Fracture dislocations of the hand are difficult and often unforgiving injuries. Keys to treatment include early recognition, stable concentric reduction, and protected early active range of motion maintaining joint stability. The balance between stability and mobility is difficult to manage; therefore, surgeons need a wide array of treatments to tailor management to the specific fracture pattern. With appropriate treatment, residual stiffness and pain can be minimized. This Current Concepts review aims to provide up-to-date management for proximal interphalangeal, distal interphalangeal, and metacarpophalangeal joint fracture dislocations. (J Hand Surg Am. 2014;39(4):792–802. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)

Key words: Finger, joint, fracture, dislocation, subluxation.

The following Current Concepts review the fracture dislocations of the proximal interphalangeal (PIP) joint, distal interphalangeal (DIP) joint, and metacarpophalangeal (MCP) joint. We give an initial brief overview of these injuries and then discuss the most up-to-date treatment options and their respective outcomes.

Proximal interphalangeal joint dorsal fracture dislocations

Proximal interphalangeal fracture dislocations are difficult, unforgiving injuries. Dorsal fracture dislocations are most common, with an associated volar fracture of the middle phalangeal base. The etiology of these injuries is usually an axially directed force to a fully extended digit. The relatively long lever arm of energy transmission from the fingertip, and the fixed uniplanar motion of the joint, result in this frequently seen injury pattern. Although many treatment options exist for these injuries, long-term complications are common, including stiffness, pain, and swelling.

Assessment

Initial assessment of dorsal PIP fracture dislocations involves a careful history and clinical examination followed by radiographic or fluoroscopic evaluation. Fracture chronicity and previous treatments must be clarified, because these have a role in determining ultimate treatment.

Classification of these injuries is based on joint stability as well as fracture configuration. Specifically, injured joints are classified as stable versus unstable, which helps to guide nonsurgical versus surgical treatment options. Dorsal fracture dislocations are inherently more stable in flexion and unstable in full extension, which therefore allows the practitioner to determine stability using fluoroscopy coupled with range of motion examination. Those joints, with concentric reduction with 30° flexion or less, as well as those with less than 20% articular involvement of the middle phalanx base, are considered stable. Those with 30% to 50% joint involvement or those requiring increased flexion to provide stability are considered tenuous, whereas those with greater than 50% articular involvement are considered generally unstable (Fig. 1).

Radiographs or fluoroscopy can be used for fracture assessment and lateral images are often the most useful. Complete dislocation is usually obvious; however, subtle joint subluxation can often be missed.
The radiographic V sign is a finding on the lateral radiograph that results from dorsal subluxation of the middle phalanx articular surface, producing a radiolucent V sign indicative of the subtle instability (Fig. 2).

Along with static radiographic examination, fluoroscopic evaluation can be invaluable in determining injuries that will be amenable to operative versus nonsurgical treatment. Joints that have concentric gliding motion about the rotational axis of the head of the proximal phalanx are likely to be amenable to nonsurgical treatment. Those that have motion that hinges on the fracture edge are more likely to fail nonsurgical treatment and to result in late posttraumatic arthrosis and associated stiffness and pain.

A combination of these assessment tools will help guide the hand surgeon to treat PIP dorsal fracture dislocations appropriately with the best possible outcomes.

**Treatment options and outcomes**

Injury pattern and surgeon preference have key roles in determining treatment options for PIP fracture-dislocations. The goals of treatment have remained unchanged over the years. They include a stable, concentric reduction of the PIP joint to allow smooth gliding motion as early as possible in the postinjury period. In addition, edema control has been a mainstay of treatment regardless of other interventions.

Treatment options include extension block splinting, extension block pinning, external fixation, dynamic traction, Kirschner wire joint transfixation, open reduction internal fixation (ORIF), volar plate arthroplasty, and hemihamate arthroplasty. These treatment modalities have been described in previous reviews; we will provide a general overview as well as recent updates.1

**Extension block splinting and pinning**

As noted previously, dorsal fracture dislocations of the PIP joint that are stable, in slight flexion (<30°) can be managed nonsurgically. The mainstay of treatment for these patients is to maintain a concentric reduction by preventing full extension at the PIP joint. This can be achieved via extension block splinting or extension blocking pinning in the compliant patient.

