










Plating after lengthening in treating phalangeal and metacarpal deficiency: An alternative method

Rui Zhang, MD¹, Mengwei Wang, MD^{2*}, Xiaoyu Wang, MD¹, Li Shi, MD³, Shenghe Liu, MD¹,
Jia Xu, MD¹, Qinglin Kang, MD¹

¹Department of Orthopedics, Shanghai Jiao Tong University Affiliated Sixth People's Hospital, Shanghai, China

²Department of Trauma and Microscopic Orthopedics, Renmin Hospital of Wuhan University, Wuhan, China

³Department of Traumatic Surgery, Chongqing Municipal Fourth Hospital, Chongqing, China

The reconstruction of traumatic or congenital short phalanges and metacarpals is a challenging topic in hand surgery and microsurgery.^[1,2] Several methods for their reconstruction have been investigated in early reports, including bone grafting and toe-to-hand transfer.^[3-5] However, these methods are reported to be invasive, as the operation to the donor site damaged its integrity and may result in complications.

Distraction osteogenesis (DO) has become a relatively widely accepted option for the lengthening of long bones.^[6] This method has been applied for phalanges and metacarpals lengthening and obtain favorable results in recent years.^[7-13] Although DO is a less-invasive technique compared with earlier

Received: January 18, 2022

Accepted: March 23, 2022

Published online: July 06, 2022

Correspondence: Qinglin Kang, MD. Department of Orthopedics, Shanghai Jiao Tong University Affiliated Sixth People's Hospital, 200233 Shanghai, China.

E-mail: orthokang@163.com

Correspondence: Jia Xu, MD. Department of Orthopedics, Shanghai Jiao Tong University Affiliated Sixth People's Hospital, 200233 Shanghai, China.

E-mail: xujia0117@126.com

Doi: 10.52312/jdrs.2022.566

* Co-First Author

Citation: Zhang R, Wang M, Wang X, Shi L, Liu S, Xu J, et al. Plating after lengthening in treating phalangeal and metacarpal deficiency: An alternative method. Jt Dis Relat Surg 2022;33(2):265-272.

©2022 All right reserved by the Turkish Joint Diseases Foundation

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes (<http://creativecommons.org/licenses/by-nc/4.0/>).

ABSTRACT

Objectives: This study aims to investigate whether plating after lengthening in patients with phalanges and metacarpals deficiency could significantly shorten the duration of external fixation and decrease bone healing index.

Patients and methods: Between February 2010 and December 2018, 11 phalanges in nine patients (6 males, 3 females; mean age: 28.4±4.4 years; range, 22 to 35 years) and nine metacarpals in six patients (2 males, 4 females; mean age: 21.0±2.9 years; range, 16 to 25 years) were lengthened at a rate of 0.25 mm in two increments. A unilateral external fixator was applied in all cases. A locking compression plate was applied at the end of the distraction period before the external fixator was removed. Removal of the plate was considered two years after the internal fixation.

Results: The desired length and bone consolidation were achieved in all cases. The additional lengths achieved in the phalanges and metacarpals group were 18.3 mm and 27.7 mm on average, respectively. The bone healing indexes in the phalanges and metacarpals were 1.33 and 1.44 mo/cm, respectively. No significant difference was observed in the pre- and postoperative range of motion of involved metacarpophalangeal joint of both phalangeal (95% CI: -0.469~1.014, t=0.820, p=0.432) and metacarpal (95% CI: -0.689~0.975, t=0.420, p=0.689) lengthening cases. Only one case of minor complication (track infection) occurred.

Conclusion: Plating after lengthening is an ideal method for phalanges and metacarpals deficiency. Its advantages include shorter duration of external fixation, lower complication rate, and early functional recovery.

Keywords: Complication, deficiency, distraction osteogenesis, external fixation, metacarpal, phalange, plating after lengthening.

approaches, several problems brought about while utilizing the external frame alone including pain, joint stiffness, nail-track infection and discomfort, still remains.^[10,14]

The disadvantages of using external fixation alone encouraged us to make changes. We replaced the external fixator with a locking compression plate (LCP) after adequate length was achieved through

DO to shorten the long period of external fixation. The whole consolidation phase, therefore, was fixator-free. The method was called plating after lengthening (PAL). In the present study, we aimed to investigate whether PAL in patients with phalanges and metacarpals deficiency could greatly shorten the duration of external fixation and decrease bone healing index (BHI).

