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HANDSURGERY

Dorsal transosseous reduction and locking plate fixation for articular depressed middle phalangeal base fracture

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Abstract

Purpose An articular depressed fragment at the base of the middle phalanx can be an obstacle to congruent reduction and stable fixation. This study assessed the outcomes of a transosseous reduction technique combined with locking plate fixation for the treatment of articular depressed middle phalangeal base fracture.

Methods Between 2015 and 2017, seven patients (eight fingers) with intraarticular comminuted middle phalangeal base fracture were included in this study. Mean follow-up was 19 months (range 12–30 months). All patients showed depression of the articular fragment on sagittal computed tomography (CT) scan and were treated with a transosseous reduction technique and dorsal locking plate fixation. Radiographic evaluation was performed to ensure restoration of a concentric articular surface postoperatively. Total active range of motion (TAM) of the finger, grip strength, and the quick Disabilities of the Arm, Shoulder and Hand (quick DASH) score were evaluated at the last follow-up. Complications were also assessed.

Results All fractures obtained bony union with a concentric joint. There was no significant loss of reduction during the follow-up period. The mean active proximal interphalangeal (PIP) joint and distal interphalangeal joint motion arcs at follow-up were 89° and 61°, respectively. Mean TAM of the affected finger and mean grip strength were 94% (range 80–100%) and 94% (range 86–100%) of the contralateral side, respectively. Mean quick DASH score was 2.3 (range 0–9.1). All patients returned to work. No surgery-related complications occurred.

Conclusions This technique provides satisfactory restoration of articular congruence and enables the early joint mobilization of articular depression-type fractures of the base of the middle phalanx.

Type of study/level of evidence Therapeutic, level IV.

Keywords Articular depression · Intraarticular fracture · Middle phalanx · Plate fixation · Transosseous reduction

Introduction

Comminuted intraarticular fractures at the base of the middle phalanx remain challenging to treat. They are prone to pain, stiffness, and loss of reduction that can lead to permanent hand function impairment [1, 2]. Several operative and non-operative techniques and approaches have been devised, including distraction by an external fixator, closed or open internal fixation, and hamate arthroplasty, but there is no universally accepted treatment [3–11].

Closed reduction can be used, but it is difficult to disimpact and stabilize the depressed segments using this technique [5]. Percutaneous reduction technique using K wire frameworks was introduced to overcome this limitation [12, 13]. However, accomplishing reduction without losing control of the small articular fragments is technically difficult; furthermore, handling complex structures such as tendon sheaths, joint capsules, and the volar plate may require advanced proficiency [14].

A transosseous reduction technique was used in this study to achieve reduction of the impacted articular fragment without opening the joint Dorsal locking plate fixation was combined with the transosseous reduction technique to buttress the reduced fragment and start the early mobilization. The aim of this study was to assess the outcomes of this

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technique for the treatment of articular depressed middle phalangeal base fractures.

Materials and methods

Patients with an intraarticular fracture of the base of the middle phalanx who were treated by transosseous reduction and locking plate fixation from 2015 to 2017 were retrospectively reviewed. All associated data were collected after obtaining permission from our institutional review board. Inclusion criteria were a minimum follow-up of 1 year after surgery and complete medical and radiographic records. Seven patients (eight fingers) met these criteria. Patients were excluded from the study if they had tendon lacerations, neurovascular injuries, multiple joint fractures in a single digit, or open fracture.

There were six men and one woman with a mean age of 39 years (range 18–76 years). Mean follow-up was 19.4 months (range 12–30 months). Table 1 summarizes demographics, mechanism of injury, plate construct, and follow-up data for each patient in this series. Articular depression was evaluated on sagittal computed tomography (CT) and defined as a step-off greater than 2 mm for at least one articular fragment. All patients had intraarticular fractures of the base of the middle phalanx and showed one or more depressed articular fragments on preoperative CT. Types of treated fractures included seven volar lip fractures, one dorsal lip fracture, and one fracture of both lips (i.e., complete articular fracture). Heights of the damaged articular surface, including the central impacted fragment and intact dorsal surface, were measured from the preoperative lateral plain radiograph by the principal investigator using a distance measuring tool integrated with a picture archiving and communication system. Mean height of the largest fracture fragment was 4.1 mm (range 2.4–5.6 mm). Except for the complete articular fracture, the degree of articular involvement ranged from 54 to 77% (mean, 63%). Four patients had an unstable proximal interphalangeal (PIP) joint, defined by subluxation seen on the lateral radiograph.