Splints can be fabricated to allow full flexion and limit extension to prevent reaching the point of instability, as noted during the initial assessment of the patient. This can be achieved through dorsal blocking splints and figure-of-eight splints. The amount of extension can slowly be increased over a period of 3 weeks, as determined by fracture stability. Serial weekly radiographs are imperative to detect subsequent loss of reduction, which can lead to poor outcomes.

In a prospective study of 27 patients treated with extension block splinting, Hamer and Quinton2 found that 70% had good results and that poor results occurred in those who lost reduction in the splints. They concluded that most of these fractures could be treated by splinting; however, those authors...
cautioned about the need for close follow-up to help avoid loss of reduction.

More recently, extension block pinning, first described by Viegas, has been used in techniques not only to prevent extension, but also to provide for fracture reduction. At a mean 5-year follow-up, Waris and Alanen retrospectively reviewed 18 PIP fracture dislocations treated with extension block pinning combined with intramedullary fracture reduction of the volar lip of the middle phalanx using a 1-mm pre bent Kirschner wire through a cortical window in the middle phalanx. They showed that the mean articular stepoff decreased from 2.1 to 0.5 mm and that PIP motion averaged 83° with a mean flexion contracture of 3°. They concluded that this technique was useful in the treatment not only of stable fractures, but also of unstable fractures that were made more stable by indirect fracture reduction and extension block pinning.

External fixation and dynamic traction
Proximal interphalangeal fracture dislocations that are unstable or comminuted can be treated in a relatively minimally invasive way by external fixation as well as dynamic traction. Either as an isolated treatment or in conjunction with ORIF, many commercially available digital external fixators are available and offer both static as well as dynamic options. Disadvantages of these include increased cost compared with Kirschner wire dynamic traction, as well as risk of pin track infections and pin loosening. Dynamic traction systems have many different configurations; however, the basic principle remains that the pins counteract the tendency of the middle phalanx to subluxate dorsally while the rubber bands apply constant longitudinal traction to offload the articular surface and prevent further fracture displacement. Similar to extension block splinting, routine serial radiographs are needed to ensure maintenance of joint reduction.

Henn et al recently reported their surgical technique for dynamic external fixation using 3 Kirschner wires and rubber bands, and reported on 8 patients with an average follow-up of 26 months. Average PIP motion was from 1° to 89° and grip strength was 92% of the contralateral side. Two patients had radiographic evidence of early arthritis and 3 had an articular stepoff of 1 mm or greater.

Ruland et al retrospectively reviewed 26 PIP fracture dislocations and 8 pilon-type fractures treated with dynamic distraction external fixation at a mean follow-up of 16 months. Average PIP arc of motion was 88° and the DIP arc was 60°. Eight patients (24%) had superficial pin site infections treated with oral antibiotics; however, no deep infections were noted. All patients returned to their preinjury level of activity, even though these were active duty military personnel with high physical demands.

Both of these techniques require technical expertise and not all outcomes are favorable. Agarwal et al reported on 25 patients with a mean follow-up of 13 months. Mean arc of PIP motion was only 67° and DIP motion was 41°. Three patients had immobile DIP joints and 7 (28%) had superficial pin site infections. Loss of motion at both joints was a major factor in poor outcomes. The authors suggested that a few technical considerations be kept in mind with this treatment modality: (1) The traction pin should be centered in the head of the proximal phalanx; (2) the horizontal limb of the traction pin must be perpendicular to the long axis of the ray; (3) both vertical limbs on the traction pin should be appropriately distanced from the digit so as to clear the sides of the digit and not impede adjacent digits; and (4) true concentric glide must be present with PIP joint flexion so that subluxation does not occur.

Open reduction internal fixation
Open reduction internal fixation of fracture-dislocations about the PIP joint has a limited but important role. Postoperative stiffness and loss of reduction are the main concerns with this method of treatment. Volar, dorsal, and midlateral approaches have been described for this treatment modality. Large partial articular fractures with minimal or preferably no comminution are the ideal candidates, whereas extensive comminution or chronicity of injury may limit the applicability of this treatment. Although technically demanding, stable fixation obtained through this approach can allow early postoperative range of motion protocols to provide the best possible outcomes.