PATIENTS AND METHODS

This retrospective study was conducted at Shanghai Sixth People's Hospital, Department of Orthopedics between February 2010 and December 2018. A total of 11 phalanges (8 traumatic and 3 congenital) in nine patients (6 males, 3 females; mean age: 28.4 ± 4.4 years; range, 22 to 35 years) and nine metacarpals (2 traumatic and 7 congenital) in six patients (2 males, 4 females; mean age: 21.0 ± 2.9 years;

range, 16 to 25 years) were treated with the PAL method. All patients were right-hand dominant.

All traumatically shortened phalange cases were due to transverse electric-saw laceration, and previous amputations were performed to obliterate the damaged distal to proximal interphalangeal joints. While in traumatically shortened metacarpal cases, electric-saw laceration led to the amputation around the metacarpophalangeal (MCP) joints (Tables I and II).

Surgical technique

Two main operations, DO and plating, respectively, are required to perform PAL. First, the shortened phalanges and metacarpals were osteotomized and lengthened with the external fixator. The second operation of plating was performed during consolidation period.

TABLE I

Demographic information of patients treated with phalangeal PAL

Case	Age (year)	Sex	Dominant hand	Affected side	Affected phalanges	Cause of brachydactyly
1	35	F	Right	Right	Index	Traumatic amputation distal to PIP joint
2	23	M	Right	Left	Thumb	Congenital
3	28	M	Right	Right	Middle	Traumatic amputation distal to PIP joint
4	34	M	Right	Left	Index	Traumatic amputation distal to PIP joint
				Left	Middle	Traumatic amputation distal to PIP joint
5	28	F	Right	Right	Thumb	Congenital
6	27	M	Right	Left	Index	Traumatic amputation distal to PIP joint
7	22	M	Right	Left	Index	Traumatic amputation distal to PIP joint
				Left	Middle	Traumatic amputation distal to PIP joint
8	26	F	Right	Left	Thumb	Congenital
9	33	M	Right	Right	Index	Traumatic amputation distal to PIP joint

PAL: Plating after lengthening; F: Female; M: Male; PIP: Proximal interphalangeal.

TABLE II

Demographic information of patients treated with metacarpal PAL

Case	Age (year)	Sex	Dominant hand	Affected side	Affected phalanges	Cause of brachydactyly
1	23	F	Right	Right	Fifth	Traumatic amputation proximal to MCP joint
2	21	F	Right	Left	Fifth	Congenital
3	16	M	Right	Left	Fourth	Traumatic amputation proximal to MCP joint
4	19	F	Right	Right	Third	Congenital
				Right	Fourth	Congenital
5	25	F	Right	Right	Fourth	Congenital
			Right	Left	Fifth	Congenital
6	22	M	Right	Left	Fourth	Congenital
				Left	Fifth	Congenital

PAL: Plating after lengthening; F: Female; M: Male; MCP: Metacarpophalangeal.

The operations of installation of external fixator and osteotomy were performed under brachial plexus anesthesia, and a pneumatic tourniquet was applied to the upper arm. A small incision of approximately 2 cm was made on the dorsal ulnar or radial side of the phalanges or metacarpals, which was perpendicular to the longitudinal axis of the bone, to perform further osteotomy. Two pins were first inserted into the proximal and distal metaphysis bone navigated by the guide plate of the unilateral fixator. Before installing the intermediate and distal pins, the shortened phalanges or the stumps were extended. We, then, pushed the dorsal skin toward the proximal end and then inserted a 1.2-mm Kirschner wire through the bone of the finger or the stump to create longitudinal stability. The excess palmar skin was stored between the proximal end and the middle side and, thus, during the distraction period, the skin would move with the tracks of the pins, cutting the skin as little as possible. The rest pins were, then, drilled into the bone according to the guide plate, leaving adequate space for osteotomy around the incision.

The level of osteotomy was chosen at the diaphysis in all cases. Osteotomy was performed below the periosteum in the middle part of the phalangeal or metacarpal bone. The external fixator was, then, installed and screws were tightened. The unilateral mini fixator (CIIC Medical Instrument Co., Ltd., Shanghai, China) was applied for lengthening. When a nut was turned 360°, the hollowed bolt traveled 1 mm on the rod. Sterile gauze was wrapped around the nail tracks tightly, and oral cephadroxil medication was given 500 mg twice daily for the first five days after operation to prevent substantial infection.