Surgical technique

A midline longitudinal or curvilinear skin incision was made on the dorsal side of the middle phalanx of the PIP joint. A cortical window ranging from 2 to 3 mm in diameter was created with a high-speed burr on the dorsal cortex, which had a level just distal to the impacted articular fragment. After gentle axial traction of the distal phalanx was applied to allow reduction of the impressed fragment, transosseous reduction was performed by manipulating the impacted fragment under C-arm guidance with a fine-tipped instrument,

Table 1 Patient characteristics, injury type, and follow-up information

Patient	Age, years	Gender	Mechanism of injury	Finger	Fracture pattern	Implant	PIP motion (E/F)	Grip strength (%)	Quick DASH	Follow-up, months
1	42	M	Punching	Middle	Volar lip	4-Hole plate	5/95	97	2.3	22
				Ring	Volar lip	4-Hole plate	0/90			
2	18	F	Ground-level fall	Middle	Dorsal lip	3-Hole plate	0/95	100	0	19
3	76	M	Ground-level fall	Ring	Both lips	6-Hole plate	10/80	90	9.1	19
4	33	M	Ground-level fall	Middle	Volar lip	4-Hole plate	5/100	80	4.5	19
5	42	M	Baseball activity	Index	Volar lip	6-hole plate	0/95	100	0	30
6	45	M	Basketball activity	Index	Volar lip	3-Hole plate and 1 mini screw	5/90	94	0	12
7	18	M	Baseball activity	Index	Volar lip	3-Hole plate	0/90	95	0	12

E/F extension/flexion, *Quick DASH* quick disabilities of the arm, shoulder, and hand questionnaire

such as a K wire or microcurette, through the cortical window. If there were dispersed fracture fragments that were adjacent to the joint, they were gently manipulated into position with the fine-tipped instrument after external manual compression. Alternatively, when the fracture had a dorsal lip fracture component, the dorsal fracture site was used for insertion during reduction by the K wire, without creating a cortical window. Six fractures were reduced through the created cortical window, and two fractures were reduced through the dorsal fracture site. When a large bone defect was created after reduction, small pieces of allogenic bone chips or bone substitutes were inserted through the window to increase reduction retention. The fracture was stabilized with a locking plate. The plate was reshaped by cutting off unnecessary parts before fixation, so that it could be inserted without interfering with the extensor mechanism. This study used 1.5-mm locking plates (Grid plate; Medartis, Basel, Switzerland). Whole plates could be used, but only two rows of the plate were usually required to fix the partial articular fracture during this procedure. After reshaping to remove the unnecessary parts of the plate, the actual implanted locking plate configuration was three holes in three cases, four holes in four cases, and six holes in two cases. At least one of two proximal locking screws of the plate were inserted subarticularly to buttress the disimpacted articular fragment and grafted bone tamps (Fig. 1). After fixation was completed, posteroanterior, lateral, and external and internal oblique radiographic views on the C-arm image were assessed to ensure a proper screw length without any intraarticular violation. The range of motion of the PIP joint was checked to verify that there were no mechanical obstacles limiting motion. The wound was then copiously irrigated and simply closed. Postoperatively, the fingers were maintained in full extension in an aluminum splint. One or two days after that, depending on the patient's ability to tolerate pain, active mobilization commenced, and the aluminum splint was changed to a detachable resting trough splint. Gentle passive flexion and extension exercise were added at 2 weeks, but forceful manipulation was avoided until confirmation of bone healing. Bandage or buddy strapping was not used, because they often interfere with full motion of the finger. Splints were discontinued at 3 weeks.

Assessment

The total active range of motion (TAM) of the affected finger and grip strength were assessed and compared with those of the normal contralateral finger [15]. Posteroanterior, oblique, and lateral plain radiographs were obtained at the end of postoperative weeks 3, 6, and 12 to assess the loss of reduction and progress of bony union. A postoperative CT scan was available for five patients, and was used to evaluate