Recent literature has focused more on reconstructive options for fracture-dislocations about the PIP joint; however, outcomes have been similar to those previously reported. Hamilton et al retrospectively reviewed 9 patients with unstable dorsal fracture dislocations treated by ORIF with mini-fragment screw fixation. At an average of 42 months postoperatively, the mean PIP arc of motion was 70°, with better motion noted for the 2 patients with only 1 fracture fragment (85°) versus those with multiple fragments (65°). Eight of 9 joints had a residual flexion contracture with a mean flexion contracture of 14°. The authors concluded that this was a viable treatment option, but it should be approached cautiously in the setting of comminution with a known universal risk of PIP flexion contracture. Similarly, Lee...
and Teoh\textsuperscript{10} reported their results using a dorsal approach and similar treatment. Twelve patients were reviewed and average PIP arc of motion achieved was 85°. Seven of the 12 digits had flexion contractures at final follow-up. Although ORIF is a viable option for simple noncomminuted fracture patterns, reconstruction via volar plate arthroplasty or hemihamate arthroplasty may be a better option for more complex injury patterns.

**Volar plate arthroplasty**

Volar plate arthroplasty is a time-tested procedure that has been used to reconstruct PIP fracture dislocations involving less than 50\% to 60\% of the articular base of the middle phalanx. As initially described, the procedure reconstructs a volar soft tissue buttress to a dorsally unstable articulation. To our knowledge, there have been no recent reports regarding this surgical procedure, and previous reports looking at combined outcomes show better results when surgery was performed within 6 weeks of injury (95° vs 78° PIP motion), with worse outcomes when more than 50\% of the articular base is involved.\textsuperscript{1} Because of the need for considerable PIP flexion postoperatively for larger defects, complications for this procedure have been noted to include persistent flexion contractures of the PIP joint along with angular deformities, recurrent subluxation, hyperextension, pin and wire track infections, and residual pain and stiffness.\textsuperscript{11}

**Hemihamate arthroplasty**

Most of the recent literature on the treatment of dorsal PIP fracture dislocations has addressed hemihamate arthroplasty. This treatment option aims to reconstruct the volar buttress of the middle phalanx with an autologous osteochondral graft from the dorsal distal hamate in fractures that involve 50\% or more of the articular surface (Fig. 3). Looking at the suitability of this graft, Capo et al\textsuperscript{12} studied fresh-frozen cadavers to assess biomechanics and radiographic features of the PIP as well as carpometacarpal (CMC) joints before and after hemihamate arthroplasty. They showed that there was no tendency for the CMC joint to subluxate, the hamate’s central ridge and bicondylar facets were similar to those of the middle phalanx base, and harvesting of the graft led to no clinical instability of the CMC joint.

A recently described modification to the surgical technique brings to light the slight difference in articular contour between the hamate and the base of the middle phalanx. Yang et al\textsuperscript{13} retrospectively reviewed 11 patients who had undergone a modified hemihamate arthroplasty. The authors’ modifications...
included a forceful volar subluxation of the 4th and 5th CMC joints with distal to proximal osteotomy of the hamate performed in a volar oblique fashion so that the graft would sit obliquely into the recipient site and better reproduce the volar buttress of the middle phalangeal base. They reported average PIP joint motion of 85.4° at a mean follow-up of 38 months.

In a longer follow-up of 8 patients, Afendras et al14 reported their outcomes with a mean follow-up of 5 years. They noted a mean arc of motion of 67° and grip strength of 91% of the contralateral side. Upon radiographic examination, 2 patients had severe arthritis of the PIP joint and 2 had mild arthritis, but only 1 was symptomatic with troublesome pain.

Similarly, Calfee et al15 reported on 22 patients with a mean follow-up of 4.5 years after hemihamate arthroplasty. Fourteen acute injuries (< 6 wk) and 8 chronic injuries (mean, 30 wk) were included. Mean PIP joint arc of motion was 70° (acute, 71°; chronic, 69°) and grip strength was 95% of the contralateral side. One dissatisfied patient underwent revision surgery; chronic injuries were noted to have an increased visual analog scale pain rating (2.5 vs 1.6) compared with those with acute treatment.

