

Results of Osteotomy, Open Reduction, and Internal Fixation for Late-Presenting Malunited Intra-articular Fractures of the Base of the Middle Phalanx

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Purpose: To present our results in the treatment of late-presenting impaction fractures of the base of the middle phalanx treated by osteotomy with full exposure of the articular surface to restore the normal anatomy.

Methods: Eleven patients with a malunited (impacted) fracture of the base of the middle phalanx were treated by osteotomy more than 5 weeks after the injury. All fractures had varying degrees of impaction, comminution, and dorsal subluxation. The malunited joint surface was visualized by dislocating the joint by hyperextension (shotgun approach). The restoration of the cup-shape contour of the middle phalangeal base was accomplished by osteotomy and mobilization of small osteochondral fragments. Rigid fixation was performed by cerclage wire, screws, or a combination of these. A distal radius bone graft was placed beneath disimpacted fragments in 9 of the 11 procedures.

Results: Ten of 11 patients were followed-up for more than 1 year. One patient with a volar lateral impaction fracture was lost to follow-up study 4 weeks after the surgery and was excluded from the results. All patients except 1 achieved a functional range of motion of the proximal interphalangeal joint. Moderate limitations of the distal interphalangeal joint motion were common. Grip and thumb-affected finger tip pinch strengths were 95% and 90%, respectively, of the healthy side. The average pain level (as rated on a visual analog scale of 0–10) improved from a preoperative score of 9.1 to a postoperative score of 0.8. One patient was somewhat dissatisfied; all other patients were satisfied or very satisfied. All returned to their previous work at an average of 13 weeks after surgery.

Conclusions: Favorable results have been achieved in this challenging scenario in the short- and middle-term in 9 of 10 patients. Previous surgery and moderate to severe wearing of the cartilage of the proximal phalanx head negatively affected the results. (*J Hand Surg* 2005;30A:1039.e1–1039.e14. Copyright © 2005 by the American Society for Surgery of the Hand.)

Key words: Impaction fractures, malunion, PIP joint injuries, osteotomy.

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Received for publication November 16, 2004; accepted in revised form March 24, 2005.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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0363-5023/05/30A05-0001\$30.00/0

doi:10.1016/j.jhsa.2005.03.018

Note: To access the supplementary materials accompanying this article, visit the September 2005 online issue of *Journal of Hand Surgery* at www.jhandsurg.org.

Fractures of phalanges often are neglected or are regarded as trivial injuries.¹ When proper early treatment is not performed injuries to the proximal interphalangeal (PIP) joint may lead to prolonged disability, pain, and stiffness.²

Treatment for malunited fractures of the base of the middle phalanx varies from waiting until pain prompts arthrodesis or joint replacement³ to some type of soft-tissue⁴ or osteochondral arthroplasty.^{5,6} Given the unpredictability of the results⁷⁻⁹ and its high technical complexity, case series about open reduction and internal fixation (ORIF) are sparse.^{2,7,8,10,11} In those articles the PIP joint usually was approached through the lateral side and the osteotomy was accomplished without exposure of the articular surface. In our experience this provides a limited and insufficient view of the deformity and creates difficulties in dealing with the depressed central fragments. To view the entire malunited base of the middle phalanx we propose the hyperextension volar approach used by Eaton and Malerich^{4,12} to perform arthroplasties (the shotgun approach) combined with a thorough manipulation of the malunited fragments. This approach permits fixation with screws and cerclage wire, allowing immediate motion in most cases.

From July 1999 to July 2003 we treated 11 patients with late-presenting impacted fractures of the base of the middle phalanx by osteotomy to mobilize the healed displaced fragments and internal fixation. We report the subjective and objective outcomes of this group of patients after an average of 28 months (minimum, 12 mo) of follow-up study. The description of the surgical technique, indications of the type of internal fixation, and difficulties encountered are presented in detail.

Materials and Methods

Patient Demographics

From July 1999 to July 2003 we prospectively followed up 11 consecutive patients with malunited impacted fractures of the base of the middle phalanx treated by osteotomy, open reduction, and internal fixation. All patients gave written consent to be included in this study. The time from the traumatic event to the surgery ranged from 5 to 22 weeks (mean, 9 wk). Ten of the 11 patients had been on sick leave from their jobs since the injury. Patients' ages and affected fingers are presented in Table 1.

The mean age at surgery was 32 years (range, 18–49 y). Seven patients were men, 10 were right-handed, and 6 injuries occurred on the dominant

Table 1. Patients' Demographics and Preoperative Findings

Patient	Active ROM (deg)					X-ray Preoperative Data					
	Age	Finger	Delay (wk)	Pain (VAS)	PIP (ext/flex)	DIP (ext/flex)	Type of Fracture ¹⁵	Step-off (mm)	Impaction* (%)	Subluxation† (%)	Angular Deformity (deg)
1	49	Middle	6	9	40/55	20/23	Volar-lateral	3.0	28	33	22
2	19	Middle	22	10	20/40	20/50	Volar	3.5	66	20	0
3	18	Middle	9	7	22/40	15/22	Volar	4.0	42	70	0
4	39	Middle	10	9	20/65	0/48	Volar-lateral	2.0	60	40	15
5	42	Small	8	9	15/24	12/38	Volar	2.5	70	10	5
6	31	Small	9	10	30/48	23/34	Volar-lateral	4.0	59	61	10
7	31	Ring	8	10	10/30	0/0	Volar-lateral	4.0	60	30	18
8	27	Index	5	9	24/38	24/26	Volar-lateral	2.0	35	10	0
9	29	Middle	12	9	10/20	20/20	Volar	4.0	76	56	2
10	19	Index	6	10	17/25	12/25	Volar	3.0	51	73	10
11	45	Middle	5	8	29/29	20/20	Volar-lateral	3.0	46	20	15

ext, extension; flex, flexion.

*Percentage of middle phalanx surface impacted in the lateral x-ray calculated with Hamer and Quinnton's method.¹⁶

†Percentage of middle phalanx dorsal to the axis of the proximal phalanx dorsal border.

side. Seven injuries were work related and were covered under workers' compensation. Two patients (patients 2, 10) had a concomitant bone mallet finger in the same digit. All were closed fracture-dislocations.

