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A Simple, Easy, and Reliable Technique of Phalangeal Corrective Osteotomy for Overlapping Fingers

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Background: The theory that malrotation is best assessed by making a fist and looking for digital overlap was the basis for devising a simple, easy, and reliable technique for phalangeal corrective osteotomy.
Methods: This study assessed the phalangeal corrective osteotomy technique in 7 digits, involving 7 cases in 6 patients; 1 patient required treatment bilaterally. This technique required the use of a small hologram 2-row plate and screws to maintain stable fixation during aggressive postoperative therapy. Evaluation of the clinical results was based on the total range of active motion (%TAM), the grading of results according to Büchler, and the severity of pain reported by patients using the visual analog scale. The disability of the arm, shoulder, and hand questionnaire was completed preoperatively and at final follow-up by patients.
Results: Corrective osteotomy corrected the overlapping of digits in all of the patients. There were no perioperative complications. Bone union was obtained in all cases, on average 13.4 weeks after surgery. Two osteotomies required secondary tenocapsulolysis concomitant with implant removal surgery. In light of total range of active motion and Büchler's grade, all the patients had excellent to good results for both criteria at final follow-up. No patient complained about pain. Mean disability of the arm, shoulder, and hand scores significantly decreased from 16.9 (range, 11.3–26.5) preoperatively to 3.9 (range, 0–7.6) postoperatively.
Conclusions: Phalangeal corrective osteotomy was performed using a simple, easy, and reliable technique. *(Plast Reconstr Surg Glob Open 2015;3:e454; doi: 10.1097/GOX.0000000000000421; Published online 16 July 2015.)*

Management of fractures of the phalanges is complicated by numerous problems. Neglect or inadequate treatment can lead to significant disability, given the intricate relationship between the flexor and extensor tendons, and the architecture of the phalanges. Although failure to obtain bone union following phalangeal fractures is rare, concomitant complications can emerge. Malunion is considered a common complication of fractures of the phalanges of the hand. Although rotational alignment is just as essential as alignment in the coronal and sagittal planes, given the typical 3-dimensional nature of malunions, preoperative assessment is made more difficult when relying on 2-dimensional radiographic data. Even a small amount of rotational malunion can cause significant functional impairment. As little as 5-degree malrotation can cause 1.5 cm of digital overlap,[1] but sometimes this cannot be fully appreciated

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until the digits regain a certain level of active joint mobility. Malunion of the phalangeal bone may cause cosmetic deformities and functional deficits that include scissoring or overlapping of the fingers, a disturbance in tendon balance, and a reduction of grip strength.[2] Thus, surgical intervention is necessary for this condition. However, previously described techniques require precise geometric assessment of the deformity and complicated preoperative plotting.[3,4] Surgeons may experience challenges related to the precise correction of a malrotation during surgery, as planned corrections can be difficult to perform.

According to the theory that posits malrotation is best assessed by making a fist and looking for digital overlap, a simple, easy, and reliable technique was devised. That technique uses a small hologram 2-row plate and screws for the treatment of either rotational or angular malunion combined with rotation of the phalangeal bone, which can better withstand the strain of aggressive postoperative therapy.

PATIENTS AND METHODS

Surgical Indications

The technique we describe, phalangeal corrective osteotomy for overlapping fingers, is indicated for malunion of extra-articular proximal and middle phalangeal factures. Even when the original fracture site is close to the level of the joint, an osteotomy can be performed by moving the osteotomy site proximal or distal enough to allow for the placement of three screws. However, a malunion at the level of the joint is a contraindication for this technique.

Illustrative Case

A 46-year-old man presented with posttraumatic phalangeal malunion. He had received treatment by closed reduction and K-wire fixation for the fracture of his left index's proximal phalange 12 months previously. Anteroposterior and lateral radiographs revealed an acceptable bony alignment. However, the rotational malalignment was not able to be detected by viewing the anteroposterior and lateral radiographs (Fig. 1). Upon physical examination, ulnar rotation and overlapping of the index finger was revealed during grasping (Fig. 2).

Surgical Technique

Axillary block anesthesia was performed, and a nonsterile tourniquet was applied. A longitudinal incision was made on the dorsum of the phalanx that was malunited. The procedure used is outlined in the following steps.