Preferred treatment algorithm and postoperative protocol: dorsal PIP fracture dislocation

Our preferred approach is hemihamate replacement arthroplasty for articular surface involvement between 40% and 90%, except for extremely rare, large, non-comminuted volar fragments that are amenable to ORIF. Our postoperative rehabilitation protocol includes the following: early active range of motion (AROM) by postoperative day (POD) 1 to 3 with extension block splinting at 5° to 10° flexion with a protective volar position splint between exercises; progressing to differential interphalangeal blocking by POD 7 to 10, and reduction of extension block splinting to 0° by POD 17; dynamic extension splinting by week 4; and strengthening by week 6.

PROXIMAL INTERPHALANGEAL JOINT PALMAR FRACTURE DISLOCATION

Although rare, PIP palmar fracture dislocations occur as a result of axial load combined with a palmar-directed force over the middle phalanx base. This injury usually includes a dorsal fracture at the base of the middle phalanx (Fig. 4). There has not been much recent change in the treatment of these injuries, and the largest series reported is by Rosenstadt et al,16 who reported on 13 patients, 9 acute and 4 chronic, with a mean follow-up of 55 months. Treatment included closed reduction and percutaneous pin fixation for 7 of 9 acute injuries, ORIF for the remaining 2 patients with acute injuries, and open reduction and soft tissue reconstruction for the 4 chronic injuries. Postoperative PIP joint arc of motion averaged 91° for the acute group and 70° for the chronic group. A
brief 3- to 4-week period of immobilization with simple PIP static extension splinting at 0° after closed reduction, as long as the PIP joint is reasonably congruent and concentrically reduced, is certainly preferable over more aggressive approaches.

PROXIMAL INTERPHALANGEAL JOINT RADIAL/ULNAR FRACTURE DISLOCATION

Proximal interphalangeal fracture dislocations can also occur in the coronal plane. Unlike the dorsal or palmar counterparts, these injuries usually involve a unicondylar fracture pattern at the head of the proximal phalanx and an associated coronal instability. Although these are rare injuries, recent literature has looked at different treatment options with severely comminuted unicondylar fractures. Similar to the concave hemihamate osteochondral graft, a convex autologous osteochondral graft for the proximal phalanx condyle would be an ideal solution.

In a morphometric analysis of potential osteochondral autografts, in 2010, Hernandez and Sommerkamp studied 40 cadaver proximal phalanges and 20 metacarpals (4th and 5th) to assess whether the base of the metacarpals could be used as a donor site for autologous transfer. They found that in relation to radius of curvature as well as radioulnar and dorsal-volar dimensions, the ulnar aspect of the small finger metacarpal base would provide the best match for resurfacing of distal condylar defects of the proximal phalanges. In a similar manner, Cavadas et al used osteochondral grafts from the ulnar base of the 5th metacarpal to reconstruct a condylar defect in the proximal phalanx in 16 patients. They reported an average active arc of PIP joint motion of 49° with no donor-site morbidity at midterm follow-up.

Recently, Zhang et al reported on outcomes of a novel treatment for articular defects of the head of the proximal phalanx. Fifteen patients were treated with an osteoarticular pedicle flap from the capitate to the head of the proximal phalanx. At an average of 52 months, mean active arc of motion at the PIP joint was 50°, with pinch and grip strength that was similar to the contralateral side. Although this is an innovative treatment, further research into the effectiveness and comparability with other treatment modalities is needed.

DISTAL INTERPHALANGEAL JOINT VOLAR FRACTURE DISLOCATION: MALLET FRACTURE DISLOCATION

Introduction

Unlike PIP joint injuries, DIP joint fracture dislocations usually involve palmar dislocations with boney mallet fractures of the dorsal articular surface. Stability of the DIP joint has been evaluated in the past and is noted to be proportional to the amount of articular surface involvement. Husain et al studied 29 cadaver digits with mallet fractures of differing size to compare the rate of DIP subluxation. The DIP joint remained concentrically reduced when less than 43% of the joint surface was involved, whereas subluxation consistently occurred when more than 52% of the articular surface was involved. This can be used by practitioners to construct a treatment algorithm.

Treatment options and outcomes

Treatment of DIP fracture dislocations varies from nonsurgical to surgical; to date, personal preference has a large role in treatment decisions. Aside from conservative management, surgical treatment has been recommended for fractures involving more than one third of the articular surface and those with volar subluxation of the DIP joint. Options have included extension block pinning and ORIF with screws, wires, and hook plate constructs.