In 9 cases the injury was overlooked by the initial treating physician and treated as a sprain or a minor avulsion fracture. Two patients (patients 5, 7) had prior surgery on the PIP joint elsewhere (Table 1). Patient 5 had a failed attempt of ORIF with 2 screws and had developed severe pain. Patient 7 had been treated by an extension block pinning^{13,14} 2 months earlier but the joint redislocated immediately after removal of the K-wire (6 wk after the procedure).

Range of motion (ROM) of the PIP and DIP joints was measured before surgery. Nine digits were kept immobilized for 1 to 2 weeks because they had been misdiagnosed as sprains, and no specific exercises to improve ROM were recommended once the digits were weaned from the splint. Degree of preoperative pain with motion of the PIP joint was determined with a visual analog scale (VAS) (range: 0, no pain to 10, unbearable pain) (Table 1). All patients had preoperative posteroanterior (PA) and lateral radiographs taken.

All fractures had varying degrees of impaction, comminution, and dorsal subluxation. They were classified according to Hastings and Carroll.¹⁵ There were 6 predominantly volar compression fracture-dislocations and 5 volar-lateral compression fracture-dislocations. The degree of subluxation, percentage of articular compromise (according to the method of Hamer and Quinton¹⁶ [Appendix A; this supplementary material can be viewed at the *Journal's* Web site, www.jhandsurg.org]), and size of the step-off were measured on PA and lateral views as reported in Table 1. (Measurements were taken with a Vernier caliper and rounded to the nearest 0.5 mm). Computed tomography was performed in all but 2 patients to help delineate the fracture configuration and plan the surgical approach (Fig. 1).

All surgeries were performed by the senior author (F.P.) under the same protocol. Intraoperative photographic records were taken from all joint surfaces before and after reduction. They were used to assess the degree of comminution of the volar lip and of the joint surface and the degree of wear of the cartilage of the head of the proximal phalanx. The proportion of middle phalanx base surface impacted also was calculated from these photographic records through a computer program (Volmed 2D; Informedia Designs, Leeds, UK).

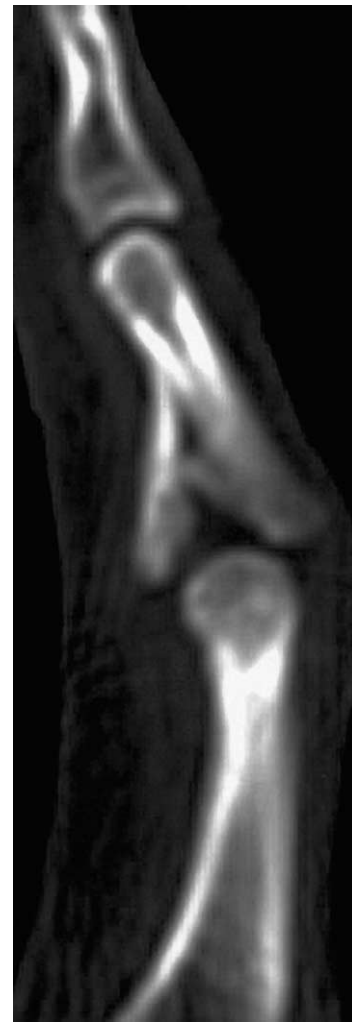


Figure 1. Sagittal computed axial tomography scan of the PIP joint of the small finger of a 31-year-old patient 2 months after sustaining a volar-lateral compression fracture (patient 6).

Surgical Technique

The surgery was performed with loupe magnification ($\times 3.5$). A slightly modified Eaton and Malerich^{4,12} shotgun approach was used. Initially a V-shaped skin incision was made with the apex at the PIP joint flexion crease and extending from the proximal to the distal digital crease. A flap with skin and subcutaneous tissue was raised to one side. Next a rectangular flexor sheath flap spanning from the distal edge of the A2 pulley to the proximal edge of the A4 pulley was elevated with its base opposite to that of the skin flap. The flexor tendons were retracted and the volar plate was released with a scalpel from the insertion of the accessory and proper collateral ligaments laterally and from the proximal edge of the middle phalanx distally. A blade was introduced gently in the space between the proximal phalanx condyles and the collateral ligament at both sides of the joint, and then by