Step 1: A dorsal midline extensor tendon splitting incision was made for the osteotomy. Before the osteot-

Fig. 1. An illustrative case of a 46-year-old man presenting with posttraumatic phalangeal malunion. Radiographs showed a completely united transverse fracture of the proximal phalanx. The bony alignment appeared to be acceptable when (A) anteroposterior and (B) lateral radiographs were viewed; however, rotational malalignment cannot be detected by viewing 2-dimensional radiographs.

omy, tenocapsulolysis was performed if necessary. The periosteum was sufficiently elevated in the midportion to allow access for transverse cutting of the phalangeal bone at the midpoint using a high-speed saw (Fig. 3).

Step 2: A 1.2-mm axial K-wire was inserted intramedullary in the distal fragment of the phalangeal bone in an anterograde fashion. The axial K-wire was subsequently pulled out distally until the distal end of the osteotomy site with the proximal interphalangeal (PIP) and the distal interphalangeal joints was passively and fully flexed (Fig. 4).

Step 3: The axial K-wire was inserted into the intramedullary space in a retrograde fashion beyond the osteotomy site until it reached the proximal end of the phalangeal bone (Fig. 5). Care was taken to ensure the axial K-wire passed through the midline of proximal phalanx in both the anteroposterior and lateral views (Fig. 6). In the case with the combined angular deformity, osteotomy was able to be performed using an open wedge method as the unilateral cortex can also be used to hinge the osteotomy open to the correct angulation (Fig. 7).

Step 4: The patient's hand was held passively, and a fist was made to monitor for the overlap of digits and any deviance of the convergence of the palmar digits toward the scaphoid tubercle (Fig. 8). The digit was rotated into the correct position. The axial K-wire was inserted further to penetrate the metacarpophalangeal (MCP) joint while the fist position was maintained. Eventually, the axial K-wire was continued to the level of the dorsal metacarpal cortex while maintaining the MCP joint in a fully flexed position; the MCP collateral ligaments tightened and were unable to accommodate any malrotation of the finger (Fig. 9). The axial K-wire also worked as an extension block of the PIP joint.

Fig. 2. Upon physical examination, ulnar rotation and overlapping of the index finger was revealed during grasping. The patient's index finger deviates from the scaphoid tubercle.

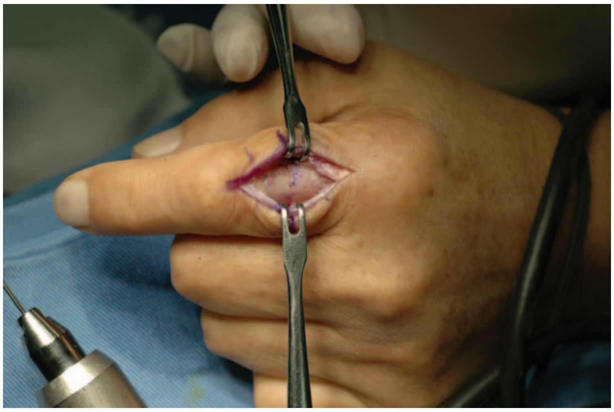

Fig. 3. Step 1: via an extensor tendon splitting approach, periosteum was elevated in the midportion, and the phalangeal bone was cut transversely at the midpoint of the phalangeal bone using a high-speed saw.

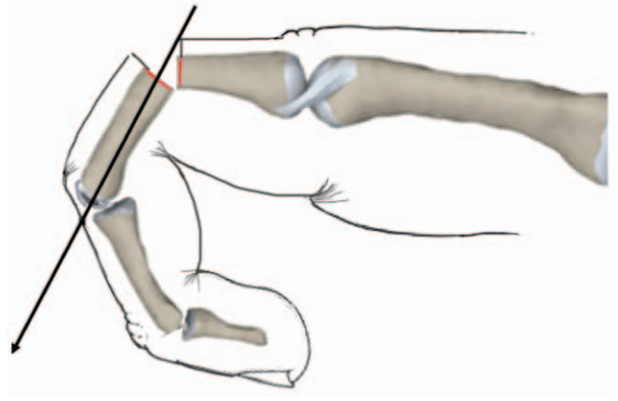

Fig. 4. Step 2: an axial K-wire wire was inserted intramedullary in the distal fragment of phalangeal bone in an anterograde fashion and pulled out distally until the distal end of the osteotomy site with the PIP and the distal interphalangeal joints was passively and fully flexed.