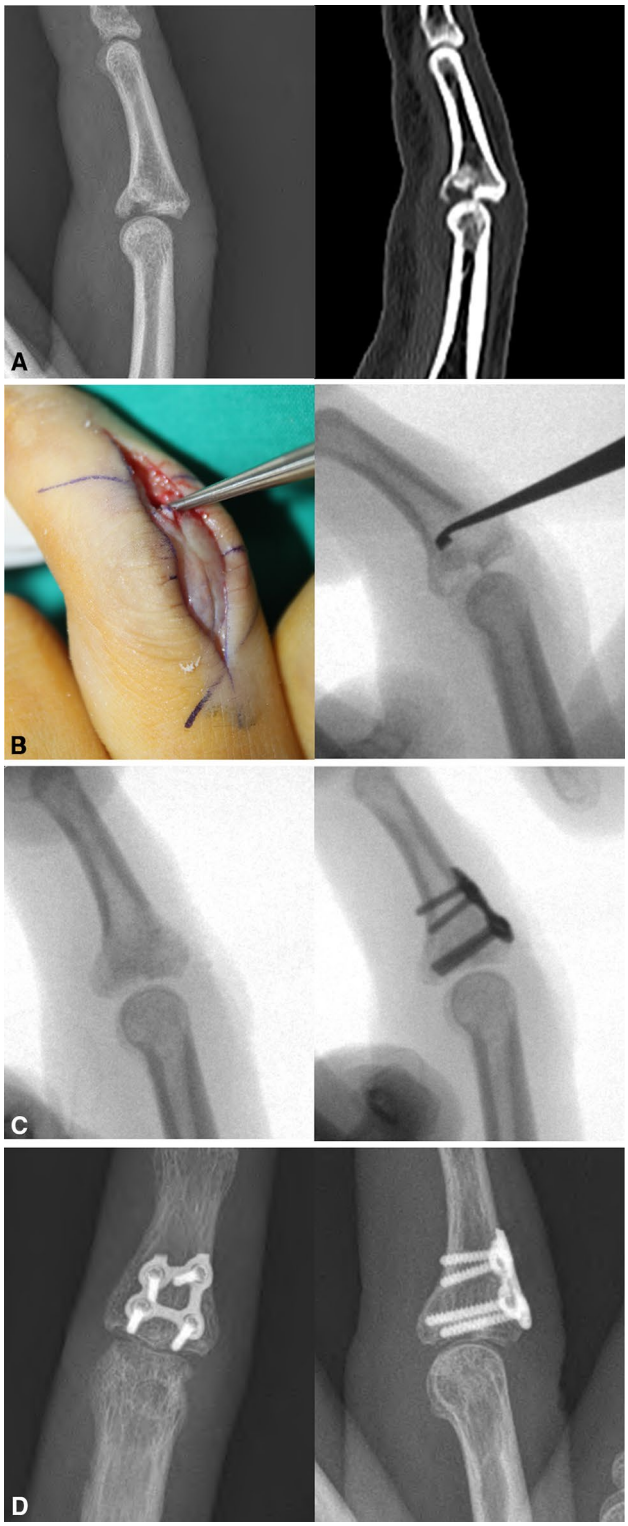

Fig. 1 Representative case of transosseous reduction and dorsal locking plate fixation. **a** Preoperative radiograph and CT scan showing a volar lip fracture with a depressed intraarticular fragment. **b** Cortical window creation on the dorsal bare area of the middle phalanx, and reduction of the impacted fragment using a microcurette inserted through the window. **c** Locking plate positioning after reduction and insertion of the most proximal screw to buttress the articular fragment. **d** Postoperative radiographs at 6 weeks

restored articular congruity. The presence of arthrosis, which was defined as joint space narrowing and/or osteophyte formation, was assessed on the last follow-up radiograph. The 0–10 visual analog scale (VAS) was used to determine the pain level in the operated joint at rest and during exertion. Patients also completed the quick Disabilities of the Arm, Shoulder and Hand (quick DASH) questionnaire at the final follow-up, and complications were assessed.

Results

All fractures were stabilized with dorsal locking plate fixation. No surgery-related complications, such as iatrogenic fractures, tendon injuries or infections, or intra-articular screw penetration were noted. The mean range of motion of the PIP joint was 89° (range 70°–95°). Mean TAM was 240°(range 200°–255°) and 94% (range 86–100%) compared with the contralateral side. Mean grip strength was 54.4 lb (range 18–80 lb) and 94% (range 80–100%) compared with the contralateral side. Mean VAS during motion was 0.6 (range 0–2) at the final follow-up. Mean quick DASH score was 2.3 (range 0–9.1). All patients returned to their original work.

All fractures achieved bony union with stable joints, and there was no significant loss of reduction during follow-up. Postoperative CT scans of five patients showed a congruent restored joint surface without subluxation. Two patients underwent secondary surgery for implant removal. One patient (patient 1) complained of a palpable implant under shallow soft tissue. The other patient (patient 2) did not have any discomfort, but she wanted the metal implant removed, because she disliked it. 1 year postoperatively, two patients (patients 1 and 5) showed subchondral sclerosis and mild joint space narrowing. Despite this, the patients reported vague pain only with heavy work and had no discomfort in leisure or daily activities.