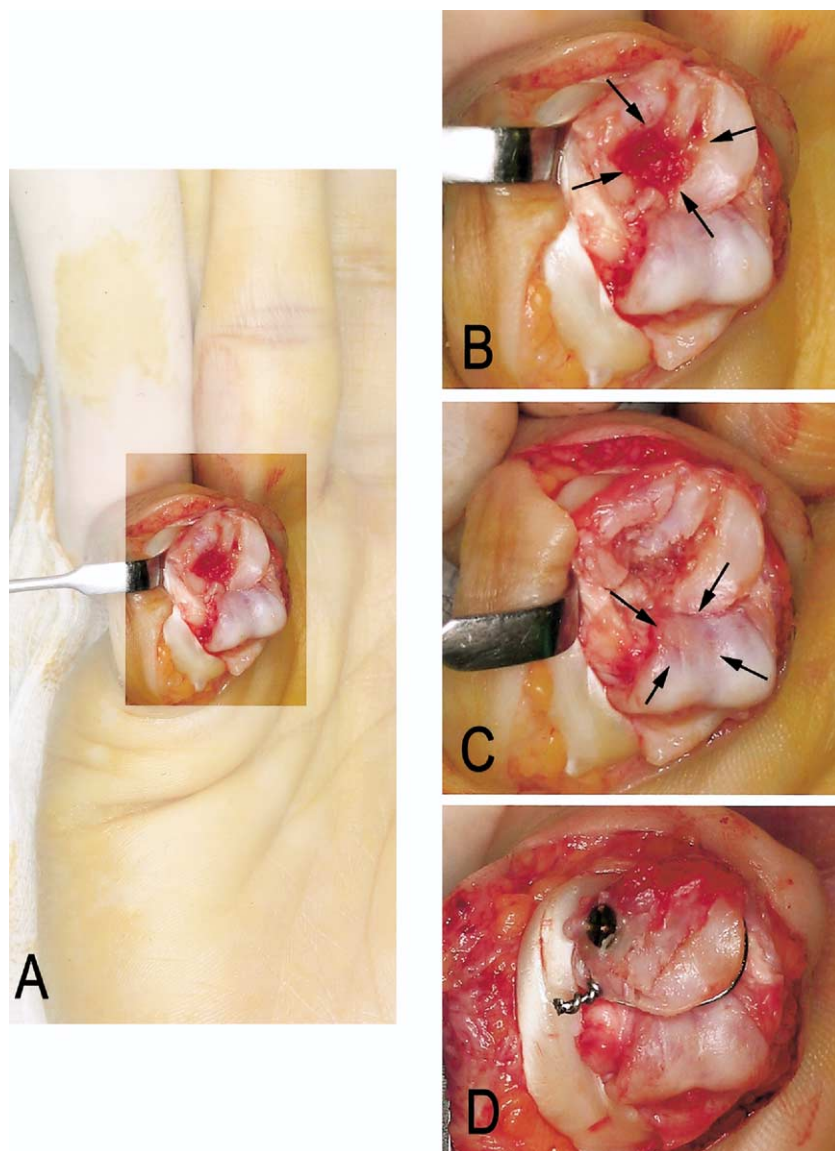


Figure 2. (A) The joint has been dislocated by hyperextension (shotgun approach). (B) Corresponding view of the middle phalanx base before excision of granulating tissue and callus (arrows). (C) After debridement the cartilage-containing fragments have been defined. Note that the cartilage cover of the dorsal half of the proximal phalanx is partially worn out (arrows). (D) Fixation has been achieved by means of a screw (for a larger volar-ulnar fragment) and a cerclage wire. Cancellous bone graft has been applied to support the fragments.

slightly twisting the blade the origin of the ligament was released from the proximal phalanx. With traction on the middle phalanx and the tendons retracted to one side the joint was hyperextended gently until the base of the middle phalanx was exposed completely. Excessive force could damage the intact dorsal articular surface and should be avoided. At times a Freer elevator was introduced dorsally to the proximal phalanx to release the dorsal capsule and any tendon adhesions that could block the reduction. In no case did we need to resort to an independent dorsal incision to release the capsule or the extensor

tendon as recommended by Bilos et al.¹⁷ A full view of the base of the middle phalanx always should precede the next step.

With fine rongeurs (1-mm bite) and small curettes the fibrous tissue and new bone were removed until all cartilage-containing fragments were delineated (Fig. 2). The aim before beginning to mobilize the fragments was to have all pieces delimited and ready to match. Some allowances should be made because deformation of the cartilage may have occurred as a consequence of the original compressive forces.

The volar lip of the middle phalanx was displaced

volarly. The articular fragments were separated with dental picks, gently disimpacted, and elevated. Ideally in fragment mobilization we tried to preserve connections to the neighbors but this was impossible at times because of the severity of displacement; thus some of these small fragments, once repositioned, behave as osteochondral grafts.

Once the depressed fragments were reduced and leveled the void underneath them was filled with cancellous bone graft from the distal radius and packed tightly with a fine dental tamp. The decision to use bone graft was made during surgery based on the presence of subchondral voids and/or foreseeable tenuous fixation. The volar fragment(s) was then repositioned and this always involved elevation, derotation, and dorsal displacement of the volar lip so the concave base of the middle phalanx could be reshaped (see Discussion section).

The fixation technique varied according to the number of fragments and the quality of the volar lip of the base of the proximal phalanx (Fig. 3). In general terms our policy was as follows.

- If there was a structurally intact volar marginal fragment, 1 or two 1.3- or 1.5-mm titanium lag screws (Synthes, Paoli, PA) were applied. This volar lip fragment then was used to hold the central comminuted fragments (Figs. 3A, B). Washers were used when the volar fragment was thought to be at risk for fragmentation.
- If there was not a structurally intact volar lip fragment then a modification of Weiss's¹⁸ cerclage wire technique was used. The principle of this technique is to hold the fragments by encircling wire around the base of the middle phalanx. Distal or proximal migration of the wire at the final turn of twisting is extremely frustrating. To overcome this difficulty we recommend passing the encircling wire through a canal made with a 1-mm K-wire through the subchondral bone of the healthy plateau; this actually would be a hemicerclage. Additionally we have noticed with Weiss's¹⁸ technique that the small central fragments may extrude during the final tightening of the wire. To avoid this the assistant pressed the fragments down with the pulp of the finger or with the flat surface of a Freer elevator while the surgeon tightened the wire (Fig. 3C).
- If a volar fragment was large enough for screw fixation but not large enough to support all fragments of the volar rim it was fixed with a screw