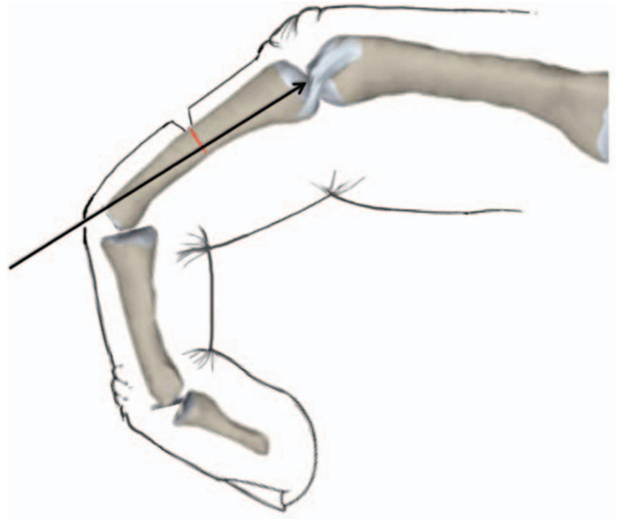

Fig. 5. Step 3 the axial K-wire was inserted into the intramedullary space in a retrograde fashion beyond the osteotomy site until the proximal end of phalangeal bone.

Step 5: A 1.7-mm hologram plate was applied on the dorsal cortex, and the holes were filled with screws of an appropriate length. At least 3 screws should be placed in each bony fragment (Fig. 10). A hologram 2-row plate can be used to reduce the risk of screws causing irritation and to avoid the axial K-wire. Upon tightening the screws, any volar/dorsal malalignment was consequently also corrected. In the case with a bone defect caused by open wedge osteotomy (more than 3 mm), a cancellous bone graft filled the space after a definitive fixation was performed (Fig. 11).

Finally, the axial K-wire was removed, and the surgeon visually confirmed the completeness of correction of the digital overlap at any finger position (Fig. 12). When possible, the periosteum and extensor tendon were closed separately over the plate with 6-0 or 5-0 nylon. A fine suture was used to close skin wounds after confirming the correct placement of

Fig. 8. Step 4: the hand was held and a fist was made before the digit was rotated into the correct position. Eventually, the axial K-wire was inserted further to the dorsal metacarpal cortex maintaining the MCP joint in a fully flexed position. The axial K-wire also worked as an extension block of the PIP joint.

Fig. 6. Step 3: an intraoperative radiograph. Care was taken to ensure the axial K-wire passed through the midline of proximal phalanx in the anteroposterior view.

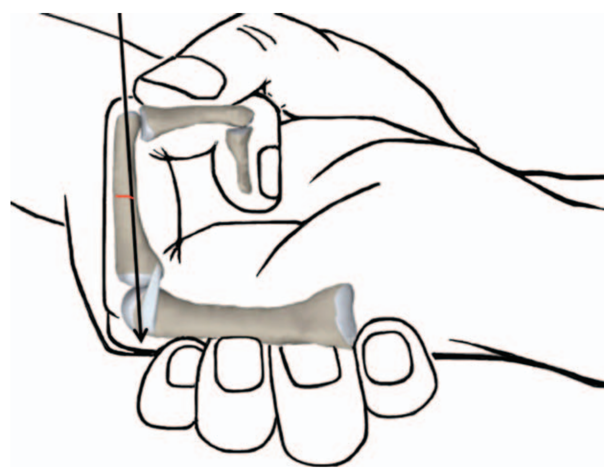

Fig. 9. Step 4: Schematic drawings of Step 4.

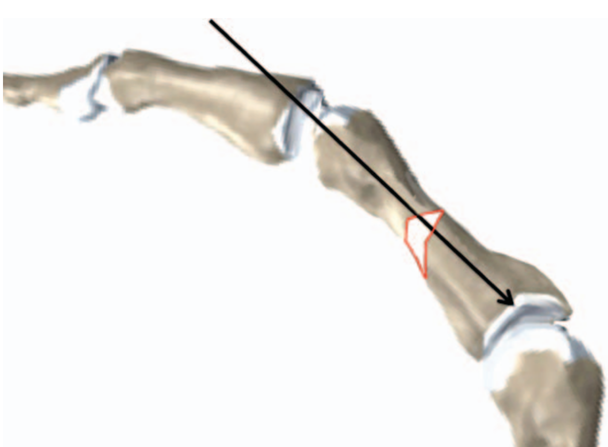

Fig. 7. Step 3: in the case with a bone defect caused by open wedge osteotomy, a cancellous bone graft was used to fill those spaces.

Fig. 10. Step 5: A 1.7 mm hologram plate was applied on the dorsal cortex and the holes were filled with screws of an appropriate length.