In all cases, lengthening was started after a 10-day latency at a rate of 0.25 mm per 12 h and was not stopped until the final length was achieved. Two signs indicating final length were reached: (i) the lengthened bone reached the length of the contralateral or healthy bone radiologically, and (ii) distal skin or the neurovascular tissues permitted no more distraction, which was indicated by paleness or numbness. Passive and active tendon gliding and joint movement were also encouraged after the latency to avoid tendon adhesion and joint stiffness.

After the final length was obtained, general anesthesia or brachial plexus block anesthesia was utilized, and a pneumatic tourniquet was applied. The external fixator was, then, replaced by an LCP at the end of the distraction period. A small incision was created through plane avoiding existing pins and previous surgical plane. The AO LCP (Johnson & Johnson Medical Devices Co., Ltd., Shanghai, China)

was, then, inserted and fixed to the elongated bone. The external fixator was not removed until full installation of the plate to provide adequate stability. Monthly follow-up was scheduled to ensure the consolidation.

One week after the LCP fixation, passive and active movement practices of the joints of the treated phalanges and metacarpals were allowed to prevent joint stiffness and tendon adhesion. Physical therapies, including electrotherapy and thermotherapy, were carried out to eliminate neurovascular complications. Removal of the plate was considered two years after the internal fixation.

Radiographic evaluation

The length of the elongated bone was measured with X-ray tests pre- and postoperatively. The difference between the pre- and postoperative lengths of the lengthened bone was calculated as ΔL . The external fixator time (EFT), which refers to the duration of wearing the external fixator, consolidation time (CT), follow-up time (FT), and the total time (TT) from the first operation to observed full consolidation of the bone was recorded in each case. Consolidation was tested with radiography and evaluated by two experienced orthopedists. In general, full consolidation is achieved at six to seven weeks postoperatively in phalanges and metacarpal bones. External fixation index (EFI) and BHI were calculated to evaluate the efficiency of the PAL method.^[15,16] The EFI and BHI are calculated using the following formulae:

$$\text{EFI} = \frac{\text{EFT}}{\Delta L} \text{ (d/cm)} \quad \text{BHI} = \frac{\text{TT}}{\Delta L} \text{ (mo/cm)}$$

Functional evaluation

All patients were asked to finish the Michigan Hand Outcome (MHO) Questionnaire to evaluate the treatment at every follow-up after internal fixation.^[17] Two-point discrimination (2PD) and pinch force (PF) of the involved and healthy phalanges or metacarpals were tested three months after LCP fixation. The PF of the elongated phalanges or the ipsilateral phalanges of the elongated metacarpals was compared with the PF of contralateral phalanges, and the relative PF (rPF) was calculated with the following formula to demonstrate the PF of the elongated fingers.

$$\text{EFI} = \frac{\text{ipsilateral PF}}{\text{contralateral PF}} \times 100\%$$

For thumb-elongated patients, Kapandji opposition test was performed to evaluate its function. For

elongated congenital short metacarpals and other fingers, pre- and postoperative (at last follow-up) range of motions (ROMs) of flexion and extension of each involved MCP joint were measured to evaluate joint stiffness.

Complications including infection, delayed bone healing, fracture, rupture of tendon, joint stiffness and paresthesia were recorded.

Statistical analysis

Statistical analysis was performed using the GraphPad Prism version 5.0. (Graphpad Software

Inc., San Diego, CA, USA). Normal distribution was checked statistically. Descriptive data were expressed in mean ± standard deviation (SD) for continuous variables, and in number and frequency for categorical variables. Paired two-group t-test was applied to compare outcomes. A *p* value of <0.05 was considered statistically significant.

RESULTS

Efficacy results

The details of the efficacy results of each case are summarized in Table III and Table IV. The mean FT

TABLE III Phalanges elongation												
Case	Phalanges	FT (mo)	ΔL (mm)	EFI (d/cm)	CT (w)	BHI (mo/cm)	rPF (%)	2PD (mm)	Kapandji opposition	MHO score (%)	ROM of MCP (°)	
											Pre-	Post-
1	Index	64	20	25.0	6.0	1.53	67	8	-	85	85	85
2	Thumb	34	21	24.8	7.9	1.67	81	15	5	79	83	82
3	Middle	33	19	25.3	4.5	1.40	86	10	-	83	84	84
4	Index	37	16	26.3	6.8	1.20	88	6	-	82	85	83
	Middle	37	16	26.3	6.8	1.20	40	6	-	91	81	82
5	Thumb	39	23	24.3	6.5	1.47	80	8	9	88	82	82
6	Index	34	13	27.7	4.9	1.13	63	11	-	67	86	85
7	Index	41	18	25.6	6.3	1.33	89	9	-	78	85	83
	Middle	41	18	25.6	6.3	1.33	78	9	-	84	83	83
8	Thumb	39	22	24.5	7.1	1.23	82	6	8	89	84	85
9	Index	30	15	26.7	6.1	1.17	89	7	-	87	82	83
Mean		39.0	18.3	25.65	6.29	1.33	70.0	8.6	7.3	83.0	83.6	83.4