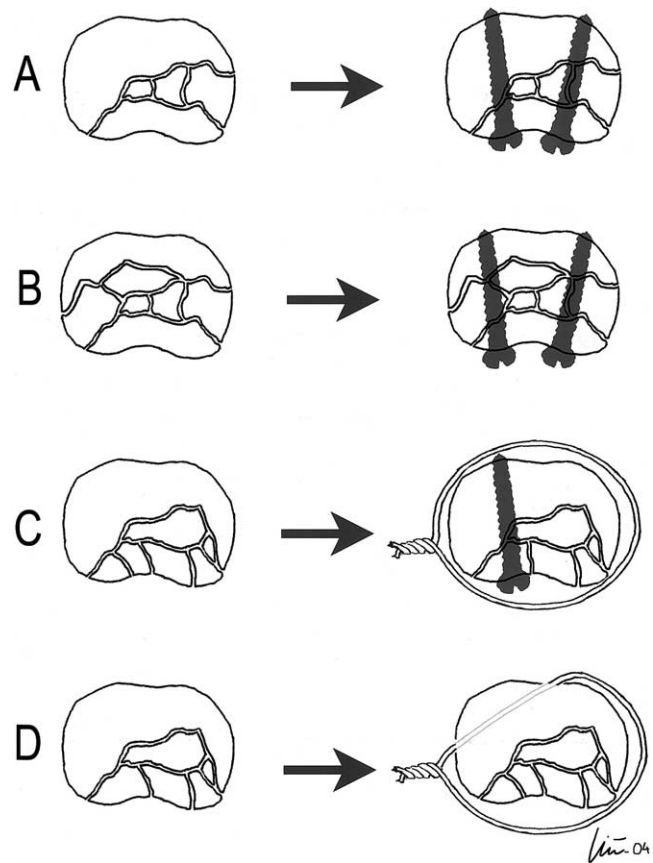


Figure 3. The fixation techniques used are summarized in this sketch where the base of the middle phalanx is viewed from the proximal side. (A) Lag screws are used if the volar fragment is intact structurally. (B) Even when there is severe comminution of the central area, if the volar fragment is sturdy the use of lag screws is the preferred technique. (C) Weiss's cerclage or hemicerclage wire technique is indicated when there is not a structurally intact volar lip fragment. (D) If a volar fragment is large enough for screw fixation but not large enough to retain all fragments of the volar rim it is fixed with a screw and the rest of the volar rim is stabilized by a cerclage or hemicerclage wire.

and the rest of the volar rim was stabilized by a cerclage or hemicerclage wire (Fig. 3D).

The joint then was reduced by combining traction and flexion. Fluoroscopy was used to check the reduction. The collateral ligaments were not repaired. The flexor sheath was repaired and the skin was closed.

When a strong volar buttress could not be restored because the fixation was not sturdy an extension block 1-mm K-wire was inserted in the head of the proximal phalanx.^{13,14}

The postoperative regimen varied depending on the stability achieved. When a good volar buttress was obtained immediate protected ROM was started

with splints between exercises and buddy taping for the first 3 weeks. Extension was blocked at 30° by aluminof foam splints or kissing splints.^{19,20} When a K-wire was used to block dorsal subluxation the PIP joint was immobilized for 3 weeks in approximately 30° of flexion. The patient was advised to remove the protective splint several times a day and flexion and extension of the PIP joint were encouraged; however, patients rarely moved much until after the K-wire was removed.

After 4 or 5 weeks any flexion contracture was treated with dynamic splinting (Capener splint; DeRoyal, Powell, TN), foam-padded aluminum splints at night, and in some resistant cases progressive casting. When flexion deficits were detected they were treated with static splinting 3 times a day for 30 minutes.

Follow-Up Evaluation

All patients were called to a final follow-up evaluation at a minimum of 1 year (maximum, 5.2 y; mean, 28 mo) after surgery. Additionally the time to return to work was recorded. This was decided based on a full objective evaluation and according to the individual needs of each patient. Subjective final outcome was evaluated with the Spanish validated version of the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire.²¹ Patients also were asked about the degree of pain through a VAS (range: 0, no pain to 10, unbearable pain), their degree of satisfaction (very satisfied, satisfied, neither satisfied nor unsatisfied, somewhat dissatisfied, dissatisfied), and if they would repeat the surgery and/or recommend it to others.

Active ROMs without joint isolation of the PIP and DIP joints were measured using a goniometer. Grip strength and thumb-affected finger tip pinch strength were assessed and compared with the non-injured side with a dynamometer (Jamar, Padgett Instruments, Inc., Kansas City, KS) and a pinch gauge (Padgett Instruments, Inc., Kansas City, KS), respectively. The presence of both coronal and sagittal instability and crepitus were assessed.

Standard PA and lateral x-ray views of all patients were obtained. Any degree of dorsal subluxation, residual angular deformity, intra-articular step-off, presence of osteophytes, subchondral sclerosis, and signs of collapse were noted.

The scoring system devised by Ishida and Ikuta also was used to assess the final subjective and objective outcomes (Appendix B; this supplementary

material can be viewed at the *Journal's* Web site, www.jhandsurg.org).

Statistics

Nonparametric statistical tests were performed to find an association between various factors and the final outcome. The factors analyzed were age, time between trauma and surgery, previous treatment, number of fragments impacted, damage to the articular cartilage of the proximal phalanx, and PIP preoperative total arc of motion. Final outcome measures were PIP postoperative total arc of motion, percentage of grip and pinch strength, DASH score, and Ishida and Ikuta⁸ score. Spearman rank correlation, Mann-Whitney, and Kruskal-Wallis tests were used as appropriate. Significant associations were defined when the p value was less than .05. We also considered marginal associations when the p value ranged from .05 to .10.

Results

The intraoperative findings and treatments used are presented in **Table 2**. The average impacted surface as calculated with a computerized program measured 51% ± 11% of the total surface. Seven patients had 3 or more impacted fragments that needed reduction.

Patient 4 was lost to follow-up study 4 weeks after the surgery and is excluded from the results section. The clinical and radiologic results of 2 patients are shown in **Figure 4**. (Videos can be viewed at the *Journal's* Web site, www.jhandsurg.org). Detailed results for each patient are reported in **Table 3**.

The average total arc of active ROM for the injured PIP joint was 77° (range, 20°–113°) with an average flexion contracture of 14° (range, 3°–70°). The average total arc of motion of the DIP joint was 55° (range, 0°–85°) with an average flexion contracture of 2° (range, 0°–20°). When the failed surgery (patient 5) was excluded the arcs of motion improved to 84° and 63° at the PIP and DIP joints, respectively.

Grip and thumb-affected finger tip pinch strength averaged, respectively, 95% (range, 85%–104%) and 90% (range, 80%–110%) of the healthy side. When the dominant side was affected (6 patients) the average grip and pinch strengths were, respectively, 97% (range, 89%–104%) and 95% (range, 80%–110%) of the nondominant side. When the nondominant side was affected the average grip and pinch strengths were, respectively, 92% (range, 85%–98%) and 84% (range, 80%–94%) compared with the dominant side.