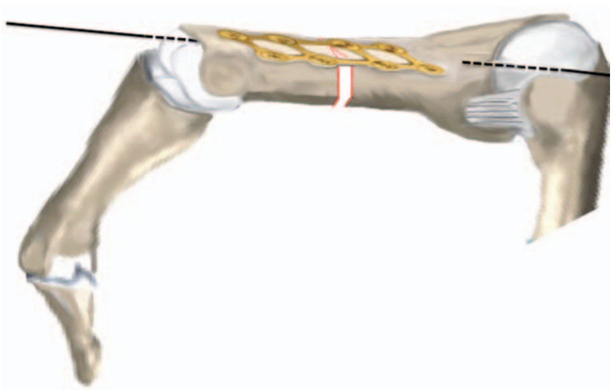

Fig. 11. The MCP collateral ligaments tightened, and they were unable to accommodate any malrotation of the finger. In the case with a bone defect caused by open wedge osteotomy, a cancellous bone graft was used to fill in the space left after definitive fixation was performed.

Fig. 12. Step 6: the axial K-wire was removed and the surgeon visually confirmed the completeness of correction of the digital overlap at any finger position.

the fixation device with anteroposterior and lateral radiographs (Fig. 13).

This technique could also be used for an osteotomy of the middle phalanx as evidenced in case 3 (Table 1). There were no specific technical differences between the middle and proximal phalanx osteotomies. The most important point of this technique is to hold a fist during the reduction and fixation for either the middle phalanx or proximal phalanx with the aid of the axial K-wire.

Postoperative Course

No patients underwent any postoperative immobilization; rather, immediate mobilization was encouraged. Passive and active range of motion (ROM) therapy was begun the day after surgery by a hand therapist. Restrictions did not apply to activities of daily living, with the exception of hard manual work. Passive range of motion exercise started 1 week after surgery when all sutures had been removed.

Patient Series

Between January 2008 and January 2013, 6 patients with 7 fingers exhibiting a malunion of the proximal or middle phalanx of the hand underwent surgical correction at our institute (Table 1). One patient (cases 4 and 5) had bilateral involvement. The original treatment of all patients was performed at another hospital. Conservative treatment was provided for 4 fingers, and 3 fingers were treated operatively by percutaneous osteosynthesis with K-wires. The extents of the bony deformities requiring correction are given in Table 2. The mean duration from initial injury to surgery was 5.1 months (range, 3–12 months) in the 7 cases with phalangeal fractures and malunion. The mean age of the patients at the time of operation was 30.4 years (range, 22–46 years).

Anteroposterior and lateral radiographs were taken for preoperative assessment. All operations were performed by the first author. All the patients underwent an operation, so that a device composed of a hologram 2-row plate and 1.7-mm (proximal phalanx) or 1.2-mm (middle phalanx) screws could be fixed internally (Profyle Hand Standard Plating Module, Stryker Osteosynthesis, Freiburg, Germany). Three patients had concomitant tenocapsulolysis. Two patients had an autogenous bone graft harvested from the distal radius for the management of a bone defect because of concomitant open wedge osteotomy. The average follow-up time was 6.6 months (range, 4–16 months). Bone union was evaluated with anteroposterior and lateral radiographs at each visit. Postoperative evaluation of the clinical results was based on the total range of active motion (%TAM), proposed by the American Society for Surgery of the Hand.[5] The grading of results was according to Büchler et al[6] (Table 3), and the severity of pain reported by patients was based on the visual analog scale (VAS range, 0 = no pain to 10 = the worst possible pain) at the final follow-up visit. All patients were followed-up by use of the disability of the arm, shoulder, and hand questionnaire, which was completed preoperatively and at final follow-up. Preoperative %TAM could not be measured because of digital overlapping of an adjacent finger. These data are summarized in Table 1.

We conformed to the Declaration of Helsinki and this research protocol was approved by the appropriate ethical committee.

RESULTS

The overlapping digits of all the patients in this study were corrected. There were no perioperative complications, such as extensor tendon injury, neurovascular injury, or any unanticipated fractures. After surgery, bone union was accomplished in all cases over an average of 13.4 weeks (range, 10–20 weeks).

Fig. 13. Step 6: postoperative radiographs. When the screws were tightened, any volar/dorsal malalignment was also corrected consequently.