FT: Follow-up time; ΔL: Difference of the pre- and post-operative length; EFI: External fixator index; CT: Consolidation time; BHI: Bone healing index; rPF: Relative pinch force; 2PD: Two-point discrimination; MHO: Michigan hand outcome; ROM: Range of motion; MCP: Metacarpophalangeal joint; Pre-: Preoperative; Post-: Postoperative.

TABLE IV Metacarpals elongation											
Case	MC	FT (mo)	ΔL (mm)	EFI (d/cm)	CT (w)	BHI (mo/cm)	rPF (%)	2PD (mm)	MHO score (%)	ROM of MCP (°)	
										Pre-	Post-
1	Fifth	38	30	23.3	7.1	1.33	86	8	91	/	/
2	Fifth	34	28	23.6	7.7	1.43	88	6	90	85	84
3	Fourth	33	24	24.2	7.4	1.53	83	10	79	/	/
4	Third	37	24	24.2	8.5	1.64	79	12	83	82	83
	Fourth	37	30	23.3	8.6	1.44	90	12	86	83	83
5	Fourth	48	24	24.2	7.1	1.50	88	6	90	80	81
	Fifth	48	32	23.1	7.2	1.29	89	6	89	81	80
6	Fourth	34	26	23.8	7.2	1.44	71	7	92	84	83
	Fifth	34	32	23.1	7.5	1.32	67	7	86	81	81
Mean	-	38.1	27.7	23.64	7.59	1.44	82.3	8.2	87.3	82.3	82.1

MC: Metacarpal; FT: Follow-up time; ΔL: Difference of the pre- and post-operative length; EFI: External fixator index; CT: Consolidation time; BHI: Bone healing index; rPF: Relative pinch force; 2PD: Two-point discrimination; ROM: Range of motion; MCP: Metacarpophalangeal joint; Pre-: Preoperative; Post-: Postoperative.

was 39.0 ± 8.6 (range, 30 to 64) months and 38.1 ± 5.5 (range, 34 to 48) months in phalangeal and metacarpal lengthening cases, respectively. The mean distraction time was 36.6 ± 5.9 (range, 26 to 46) days and 55.6 ± 6.3 (range, 48 to 64) days in phalangeal and metacarpal lengthening cases, respectively. The mean ΔL was 18.3 ± 3.0 (range, 13 to 23) mm and 27.7 ± 3.2 (range, 24 to 32) mm in phalangeal and metacarpal lengthening cases, respectively. The mean CT was 6.29 ± 0.91 (range, 4.5 to 7.9) weeks and 7.59 ± 0.55 (range, 7.1 to 8.6) weeks in phalangeal and metacarpal lengthening cases, respectively.

The mean EFI was 25.65 ± 0.98 (range, 24.3 to 27.7) d/cm and 23.64 ± 0.44 (range, 23.1 to 24.2) d/cm

in phalangeal and metacarpal lengthening cases, respectively. The mean BHI was 1.33 ± 0.16 (range, 1.13 to 1.67) mo/cm and 1.44 ± 0.11 (range, 1.29 to 1.64) mo/cm in phalangeal and metacarpal lengthening cases, respectively.

Functional results

The details of the functional results of each case are summarized in Table III and Table IV. The mean rPF was 70.0% (range, 40 to 89%) and 82.3% (range, 67 to 90%) in phalangeal and metacarpal lengthening cases, respectively. The mean 2PD was 8.6 (range, 6 to 15) mm and 8.2 (range, 6 to 12) mm in phalangeal and metacarpal lengthening cases, respectively. The 2PD was maintained in

