plate or screws. Buehler *et al.*<sup>3</sup> and Trumble *et al.*<sup>5</sup> have reported surgical correction of deformity with a plate to provide satisfactory function and outcomes for 41 cases with the malunion of the proximal phalanx. Moreover, satisfactory clinical outcomes of the surgical treatment of the malunited proximal phalanx have reported in limited cases<sup>1,4,10,15,16</sup>. However, unresolved issue is the adhesions of the flexor and extensor tendons, caused by the procedures of the internal fixation and apparatus of device for fixation. Even osteosynthesis for the fresh fractures of the phalanx always provides the adhesions of the flexor and extensor tendons, resulting in the restriction of the range of motion and the lag of flexion/extension. Thus, adhesion of the flexion and extensor tendons after internal fixation for the correction osteotomy should be inevitable. Furthermore, internal fixation of the phalanx by plate and screw occasionally would be a cause of persistence pain and stimulation of the skin, and the removal operation may be required<sup>14</sup>.

Currently, we presented 3 cases who undergone corrective osteotomy for malunion of proximal phalanges. Our methods provides cosmetically and functionally satisfactory outcomes and no patients complaints residual pain or functional disturbance. First and foremost, our minimally invasive method is simple and straightforward to undergo. Our method uses short skin incisions, the dedicated pins, 5-mm osteotome and the mini-external fixator, therefore avoiding the dissection of surrounding tendons and avoiding additional adhesions<sup>6</sup>. Osteotomy with the osteotome can preserve periosteum, which would be intact even after correction of the alignment of phalanx. Also, our procedure can be performed by a digital block of the affected finger if the patient's desire and active flexion and extension can be performed until the most accurate alignment is found when patient is awake and conscious. Furthermore, the Ilizarov mini-fixator provides the distraction osteogenesis when the shortening of the phalange<sup>7</sup>. Moreover, the three-

dimensional fixation using the Ilizarov mini-fixator would provide the stable fixation of the site of the osteotomy. On the other hand, a drawback is that our methods using an external fixator have a possibility of pin site infection. Thus, appropriate management and watchful observation of the insertion sites of the pins would be essential.

It is still unclear if this device provides satisfactory outcome for malunions of the proximal phalanx in the adult patients who had matured phalanges. Although further investigation for whether our method is applicable for adults or not would be required, the minimally invasive correction procedure using the Ilizarov mini-fixator is straightforward and reproducible solution for malunions of the proximal phalanx.

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**Conflict of Interest:** The authors declare that they have no conflict of interest. The authors alone are responsible for the content and writing of the paper.

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