Kalainov et al reviewed 22 closed mallet fractures involving more than one third of the articular surface at mean follow-up of 24.5 months after treatment with continuous extension splinting for a mean of 5.5 weeks. Nine cases had a reduced joint at presentation and 13 had joint subluxation. Across outcome measures for pain, function, and satisfaction, patients had resolution of pain and improvement of function; however, they were only marginally satisfied with finger appearance. Although not statistically significant, joints with residual subluxation were more likely to have degenerative arthrosis, swan-neck deformity, and dorsal prominence, which led to suboptimal patient satisfaction.

Much has been reported on extension block pinning of palmer DIP fracture dislocations; the most recent review was by Lee et al. Those authors treated 32 digits with a 2—extension block Kirschner wire technique. Mean articular involvement was 38.4% and 18 of 32 had joint subluxation. At mean follow-up of 49 months, all fractures united with congruent reduction of the joint surfaces. Average DIP flexion was 83.1° and mean extension loss was about 1°. No digit had a prominent dorsal bump or recurrent mallet deformity.

Open reduction internal fixation using screws, Kirschner wires, and hook plates has been described as a treatment modality. Kronlage and Faust reported on 12 patients treated with ORIF with screw fixation at an average of 31 months postoperatively. Mean DIP joint range of motion was 6° to 70°. Loss
of reduction occurred in 1 patient and arthrosis was noted in 2 (1 mild and 1 severe). Teoh and Lee reported on 9 patients treated with a hook plate fabricated from a 1.3-mm AO hand modular system straight plate. The benefit of this fixation was the avoidance of fixation directly into small avulsion fragments, which still allowed a stable tension-plate construct that allowed early active motion. At mean follow-up of 17 months, active DIP flexion averaged 64° with no extensor lag. Finally, Phadnis et al recently reported on ORIF with buried Kirschner wire fixation including both fracture fixation and DIP joint transfixation. Twenty patients with average follow-up of 12.7 months were reviewed. Seventeen patients had full extension and no deformity, whereas 3 had an extension lag of less than 10°. Eighteen patients had full flexion; 2 patients lost 10° and 15°, respectively. The best results were seen in patients treated within 2 weeks of the injury.

**Preferred treatment algorithm and postoperative protocol: volar-mallet fracture subluxation**

Our preferred approach is to treat all mallet fractures conservatively regardless of the percentage of articular surface involvement, unless the DIP joint subluxes volarly, either initially or during the course of treatment. For mallet fracture subluxations, we prefer a modified cerclage wire technique originally described by Melone (personal communication) with a 26-gauge wire inserted through the terminal extensor tendon fibers, then passed through a drill hole in the base of distal phalanx made by a 20-gauge Tuohy needle after reducing the DIP joint and stabilizing with a 0.9-mm (0.035-in) Kirschner wire (Fig. 5). Postoperative rehabilitation protocols include mallet splint with volar position splint and early AROM of the MCP/PIP joint at POD 5 to 7, followed by DIP AROM at week 4 after the transarticular pin is pulled.
Distal interphalangeal joint dorsal fracture dislocation: Leddy and Packer type III flexor digitorum profundus avulsion fracture dislocation

Dorsal fracture dislocations of the DIP joint are rare and there is no consensus on treatment of these injuries. Rettig et al. reviewed 10 patients with chronic dorsal fracture-dislocations treated with volar plate arthroplasty. At mean follow-up of 25 months, the mean DIP arc of motion was 42° and mean flexion contracture was 12°. Other treatment options for these injuries include ORIF using screw versus suture fixation. We are unaware of any recent literature reviewing outcomes from these procedures specifically; however, zone I flexor tendon repairs are presumed to have similar outcomes.

Preferred treatment algorithm and postoperative protocol: dorsal DIP (Leddy and Packer type III) flexor digitorum profundus avulsion fracture dislocation

Our preferred approach is to reduce the DIP joint by stabilizing the avulsed volar articular fragment attached to the flexor digitorum profundus tendon with 2 1.5-mm AO screws, taking great care to avoid any distal angulation where a prominent screw tip might irritate the overlying germinal matrix (Fig. 6). Our postoperative rehabilitation protocol follows typical zone I flexor tendon protocols.