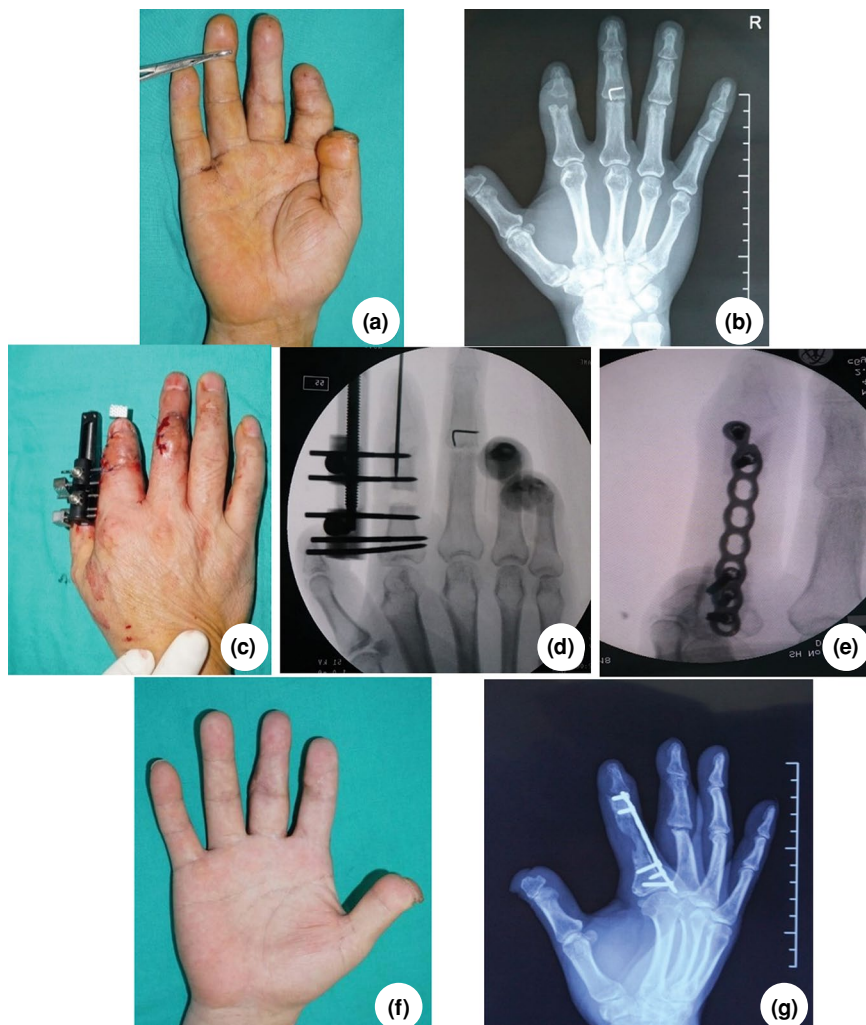


FIGURE 1. Posttraumatic brachydactyly of right index finger treated with PAL. (a, b) Preoperative physical appearance and radiography showed that middle phalanx was amputated with the distal phalanx replanted to the proximal residual. (c, d) Postoperative physical appearance and radiography with external fixator installed. (e) Final length was reached and the external fixator was replaced by LCP. (f, g) Physical appearance and radiography showed satisfactory length and bone consolidation at final follow-up.

PAL: Plating after lengthening; LCP: Locking compression plate.

each patient due to our definition of final length. The mean MHO score was 83.0% (range, 67 to 91%) and 87.3% (range, 79 to 92%) in phalangeal and metacarpal lengthening cases, respectively. In thumb elongation cases, the mean point of Kapandji opposition test was 7.3 (range, 5 to 9). Mean pre- and postoperative ROM of each involved MCP joint was 83.6° and 83.4°, respectively, in phalangeal lengthening cases. Mean pre- and postoperative ROM of each involved MCP joint was 83.6° and 83.4°, respectively, in metacarpal lengthening cases. No significant difference was observed in the pre- and postoperative ROM of involved MCP joint of both phalangeal (95% confidence interval [CI]: -0.469~1.014, $t=0.820$, $p=0.432$) and metacarpal (95% CI: -0.689~0.975, $t=0.420$, $p=0.689$) lengthening cases.

Only one case of minor complication (track infection) occurred. No major complications include delayed union, refracture, rupture of tendons, insufficient blood supply of distal part of the elongated finger, sensory loss or stiffness of joints occurred. All patients achieved complete consolidation of the bone callus and at the final follow-up, were satisfied with the functional and cosmetic outcomes. Typical phalangeal and metacarpal PAL cases were presented in Figures 1 and 2.