Table 1. Distribution of Osteotomies

Case	Age (yr)	Gender	Injured Finger	Malunited Bone	Fracture Type	Facture Site	Primary Treatment
1*	24	Male	Right ring	Proximal phalanx	Oblique	Midshaft proximal epiphysis	Conservative
2	28	Male	Right middle	Proximal phalanx	Transverse	Midshaft	Percutaneous K-wire
3	33	Female	Right ring	Middle phalanx	Transverse	Distal epiphysis	Conservative
4†	22	Male	Right index	Proximal phalanx	Spiral	Midshaft	Conservative
5†			Left ring	Proximal phalanx	Spiral	Midshaft proximal epiphysis	Conservative
6	38	Female	Left little	Proximal phalanx	Oblique	Midshaft proximal epiphysis	Percutaneous K-wire
7*	46	Male	Left index	Proximal phalanx	Transverse	Midshaft	Percutaneous K-wire

*Cases 1 and 7 required secondary tenocapsulolysis and a pedicle adipose flap concomitant with implant removal.
†Cases 4 and 5 are in the same patient who had bilateral involvement. This patient's operations were performed with a 2-week interval.

Table 2. Case Series

Case	Age (yr)	Gender	Time from Injury to Osteotomy (mo)	DASH at First Visit	Implant	Bone Graft	Concomitant Tenocapsulolysis
1*	24	Male	3	26.5	8-hole hologram plate and 1.7-mm screws	No	Yes
2	28	Male	6	14.0	8-hole hologram plate and 1.7-mm screws	Yes	Yes
3	33	Female	4	19.5	6-hole hologram plate and 1.2-mm screws	No	No
4†	22	Male	4	16.0	8-hole hologram plate and 1.7-mm screws	No	No
5†			4	—	8-hole hologram plate and 1.7-mm screws	No	No
6	38	Female	3	14.0	8-hole hologram plate and 1.7-mm screws	Yes	Yes
7*	46	Male	12	11.3	8-hole hologram plate and 1.7-mm screws	No	No

*Cases 1 and 7 required secondary tenocapsulolysis and a pedicle adipose flap concomitant with implant removal surgery.
†Cases 4 and 5 are in the same patient who had bilateral involvement. This patient's operations were performed with a 2 week interval.
DASH, disability of the arm, shoulder, and hand questionnaire.

There was one case of delayed union (Table 4, case 7).[7] Two osteotomies required secondary tenocapsulolysis concomitant with implant removal surgery (Table 4, cases 1 and 7) because of unacceptable PIP joint contracture (flexion < 60 degree). No patient experienced a postoperative complication, such as plate breakage and/or misalignment. In light of the %TAM and Büchler's grade assessments, all the patients had excellent to good results at final follow-up. No patient complained of pain (VAS, range, 0–1). The mean DASH score significantly decreased from 16.9 (range, 11.3–26.5) preoperatively

Table 3. Grading of Results using Büchler's Criteria

Excellent	>8 criteria satisfied
Good	7 criteria satisfied
Fair	5 or 6 criteria satisfied
Poor	<5 criteria satisfied

Criteria are as follows: 1, complete correction of preoperative deformity; 2, full bony union; 3, patient experiencing no pain; 4, patient has returned to work; 5, patient satisfaction rating of good or excellent; 6, no tropic or sensory problems; 7, no tendon adhesions; 8, range of motion to within 10 degrees of full range in each joint; 9, flexion brings fingertip to within 1 cm of palm.

to 3.9 (range, 0–7.6) postoperatively (paired t test, $P = 0.003$). These results are summarized in Table 4.

DISCUSSION

Several aspects of corrective osteotomy for the malunion of phalangeal bones remain debatable. There exists a controversy over whether it is better to correct malrotation in situ[3,4,6,8,9] or to perform a corrective procedure at the metacarpal.[10–16] The advantages of in situ phalangeal osteotomy are that it can address other concomitant phalangeal deformities and provide the opportunity to perform tenocapsulolysis.[17] However, phalangeal osteotomy carries the risk of inadvertent intraoperative injury and requires more time for bone healing.[4,17] The technical ease of performing the procedure and the fact that there is no need to expose the phalangeal malunion site are the advantages of metacarpal osteotomy. In terms of disadvantages, metacarpal osteotomy may cause the zigzag finger deformity that can occur when a compensatory deformity is intentionally created at the metacarpal to compensate for a phalangeal deformity.[6,17] Another disadvantage of metacarpal osteotomy is that a relatively small amount of correction is made possible through the metacarpal.[11]

Potenza et al[2] reviewed the results of 24 phalangeal in situ osteotomies, and 2 of the 24 (8%) patients had a secondary tenocapsulolysis. Büchler et al[6] recorded secondary tenocapsulolysis in 5 of 25 (20%) patients who underwent proximal phalangeal osteotomies. In this study, 2 of 7 (29%) cases required secondary tenocapsulolysis.