MCP Joint Dorsal Dislocation

Metacarpophalangeal joint dislocation most often occurs dorsally; the index finger is the most commonly involved. These injuries are categorized as complex when they are irreducible by closed means. They often present with MCP joint extension with flexion at the PIP and DIP joints. Puckering of the skin can be seen over the palmer surface of the MCP joint, which is pathognomonic of the injury (Fig. 7).

Afifi et al. studied complex MCP dislocation in 6 cadavers to determine methods for operative reduction of the joint. They noted that the flexor tendons went ulnar to the metacarpal head in every case, the radial digital nerve was superficial and radial to the metacarpal head (5 of 6 cases), and the lumbrical was radial to the metacarpal head (5 of 6 cases). Division of the superficial transverse metacarpal ligament, natatory ligament, flexor tendons, lumbrical muscles, or deep transverse metacarpal ligament did not help with reduction, whereas division of the volar plate was needed for all 6 reductions. The authors concluded that careful dissection is needed to prevent iatrogenic injury to the various structures involved in this injury pattern.

Closed reduction of the dorsally dislocated MCP joint is attempted with hyperextension to recreate the injury deformity followed by sliding the proximal phalanx around the metacarpal head. Longitudinal traction is usually avoided because of the possibility of creating a complex dislocation by allowing the volar plate (which ruptures proximally) to interpose between the articular surfaces. In addition, the metacarpal head, which is between the lumbrical muscle radially and flexor tendons ulnarly, is further incarcerated by longitudinal traction. Surgical reduction, on the other hand, can proceed either via a volar or dorsal approach.

Durakbasa and Gunerı followed 7 cases of complex MCP joint dorsal dislocations treated with an open volar approach for reduction. At mean follow-up of 91 months, range of motion, grip power, stability, and sensation were normal. At the time of surgery, the volar
plate was found to impede reduction in all cases. The longitudinal split made in the volar plate to aid in reduction could be repaired from the volar approach, and the authors cited no complications as a result of iatrogenic injury to other anatomic structures. Along with this, an elevator can be used from the volar approach to free the volar plate from within the joint, which prevents the need for the longitudinal split altogether.

Dorsally, the MCP joint can be accessed with minimal risk to anatomic structures. The volar plate can be visualized and divided longitudinally to allow

FIGURE 7: A Lateral clinical picture showing index finger dorsal MCP fracture dislocation. B Clinical picture showing pathognomonic skin puckering over the palmer surface of the MCP joint.

for joint reduction. Advocates of this approach cite the ease of exposure and relatively little risk to the radial neurovascular bundle, unlike the volar approach. That being said, personal preference usually has a role in determining surgical approach.

Preferred treatment algorithm and postoperative protocol: dorsal MCP dislocation

Our preferred approach is dorsal with longitudinal division of the volar plate, because most associated condylar fractures of the metacarpal are more easily addressed through this approach (Fig. 8). The associated metacarpal condylar fractures are usually stabilized with small Herbert screws, or the articular corner fractures of the proximal phalanx are stabilized with 1.5- to 2.0-mm AO screws or Kirchner wires. Our postoperative rehabilitation protocol includes dorsal block splinting of the MCP joint in 30° flexion with early AROM of IP and MCP joints by POD 5 to 7, depending on fracture construct stability.

MCP joint volar dislocations

Similar to DIP dorsal fracture dislocations, MCP volar dislocations are rare injuries and there is no consensus regarding treatment of these injuries. Unlike the dorsal counterparts, there are usually no interposed anatomic structures with these injuries and closed reduction is usually successful. We are unaware of any recent literature looking at outcomes of these closed reductions.

Preferred treatment algorithm and postoperative protocol: volar MCP dislocation

Our preferred approach is to perform a closed reduction in the vast majority of these rare injuries because the proximally detached dorsal capsule, or more remotely, the distally disrupted volar plate, seldom blocks reduction. In the rare exception where closed reduction is unsuccessful or there is a significant associated fracture, a dorsal approach for ORIF is preferred (Fig. 9). Postoperatively, the MCP joint is splinted only briefly in extension at neutral, serially flexing the MCP joint down by 20° to 30° weekly to prevent an MCP extension contracture.

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