Pain level as measured by VAS decreased from a mean score of 9.1 (range, 7–10) before surgery to 0.8

Table 2. Intraoperative Findings and Treatment Dispensed

Patient	Percentage of Impacted Surface	Impacted Fragments*	Proximal Phalanx Cartilage Statust	Volar Lip	Fixation Technique	Bone Graft	K-Wire Extension Block	Postoperative Regimen
1	33	1	0	Comminuted	Hemicerclage	Yes	No	Splint 3 weeks
2	59	2	0	Comminuted	1.3-mm screws × 2#	Yes	No	Splint 3 weeks
3	53	2	+	Structurally intact	1.3-mm screws × 2	Yes	Yes	Immediate
4	60	3+	++	Comminuted	Cerclage	Yes	Yes	Protected for 3 weeks
5	62	2	+++	Structurally intact	1.5-mm screw + washer	No	No	Immediate
6	54	3+	+	Comminuted	Cerclage + 1.3-mm screw	Yes	Yes	Protected for 3 weeks
7	51	3+	+	Comminuted	Hemicerclage	Yes	Yes	Protected for 3 weeks
8	46	3+	0	Comminuted	Hemicerclage	No	No	Immediate
9	71	3+	++	Comminuted	Hemicerclage + 1.3-mm screw	Yes	Yes	Protected for 3 weeks
10	58	3+	0	Comminuted	Hemicerclage	Yes	Yes	Protected for 3 weeks
11	28	3+	0	Structurally intact	1.5-mm screw + washer	Yes	No	Immediate

*Number of impacted fragments apart from the volar lip fragment (1, 2, 3, or more [3+]).

†Refers to the wearing of the cartilage of the head of the proximal phalanx and was classified as none (0), mild (+), moderate (++), and severe (+++).

#The volar lip was comminuted at the injury but had healed, so screws could be used for fixation.

(range, 0–4) after surgery. All patients returned to their previous levels of activity and would recommend the surgery to others (including patient 5, the failed surgery, because it had provided pain alleviation). All workers (n = 9) returned to work at an average of 13 weeks (range, 6–24 wk) after surgery. Objective analysis proved all joints to be stable to motion with no crepitus. The average DASH score was 7.6 (range, 0.7–47.1; median, 3.7). The average Ishida and Ikuta score was 73.1 (range, 1–100; median, 80). Both systems correlated well with each other (r = -0.67, p = .034).

Final follow-up radiographs showed no signs of dorsal subluxation, intra-articular step-off, osteophytes, subchondral sclerosis, or collapse in all but 1 patient (patient 5). Slight joint narrowing and mild enlargement of the joint on the lateral view were present in most patients.

Complications such as loss of fixation or infection have not been found. Patient 7 had a 10° ulnar angulation. This was caused by an inaccurate reduction of the ulnar plateau that was underestimated during the procedure. The deformity was suspected right after the first dressing change and did not progress afterward. Patient 11 presented with a 6° angular deformity but the deformity was bilateral. No other case of malalignment was noted. Although anatomic reduction has been achieved patient 5 had the worst functional result. This patient failed to follow postoperative instructions and missed some of the follow-up visits but he also had the worst damage to the articular surface of the head of the proximal phalanx. Gradually he lost motion and at the final postoperative visit there was little appreciable motion (Table 3). Radiographs showed signs of collapse and arthritis. No patient required removal of the internal hardware. No additional surgery has been performed or is planned at this stage.

A marginal negative correlation was observed between age and final PIP arc of motion (p = .057). Patients with previous surgical treatment fared worse in PIP arc of motion (p = .07), DASH score (p = .06), and Ishida and Ikuta⁸ score (p = .03). Patients with minor wear of the proximal phalanx head cartilage (Table 2) (PIP arc, 88°; DASH score, 3; Ishida and Ikuta⁸ score, 74) showed similar results compared with those without any proximal phalanx cartilage involvement (Table 2) (mean PIP arc, 87°; mean DASH score, 3; Ishida and Ikuta⁸ score, 87). Greater degrees of wear of the proximal phalanx head cartilage (Table 2) negatively affected the results. In the 2 patients who had a major involvement