DISCUSSION

Long period of fixator wearing has been mentioned and the complications including track infection, extrusion of sharp bone end and joint stiffness result in great discomfort for patients.^[8-11,13,18] The main goal of the PAL technique is to shorten the EFT

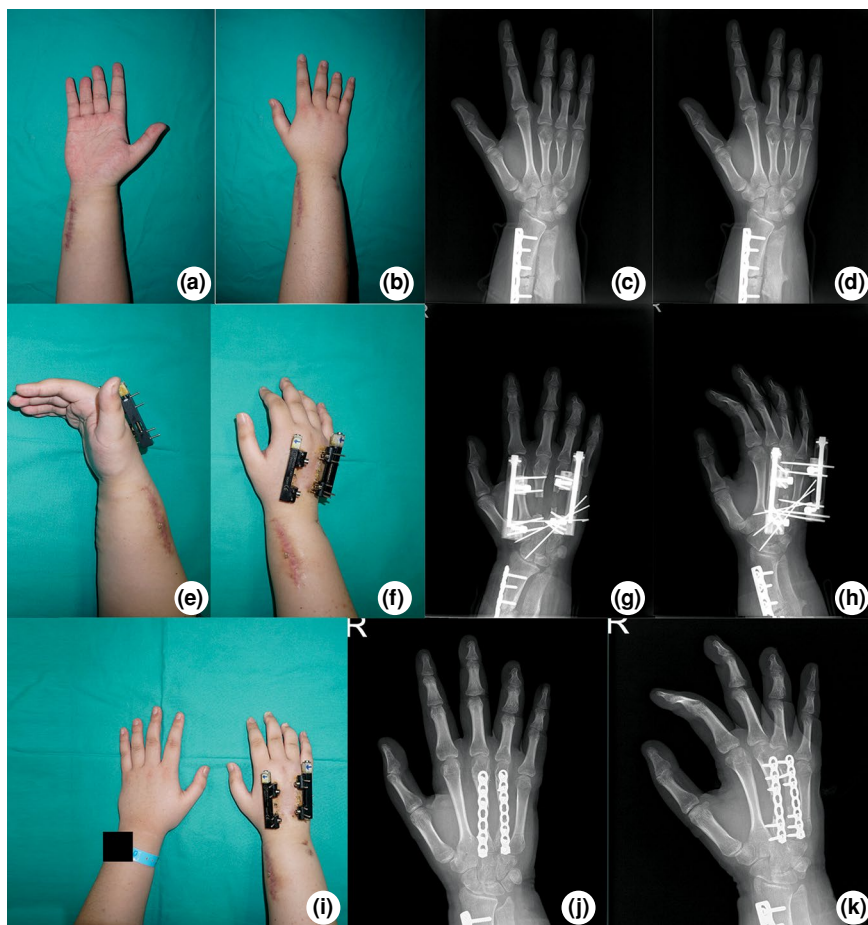


FIGURE 2. Congenital brachydactyly due to right third and fourth metacarpals shortage treated with PAL. (a-d) Preoperative physical appearance and radiography showed great metacarpal ray deficiency of the third and fourth metacarpals and fingers. (e-h) Postoperative physical appearance and radiography with external fixator installed. Captured when final length was reached in both metacarpals. (i) Comparison with the other side, which shared the deficiency but did not undergo elongation. (k) Radiography after LCP replacement. Normal lengths of the involved metacarpal rays were achieved and bone consolidation was satisfactory. PAL: Plating after lengthening; LCP: Locking compression plate.

with safe conversion to internal fixation, as long as the distraction phase is completed. Researchers have applied the PAL method for tibia or femur lengthening cases and received good results, and the PAL method was first attempted in thumb lengthening by Bodmer et al.^[7] in 2017.^[19-23] Functions and appearance of the thumbs were partially reconstructed, although the study included only five patients and four of five of their FT was less than two years.^[7] In this study, 11 phalanges and nine metacarpals were included and the minimum FT was 30 months to confirm the advantages of the PAL method.

There are two major advantages of the PAL method: first, the use of a plate greatly reduces the EFI and accelerates bone healing.^[24] In our study, the indexes were 25.65 d/cm in phalanges and 23.64 d/cm in metacarpals, which were significantly lower compared to the EFI of studies in which the external fixators were not removed until consolidation.^[14] The BHI, however, was also astonishingly smaller than external fixator-only cases. Furthermore, the LCP can promise general stability of the elongated bone which prevents secondary fracture. Consequently, the mean BHI were 1.33 mo/cm in phalanges and 1.44 mo/cm in metacarpals, lower than that of others' reports.^[1,10,14,16] A lower BHI was seen in Bodmer et al.'s^[7] study probably due to their higher lengthening rate under semicircular fixator, which could provide better stability than unilateral fixator during DO.^[7] Hence,

PAL not only relieved patients from long duration of inconvenience and discomfort wearing external fixators, but also accelerated bone healing.