Discussion

Surgical treatment of intraarticular fracture of the middle phalanx is often complicated by loss of reduction, stiffness, and permanent contractures arising from various fixation methods. Currently, there is no consensus on the optimal treatment of these fractures. In a study of partial articular fracture with a screw-achievable fragment, Hamilton et al. [8] used mini-fragment screw fixation alone via the volar approach and documented an average of 70° of PIP joint motion. Seno et al. [16] described the use of open pull-out wire fixation to treat basal split fracture with a central depressed fragment. Although excellent or good outcomes were achieved in 14 of 22 fingers, fair or poor outcomes occurred in eight fingers. Cheah et al. [9] used a custom-modulated hook plate for fragments that were too small for screw fixation in a series of 13 partial articular fractures treated with a non-locking plate and screws. They achieved a mean of 75° of PIP joint motion, but reported that the treatment was technically challenging, with three patients undergoing secondary operations to improve mobility. In cases of complete articular type fractures, the so-called pilon fractures of the middle phalanx, treatment has traditionally relied on a dynamic external fixator [17–20]. However, a recent report of locking plate fixation for middle phalangeal pilon-type fractures was encouraging and showed excellent finger motion recovery and reduction maintenance [5]. Most fractures in our series were volar split partial articular fractures; there were also a dorsal lip fracture and a complete articular fracture. Outcomes comparable to those reported previously for locking plate fixation were achieved. Although comminuted fractures containing articular depressed fragments were selected for treatment with this technique, there was no subsequent loss of reduction or remarkable motion limitation as described in contrast to the previous studies.

Volar, dorsal, or lateral approaches have been used to treat middle phalangeal base articular fractures. Most previously reported volar split fractures were treated using a palmar approach, which offers good visualization of the joint surface and accurate fragment reduction [3, 8, 9, 13]. However, handling of the surrounding volar complex structures is necessary when using a volar approach. If the fracture has small, comminuted fragments on the volar side, widely opened volar fracture sites can lead to difficulties in reduction and cause the surgeon to lose control of the smaller fragments. In these cases, a dorsal approach combined with a transosseous reduction technique is particularly useful, because it allows direct control of the smaller fragments without opening of the comminuted fracture site. A locking plate and screws rather than screws alone were used this study, because subchondral locking screws are more advantageous for early ROM while having a buttressing effect on the central impacted articular fragment in addition to direct screw purchase of the volar fragment.

The application of small locking plates did not appear to critically compromise the extensor mechanism in our series of patients, although it is possible that dorsal soft-tissue exposure can limit joint flexion. Lee and Teoh [3] described a dorsal approach on the PIP joint to visualize the volar fragment and reported postoperative scar formation, which can lead to extensor tendon tethering. With our technique, however, soft-tissue dissection for visualization of the volar fragment can be avoided, and implantation of the small plate did not require the retraction of the extensor tendon. Especially, in partial articular fracture, the locking plate can be intraoperatively reshaped to have only three or four holes to achieve minimal irritation of the extensor mechanism. When

shaping the plate, excessive bending should be avoided as this may affect the holes for insertion of locking screws and cause failure of the locking mechanism of the plate. Meanwhile, implant removal was desired in one patient in this series due to palpable plate beneath the skin rather than extensor complication. As the plate is fixed to the relatively thin dorsal region, patients who have shallow skin should be counseled preoperatively about possible requirement of implant removal.

This study has several limitations. With other published series on middle phalangeal articular fractures, the sample size of this study was small, and there was no comparison group. There was also the possibility of selection bias, as the surgeon was allowed to choose fixation based on the fracture pattern. Because the present technique is targeted to a specific type of articular fracture, fracture characteristics should be carefully evaluated on preoperative CT scan to choose the treatment modality. A highly unstable PIP joint without a screw-achievable volar fragment should be treated with a combined fixation strategy or another fixation strategy. Because a surgical goal for these challenging injuries is to obtain a stable and congruent joint, buttressing the articular surface with subarticular locking screws is very beneficial for the early rehabilitation, which is itself essential for optimal range of motion. Furthermore, this technique may be especially useful in cases that require open reduction of depressed fragments, as these cases can be complicated by the need to handle small, adjacent articular fragments.

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Compliance with ethical standards

Conflict of interest The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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