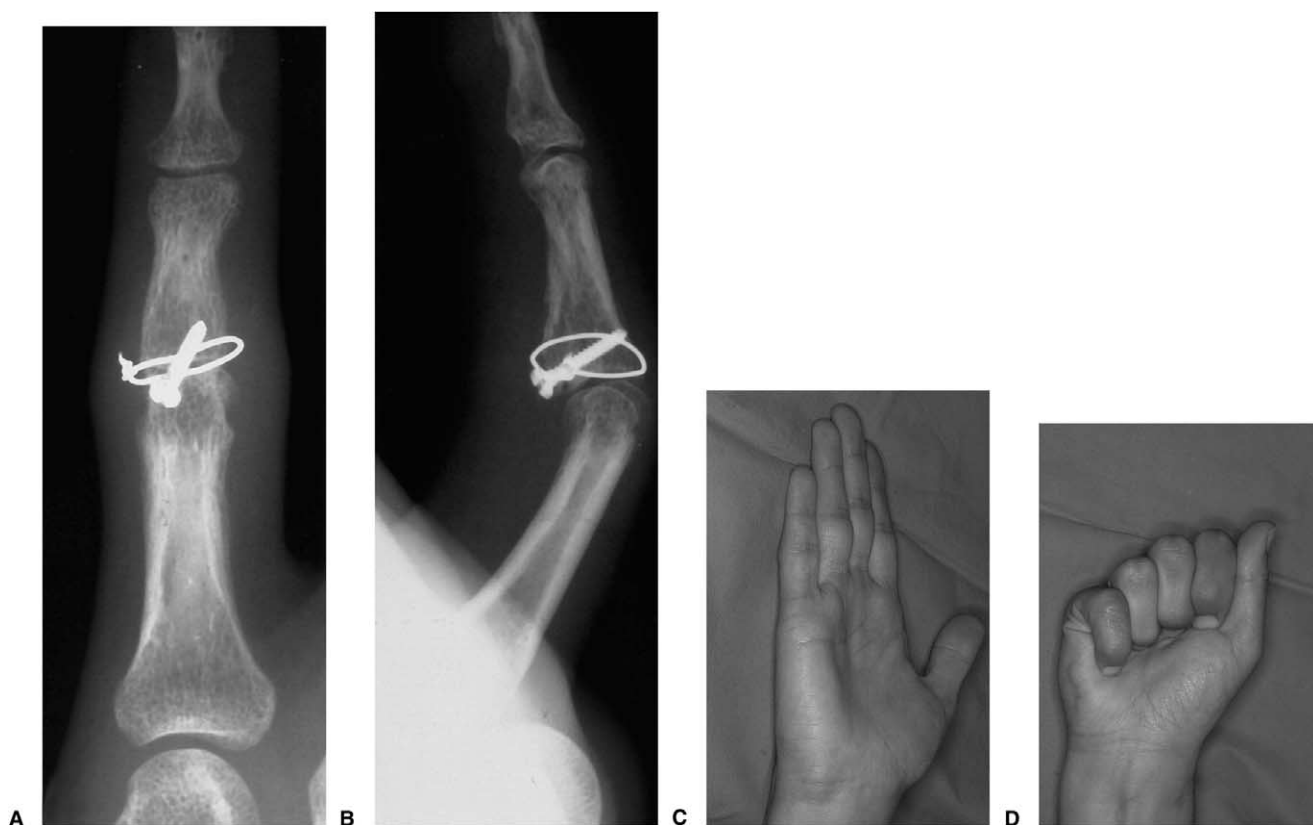


Figure 4. Patient 6. (A) Posteroanterior and (B) lateral x-ray films and (C, D) ROM 2 years after the surgery. (This patient is the same as the patient shown in Figs. 1 and 2.) (Video can be viewed at the *Journal's* Web site, www.jhandsurg.org.)

of proximal phalanx cartilage head the PIP arc of motion (mean, 38°), DASH score (mean, 26), and Ishida and Ikuta⁸ score (mean, 38) were worse compared with patients without articular cartilage involvement. The linear correlation coefficient (Spearman test) was calculated for PIP arc of motion ($r = 0.43$, $p = .21$), DASH score ($r = -0.48$, $p = .16$), and Ishida and Ikuta⁸ score ($r = -0.65$, $p = .04$) among these variables for proximal phalanx head cartilage status. Grip and pinch strengths were decreased in patients who started immediate nonprotected postoperative motion ($p = .03$ and $p = .09$, respectively). These differences persisted even when groups were separated according to dominance. No other significant or marginal associations were seen in the remaining factors that were analyzed.

Discussion

Reconstruction of malunited-impacted fractures of the middle phalanx is challenging. To deal with this difficult problem there are several options, from arthrodesis³ to joint transfer.²²

The volar plate arthroplasty by Eaton and Malerich^{4,12} is a common technique for treating dor-

sal PIP joint fracture-dislocations. In a long-term review Dionysian and Eaton²³ reported a remarkable 61° of active ROM in 9 patients treated 4 or more weeks after the injury at an average follow-up period of 11 years. Other researchers could not reproduce similar results,^{8,24} particularly when the extent of comminution was excessive. Hastings and Carroll¹⁵ reported 4 failures out of 5 patients treated after 3 weeks because of recurrent dislocation, pain, or ankylosis.

Distraction arthroplasty has been recommended even in the chronic setting.^{25,26} Good functional results even in the setting of persistent dorsal subluxation and major step-offs are reported, with an improvement in active ROM from 13° to 88° .²⁵ This nonanatomic reconstruction²⁷⁻³² conflicts with the views of other researchers,^{16,33-35} who argue that the accuracy of anatomic reduction is the most important factor to achieve a good result and that late remodeling does not occur.^{34,35} In late-presenting cases Mizuseki et al³⁶ concluded that distraction arthroplasty was not beneficial if joint incongruity existed.

Recently hemihamate osteochondral autograft arthroplasty was introduced as an alternative to volar

Table 3. Results

Patient	Follow-Up (mo)	Active ROM PIP (deg) (ext/flex)	Active ROM DIP (deg) (ext/flex)	Grip Strength (%)*	Pinch Strength (Affected Finger) (%)*	Residual Deformity	Return to Work (wk)	Pain (VAS)	Level of Satisfaction	DASH Score ²¹	Ishida and Ikuta Score ⁸
1	63	5/87	0/43	98	94	None	18	0	Very satisfied	2.2	80
2	57	5/90	20/60†	91	80	None	9	1	Very satisfied	3.7	74
3	33	3/110	0/85	85	80	None	10	0	Very satisfied	2.9	90
4	—	—	—	—	—	—	—	—	—	—	—
5	26	70/90	0/0	90	90	Swelling	24	4	Somewhat dissatisfied	47.1	15
6	24	0/90	5/65	103	100	None	14	0	Very satisfied	0.7	80
7	20	25/85	0/60	100	110	Angular deformity	6	3	Satisfied	4.4	52
8	18	0/105	0/85	90	81	None	10	0	Very satisfied	2.2	100
9	17	24/80	0/40	97	86	Mild swelling	12	0	Satisfied	4.4	60
10	13	5/95	0/75†	104	96	None	N/A	0	Very satisfied	3.7	100
11	12	8/80	0/60	89	80	Mild swelling	12	0	Very satisfied	4.4	80

*Percentage of the normal side.
 †Concomitant bony mallet finger deformity.

plate arthroplasty. Williams et al⁵ reported the results of a series of 13 patients who suffered major impaction of the base of the middle phalanx who had reconstruction with Hastings's technique. At an average follow-up time of 17 months they achieved an active ROM of 85° at the PIP joint. Most patients were treated in the acute period but 4 were in the chronic stage (>3 wk). Unfortunately the results of Williams et al⁵ are difficult to compare because it was not specified whether they were acute or chronic.

Open reduction with osteotomy and K-wire internal fixation with or without bone graft has been reported scarcely in the literature.^{2,7,8,10,11} Wilson and Rowland² reported 12 of 15 cases treated by open reduction and osteotomy more than 3 weeks after the injury. After the collateral ligament was divided the joint was reduced and maintained in 30° of flexion with a transarticular K-wire. Then the osteotomy of the volar fragment was performed and the volar fragment was reduced. They emphasized the importance of restoring the volar buttress by osteotomy and elevation of the volar lip but they found that elevation of central depressed fragments technically was not feasible in chronic cases. McCue et al¹⁰ reported 21 fracture-dislocations in the athletic population but it is not clear how many were old injuries. They released the volar plate after dividing the pulleys to retract the flexor tendons but also used a lateral approach. They did not use bone graft to support the volar lip as advocated by Wilson and Rowland.² Radiographic results were not reported.