On the other hand, phalanges and metacarpal lengthening with PAL resulted in few complications. One fracture and four joint stiffness were reported by Heo et al.^[14] In external fixator-only finger lengthening cases, probably as the thin soft tissues around the phalangeal bones could not facilitate bone healing.^[25] In the Hosny and Kandel's^[10] study, one of eight patients developed nail-track infection and in Kanchanathepsak et al.'s,^[25] two of 15 (Table V). The overall complication rate in our study was 5%, less than that of previous studies. The application of the plate greatly shortened the EFT, which eliminated the incidence of fistula formation, thereby reducing the possibility of track infection. In addition, we observed that if the skin was kept dry, there is no need for frequent re-dressing and no track infection happened.

In the present study, we observed no delayed bone healing, fracture, rupture of tendon, joint stiffness or paresthesia, which can be attributed to the advantage of LCP fixation and our postoperative precautionary measures.

There are several points that surgeons should pay attention before replacing the external fixator with LCP: (i) general state allowing no further surgery, e.g., systematic inflammation, renal insufficiency, epilepsy, etc.; (ii) acute or chronic infection around

TABLE V
Indices from other phalanges and metacarpals lengthening studies

Researchers	Type of elongation	Sample size	Mean EFI (d/cm)	Mean BHI (mth/cm)	Complications
Hosny and Kandel ^[10]	External fixator only	8	65.1	2.17	1 premature consolidation 5 MCP flexion deformity 1 pin track infection
Bodmer et al. ^[7]	PAL	5	15.4	1.10	0 complication
Heo et al. ^[14]	External fixator only	51	69.0 in phalanges 52.0 in metacarpals	2.30 in phalanges 1.40 in metacarpals	1 nonunion 1 fracture 1 premature union 2 angulation 2 dislodgment of the pin 4 delayed callus formation 4 joint stiffness 1 soft tissue thinning
Sawaizumi and Ito ^[16]	External fixator only	5	71.4	2.38	4 extensive skin tension 1 DIP flexion deformity
Kanchanathepsak et al. ^[25]	External fixator only	26	114.0 in phalanges 60.0 in metacarpals	3.80 in phalanges 2.00 in metacarpals	2 pin track infection
Ding et al. ^[9]	External fixator and secondary bone graft	201	No specific report	No specific report	2 skin rupture 2 phalangeal splitting 36 web space contraction

EFI: External fixation index; BHI: Bone healing index; MCP: Metacarpophalangeal; PAL: Plating after lengthening; DIP: Distal interphalangeal.

surgical region; (iii) severe osteoporosis where the LCP is planned to be placed; (iv) bone metabolic disease onset during distraction period; and (v) patients' refusal to the LCP conversion.

Our study has several limitations. The number of samples of this study is still small. However, we believe that selection bias was minimized in this study, as most of the patients underwent the procedure unless it was contraindicated or the patient chose the traditional external fixator-only protocol. Although the sample size was rather small and the FT was limited, there was no loss-to-follow-up. The two-step operation and the financial issues of the procedure should be also considered as disadvantages.

In conclusion, PAL technique successfully combined the advantage of external fixation and the benefits of internal fixation in phalangeal and metacarpal lengthening. Temporary external fixator was applied for stability and gradual DO. Once the desired length was achieved, the callus was permanently fixed by an LCP and the external fixator was removed. This approach can be an alternative and effective method for phalangeal lengthening with fewer complications. However, further studies are acquired to confirm its strength and weakness.

Ethics Committee Approval: The study protocol was approved by the Institutional Ethics Committee of Shanghai Sixth People's Hospital (2021-KY-113[K]). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Manuscript drafting: R.Z., M.W.; Data collection: X.W.; Data analysis: L.S.; Administrative support: S.L.; Study design: J.X., Q.K.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: Received financial support from National Natural Science Foundation of China (No. 82072421) and Natural Science Foundation of Shanghai (No.20ZR1442200).