These results implied that extensor tendon adhesions are an inevitable risk associated with phalangeal osteotomy, especially when a plate and screws are used.

Another debate surrounds techniques used for osteosynthesis. Corrective osteotomies with either lag screws, interosseous wires, K-wire fixation, or plate and screw fixation have been previously described.[2,4,6,9,12] A rigid osteosynthesis better tolerates the strain of aggressive postoperative therapy, particularly when tenocapsulolysis is performed. The plate and screw construct can provide the greatest stability among the above-mentioned techniques, which allows exercise of the hand to begin immediately so as to limit stiffness. However, the tradeoff is a difficult procedure.

The technique used in this study was relatively easier to perform, allowing bone grafting after definitive fixation. Moreover, it can be adjusted during surgery to produce a multiplanar correction. The 1.7-mm/1.2-mm hologram plate and screw construct provided sufficient internal fixation that resulted in a reliable union without any postoperative return of the deviation. In this study, on average osteotomies healed within 13.4 weeks. It is a relatively long time compared with published phalangeal osteotomy series that have healed within 7–8 weeks.[2,4,9] This may in part be attributable to the osteotomy being performed at the mid-portion of the phalanx, where there is less total surface area for union. However, bone union was accomplished in all cases, and the final results were excellent or good.

A consensus has yet to be reached on whether it is better to correct an angular deformity by an open wedge[6] or by a closed wedge method.[2,4,8] A closed wedge osteotomy is considered easier to perform and avoids the need for bone grafting, but it shortens the phalanx. A cadaver study[18] revealed that shortening of the phalanx causes a relative extensor tendon lengthening and a subsequent extensor lag, which can develop into a pseudoclaw deformity of the finger. In this study, 2 cases required an autogenous cancellous

Table 4. Results of Cases

Case	Age (yr)	Gender	TAM (degrees)	%TAM	Time to Bone Union (wk)	Büchler's Grade	VAS	DASH at Final Follow-up
1*	24	Male	260	Excellent	10	Excellent	0	4.8
2	28	Male	260	Excellent	10	Good	1	2.5
3	33	Female	220	Good	12	Good	0	3.3
4†	22	Male	260	Excellent	12	Excellent	0	0
5†			260	Excellent	14	Excellent	0	—
6	38	Female	220	Good	16	Good	1	7.6
7*	46	Male	230	Good	20	Good	0	5.0

*Cases 1 and 7 required secondary tenocapsulolysis and a pedicle adipose flap concomitant with implant removal surgery.
†Cases 4 and 5 are in the same patient who had bilateral involvement. This patient's operations were performed with a 2 week interval.
DASH, disability of the arm, shoulder, and hand questionnaire.

bone graft for open wedge osteotomy. However, bone grafting from the distal radius is minimally invasive and a well-established technique for a hand surgeon.

A final aspect on which opinions differ for corrective osteotomy for malunion concerns evaluations of the amounts of deformity and then reproducing it during surgery. It is commonly thought that meticulous planning is essential to obtain the best correction. Precise assessment of a 3-dimensional deformity requires visibility in the radial/ulnar, volar/dorsal, and axial planes. However, it is extremely challenging to assess the exact amount of deformity only on the basis of preoperative 2-dimensional data. Trumble and Gilbert[4] recommended defining the necessary wedge by marking the longitudinal axes of the fragments proximal and distal to the malunion site and then transecting these lines perpendicularly at the malunion site to resolve a combined angular and rotatory deformity. Evans et al[3] recommended using a sterilized cork as a template. The direction of the osteotomy can then be determined by preoperative experimentation with the cork. Precise geometric assessment of the deformity and complicated plotting before surgery are required when using those techniques. Even if a surgeon diligently assesses the amount of deformity, intraoperative verification is actually only possible while the patient makes a fist, so that it is possible to monitor for an overlap of the digits and deviance from the scaphoid tubercle. Because of this, a simple, easy, and reliable technique was devised to enable correction of a rotational malunion of the phalanx as demonstrated in this study. Surgeons adopting this technique would, therefore, have no need to estimate the amount of geometric rotational deformity, or prepare a sterilized template (eg, cork, rubber eraser) before surgery.

CONCLUSION

The technique used for phalangeal corrective osteotomy in this study was simple, easy, and reliable.

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