Zemel et al¹¹ reported reconstruction with reduction and osteotomy through a lateral approach in 14 patients with malunited fractures of the base of the PIP joint. They reported an increase in the PIP active flexion from 30° to 68°. Similar to Wilson and Rowland² they performed the osteotomy and elevation of depressed fragments after reduction of the middle phalanx and transfixion of the joint in 30° with a K-wire. In our view this creates technical difficulties and greatly impairs the accuracy of the reduction.

Wolfe and Katz⁷ reported 2 late-presenting cases with fracture of the base of the middle phalanx. They advocated the shotgun approach for volar base fractures but it is not clear whether they used it in the chronic cases. One patient achieved a PIP motion from 17° extension lag to 95° of flexion. The other patient had surgery at 10 weeks after the injury but they found that the joint was not reconstructable; hence, they proceeded to perform a volar plate arthroplasty. They concluded that late treatment uniformly is less successful at restoring motion. Ishida

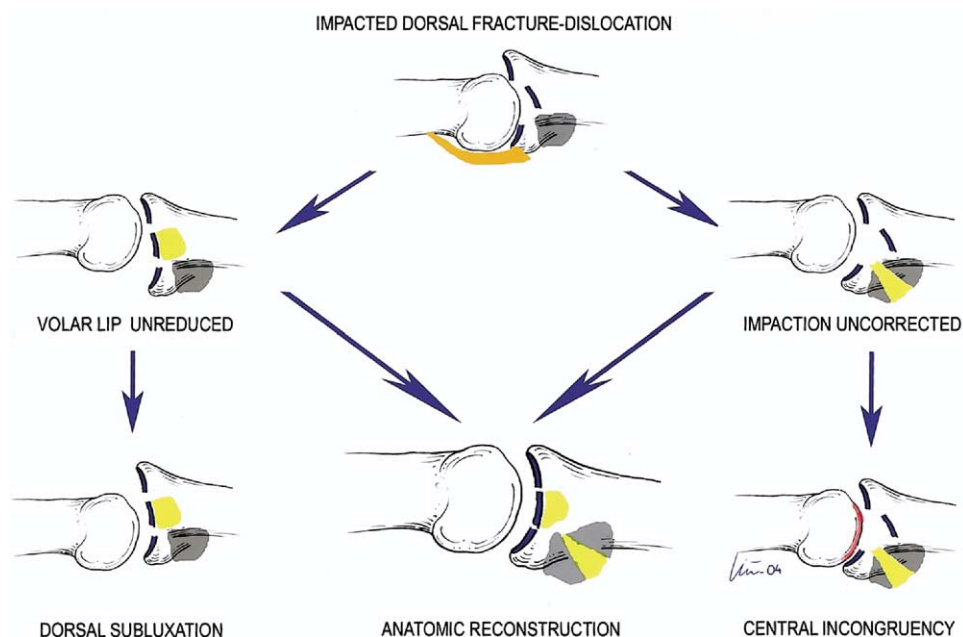


Figure 5. Impacted fracture-dislocation and clues for appropriate correction of deforming elements. In this simplified sketch only 3 elements have been depicted: dorsal subluxated main fragment, central impacted fragment, and the volar lip fragment (the callus is shown in gray) (above center). If only the central depressed fragment is elevated (bone graft in yellow) but the volar lip malposition is not corrected then a widened and flattened or even reverse-sloped joint surface with a tendency toward dorsal subluxation will result (notice V-sign) (left column). If, however, only an open wedge osteotomy of the volar lip fragment is performed to restore the volar buttress, disregarding the central depressed fragments, a widened incongruous joint will result with a tendency to erode the head of the proximal phalanx (in red) and also to slight dorsal subluxation (right column). Full correction requires not only mobilizing the articular fragment but releasing and reducing the volar lip (center below).

and Ikuta⁸ reported 9 excellent and good results out of 12 patients treated with ORIF but they did not mention any details about surgical technique and severity of the fractures. Despite these good results they favored an osteochondral graft to treat patients with chronically damaged articular surfaces or comminuted palmar fragments.

As shown in Figure 5 open wedge osteotomy and elevation of the depressed central fragments are necessary to restore the joint congruency and avoid residual dorsal subluxation. To do so a full view of the articular surface is necessary; this is provided inadequately by the lateral midline approach. Nevertheless, the shotgun approach provides a unique view of the joint surface, which in our opinion is key to performing fragment delineation and disimpaction with accuracy.

In 6 cases an extension block wire was used to keep the reduction and unload the comminuted volar fragments.^{13,14} The rationale behind this precaution is that in the Hastings and Carroll¹⁵ and Deitch et al²⁴ series all patients who redislocated after loss of fixation had more than 50% joint involvement. By preventing any load transmission through the anterior part of the middle phalanx the K-wire not only blocks

dorsal subluxation but above all avoids flattening of the articular surface of the base of the middle phalanx, a deformity that will increase the risk for late dorsal subluxation.^{2,11} Although patients with a K-wire extension block were encouraged to move in a protected range of flexion little motion could be observed while the K-wire stood in place, presumably because of transient joint incongruence.

As a result of our experience in the treatment of acute PIP joint fractures and in the very early cases of this series in which transient flexion contracture was a common event we discontinued suturing the volar plate to the volar margin of the middle phalanx. Williams et al⁵ warned that not repairing the volar plate could be associated with recurrent dorsal subluxation. Neither our experience nor Hamlet and Hastings's anatomic study (presented in 2001 at the 56th Annual Meeting of the American Society for Surgery of the Hand) support this statement. In an attempt to overcome flexion contracture we have started to use dynamic and static extension splints aggressively beginning at week 4.^{15,23,31,35}

Small limitations at the DIP joint were common.^{15,23} Dionysian and Eaton²³ blamed adhesions of the periosteum to the extensor tendon as respon-

sible, besides oblique retinacular tightness secondary to mild volar migration of the lateral bands after surgical stretching of the dorsal extensor mechanism (a boutonniere-like imbalance). Adherences of the flexor tendon in the digital canal secondary to the surgical procedure also may be involved. Although this was not included in our study we noticed that some of our patients had less active than passive flexion of the DIP joint.