REFERENCES

- Friedrich JB, Vedder NB. Thumb reconstruction. *Clin Plast Surg* 2011;38:697-712.
- Kumta SM. Unfavourable results in thumb reconstruction. *Indian J Plast Surg* 2013;46:294-302.
- Iba K, Wada T, Yamashita T. On-top plasty using a free metacarpal head graft for lengthening of proximal phalanx in symbrachydactyly—a case report. *Hand Surg* 2013;18:273-5.
- Kakinoki R, Ikeguchi R, Matsumoto T, Nakamura T. Reconstruction of a phalangeal bone using a vascularised metacarpal bone graft nourished by a dorsal metacarpal artery. *Injury* 2008;39 Suppl 4:25-8.
- Waljee JF, Chung KC. Toe-to-hand transfer: Evolving indications and relevant outcomes. *J Hand Surg Am* 2013;38:1431-4.
- Runyan CM, Gabrick KS. Biology of bone formation, fracture healing, and distraction osteogenesis. *J Craniofac Surg* 2017;28:1380-9.
- Bodmer ES, Meier R, Slongo T, Voegelin E. Thumb lengthening following amputation at the proximal phalanx using a semicircular distraction ring fixator: Results of 5 cases. *Handchir Mikrochir Plast Chir* 2017;49:42-6.
- Danilkin MY. Phalangeal lengthening techniques for brachydactyly and posttraumatic digital stumps with the use of a modified external mini-fixator. *Tech Hand Up Extrem Surg* 2016;20:61-6.
- Ding Z, Zhu X, Fu K, Zheng X. Digital lengthening to treat finger deficiency: An experience of 201 digits in 104 patients. *Biomed Res Int* 2017;2017:4934280.
- Hosny GA, Kandel WA. Distraction lengthening by callotasis of traumatically shortened bones of the hand. *J Trauma Acute Care Surg* 2012;72:1676-80.
- Iba K, Takashima K, Hanaka M, Teramoto A, Emori M, Saito A, et al. Long-term outcomes after phalangeal distraction lengthening in patients with constriction band syndrome. *J Plast Surg Hand Surg* 2021;55:268-72.
- Matev IB. The bone-lengthening method in hand reconstruction: Twenty years' experience. *J Hand Surg Am* 1989;14:376-8.
- Nazerani S, Kalantar Motamedi MH, Ebrahimipour A, Vahedian J, Nazerani T, Nazerani T, et al. A simple and light weight external fixator for distraction advancement manoplasty. *Trauma Mon* 2012;17:353-7.
- Heo CY, Kwon S, Back GH, Chung MS. Complications of distraction lengthening in the hand. *J Hand Surg Eur Vol* 2008;33:609-15.
- De Bastiani G, Aldegheri R, Renzi-Brivio L, Trivella G. Limb lengthening by callus distraction (callotasis). *J Pediatr Orthop* 1987;7:129-34.
- Sawaizumi T, Ito H. Lengthening of the amputation stumps of the distal phalanges using the modified Ilizarov method. *J Hand Surg Am* 2003;28:316-22.
- Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. *J Hand Surg Am* 1998;23:575-87.
- Codivilla A. On the means of lengthening, in the lower limbs, the muscles and tissues which are shortened through deformity. 1904. *Clin Orthop Relat Res* 1994;(301):4-9.
- Cha SM, Shin HD, Kim KC, Song JH. Plating after tibial lengthening: Unilateral monoaxial external fixator and locking plate. *J Pediatr Orthop B* 2013;22:571-6.
- Harbacheuski R, Fragomen AT, Rozbruch SR. Does lengthening and then plating (LAP) shorten duration of external fixation? *Clin Orthop Relat Res* 2012;470:1771-81.
- Nayagam S, Davis B, Thevendran G, Roche AJ. Medial submuscular plating of the femur in a series of paediatric patients: A useful alternative to standard lateral techniques. *Bone Joint J* 2014;96-B:137-42.
- Pescio F, Fletscher G, Zuluaga M. Submuscular plating of the femur through an anterior approach after bone distraction. *Strategies Trauma Limb Reconstr* 2017;12:53-8.
- Uysal M, Akpınar S, Cesur N, Hersekli MA, Tandoğan RN. Plating after lengthening (PAL): Technical notes and preliminary clinical experiences. *Arch Orthop Trauma Surg* 2007;127:889-93.
- Atik OŞ. What are the expectations of an editor from a scientific article? *Jt Dis Relat Surg* 2020;31:597-8.
- Kanchanathepsak T, Gotani H, Hamada Y, Tanaka Y, Sasaki K, Yagi H, et al. The effectiveness of distraction lengthening in traumatic hand amputation with Ilizarov mini fixator. *Injury* 2020;51:2966-9.