A combination of unfavorable factors—damage to the head of the proximal phalanx, previous surgery, and lack of motivation—in our opinion are the combined cause of our failed case (patient 5); this was a simple case from a technical standpoint. According to Zemel et al¹¹ and Ishida and Ikuta⁸ open reduction and osteotomy are contraindicated when comminuted palmar fragments exist. Although we agree that unavailability of cartilage at the base of the middle phalanx and erosions and osteochondral fractures affecting the proximal phalanx head are contraindications for this procedure, we disagree that comminution precludes a good result provided there is cartilage available for reconstruction. Six patients in this series presented with 3 or more fragments impacted (Table 2). Their average PIP arc (79°) was similar to that of the 3 patients who had 1 or 2 fragments (77°) ($p = .98$). On the other hand greater degrees of wear of the proximal phalanx head cartilage were associated with a worse final PIP arc (38°) compared with those without proximal phalanx cartilage involvement (87°), although we were unable to prove it statistically ($p = .21$). A larger number of patients would be necessary to clarify this point.

If surgical exploration shows that the cartilage on the base of the middle phalanx is absent or damaged severely we do not recommend proceeding with the reconstruction and other alternatives should be considered. Additionally although they are not absolute contraindications to reconstruction, previous surgery and lack of motivation may be other bad prognosis factors. Bilos et al¹⁷ found the worst results in their series in patients who had had a prior ORIF. Later these patients required a volar plate arthroplasty as a salvage procedure. Similarly the 2 patients in our series who had had prior ORIF procedures presented the worse subjective and objective outcomes (patients 5 and 7). Unmotivated or uncooperative patients probably do not benefit from open reduction and osteotomy. According to Light³⁷ patients must be able and willing to participate in the essential postoperative phase of rehabilitation to achieve a good functional result.

We have failed to encounter major degenerative signs in 9 of 10 cases but slight joint narrowing and/or mild enlargement of the joint in the lateral view were common. Reconstructive osteotomy cannot be expected to create a normal joint.³⁷ First, various degrees of cartilage damage on the head of the proximal phalanx were seen, not only secondary to the initial trauma but most probably wearing as a result of motion against a rough surface (the incongruent base of the middle phalanx [Fig. 3C]). Second, during the time the joint was incongruent and the time it was immobilized after surgery the cartilage is not nourished normally and some changes must be expected. Finally and most important is our concern about the blood supply of the mobilized fragments: although we took great care to preserve peripheral soft tissues attached to the volar marginal fragment or other peripheral fragments, the central depressed fragments were devoid of soft-tissue connections (although by common sense they also could become avascular by the fracture mechanism itself). Thus as pointed out by Light³⁷ the fate of the hyaline cartilage of those fragments after 10 or 20 years is unknown. Longer-term follow-up study is necessary to know if osteoarthritis develops over time. Eventually, if despite our best efforts degeneration occurs, the fact that we have preserved the joint architecture allows a better scenario for other reconstructive procedures (joint replacement arthroplasty or fusion) to be performed.

The authors thank Robert Jenkins for correcting the English version of this article and Marco-Antonio Gandarillas, MD, Head of Department of Work Related Injuries and Preventive Medicine, Hospital Sierrallana, Santander, Spain, for his help with the statistical analysis.

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Appendix A. Hamer and Quinton's Method

Hamer and Quinton's¹⁶ method to calculate the area involved at the base of the middle phalanx is based on the constant relationship between the diameter of the articular surface to the head of the proximal phalanx and that of the middle phalanx, which is found to be 1:0.82. (A) By measuring the articular surface on the head of the proximal phalanx and the size of the undamaged area on the base of the middle phalanx, a more realistic fracture size can be calculated. (B) Dorsal displacement is calculated by measuring the distance in millimeters between the long axis of the proximal and middle phalanges. To measure the percentage of subluxation this distance is divided by the estimated size of the diameter of the middle phalanx base: (diameter of the head of the proximal phalanx \times 0.82) \times 100. (Reprinted from Hamer and Quinton¹⁶ with permission from the *British Society for Surgery of the Hand*.)

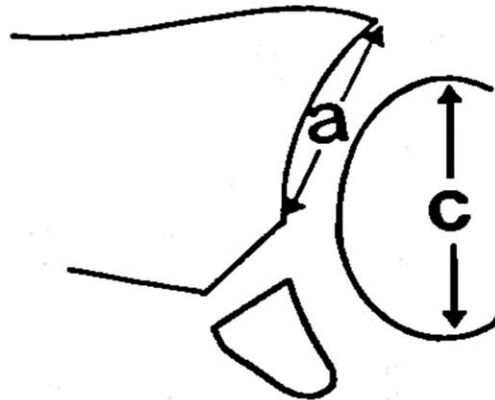
Appendix B. Scoring System for Evaluation of the Results of PIP Joint Fracture–Dislocation According to Ishida and Ikuta.⁸

ROM	$\geq 90^\circ$	60 points
	$\geq 75^\circ$	40
	$\geq 45^\circ$	20
	$< 45^\circ$	0
Pain	No pain with activity	20
	Occasional pain	10
	Frequently painful	0
Deformity	None	5
	Moderate	2
	Angulation $> 20^\circ$	0
Instability	None	5
	Moderate	2
	Angulation $> 20^\circ$	0
ADL disorder	None	5
	Moderate	2
	Severe	0
Radiographic evaluation	Normal	5
	Moderate	2
	osteoarthritic change	
	Severe osteoarthritic change or subluxation	0

Excellent, ≥ 80 points; good, ≥ 60 points; fair ≥ 40 points; poor < 40 points.

ADL, activities of daily living.

Appendix C.



A
$$\%F_{x2} = \frac{(C \times 0.82) - a \times 100}{C \times 0.82}$$

