Management of Proximal Interphalangeal Joint Fracture Dislocations

Nicholas M. Caggiano, MD, a Carl M. Harper, MD, b Tamara D. Rozental, MD, c,*

INTRODUCTION

Fracture dislocations of the proximal interphalangeal (PIP) joint of the finger are often caused by axial load applied to a slightly flexed joint. The most common injury pattern is a dorsal fracture dislocation with a volar lip fracture of the middle phalanx. Unfortunately, these injuries are too frequently written off by the patient or providers as a so-called jammed finger and are left untreated. The soft-tissue stabilizers of the PIP joint (collateral ligaments, volar plate, central slip of the extensor tendon) are often concomitantly injured, contributing to the swelling, pain, and instability of these fracture patterns. A late-presenting PIP joint fracture dislocation has a poor chance of regaining range of motion equivalent to the unaffected fingers, with unfavorable prognosis for achieving full composite fist formation and normal function of the hand. Thus, the physician must recognize these injury patterns, obtain the proper imaging, and understand the treatment algorithm of PIP joint fracture dislocations. This article is provided as a reference for the current understanding and best practices in treating PIP joint fracture dislocations.

All authors have nothing to disclose.

a Department of Orthopaedic Surgery, Beth Israel Deaconess Medical Center, 330 Brookline Avenue–Stoneman 10, Boston, MA 02215, USA; b Department of Orthopaedic Surgery, Harvard Medical School, Beth Israel Deaconess Medical Center, 330 Brookline Avenue–Stoneman 10, Boston, MA 02215, USA; c Hand and Upper Extremity Surgery, Department of Orthopaedic Surgery, Harvard Medical School, Beth Israel Deaconess Medical Center, 330 Brookline Avenue–Stoneman 10, Boston, MA 02215, USA

* Corresponding author.

E-mail address: trozenta@bidmc.harvard.edu

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ANATOMY

Proper function of the PIP joint is important to normal hand function. This is an inherently stable joint owing to the anatomic constraints that surround it.

The collateral ligament complex of the PIP joint is composed of the proper collateral and the accessory collateral ligaments. The proper collateral ligaments originate from the lateral and slightly dorsal aspect of the proximal phalangeal head just proximal to the articular surface. Its fibers course obliquely distal and volar to insert on a tubercle at the longitudinal axis of the middle phalanx, just distal to the proximal articular surface. The accessory collateral ligament arises slightly proximal and volar to the proper collateral ligament, and takes a more volar course to insert on the lateral aspect of the volar plate. In a simplified sense, the proper collateral ligament tightens with flexion, whereas the accessory collateral ligament tightens with extension.

The anatomy of the volar plate has implications for the joint contractures that commonly occur following PIP joint fracture dislocations. The volar plate is a thick fibrocartilaginous structure that functions to prevent hyperextension of the PIP joint. It is tethered to the proximal phalanx by the checkrein ligaments proximally and laterally. The central and proximal area between these checkrein ligaments is untethered and mobile. With flexion of the PIP joint, this central-proximal part of the volar plate invaginates to allow for a greater flexion amplitude. Thus, prolonged flexion and scarring of the proximal volar plate following fracture dislocation will limit the motion of the volar plate, leading to flexion contracture.

Distally, the volar plate is firmly anchored onto the middle phalanx only at its lateral margins. The central portion between these distal attachments is the relatively thin fibrous portion that does not provide much structural support.

As the extensor tendon traverses the proximal phalanx, it divides into 3 slips: 2 lateral and the medial. The lateral slips progress distally to join the lateral bands, whereas the medial slip (central slip) inserts into the dorsal aspect of the middle phalanx. All 3 slips act in concert to extend the PIP joint. The central slip is often disrupted from the middle phalanx during a volar fracture dislocation because the dorsal lip fragment on which it inserts is sheared off by the proximal phalangeal head. In this injury pattern, the lateral bands are no longer tethered to the extensor tendon via the triangular ligament and are thus permitted to sublunate volarily. As the lateral bands migrate volarly, they shorten due to the loss of their tether to the middle phalanx. Their new contracted position volar to the axis of rotation of the PIP joint causes both a flexion at the PIP joint and extension at the distal interphalangeal (DIP) joint, causing the injury pattern known as the acute boutonniere deformity.

The articular surfaces, collateral ligaments, extrinsic tendons, and volar plate all act to confer stability to the joint. The volar plate, collateral ligaments, and central slip form a box around the PIP joint that imparts inherent strength. Each of these restraining structures originates and/or inserts in close proximity to the articular margins of the joint. Therefore, periarticular fractures can dislodge these soft-tissue restraints from the respective phalanx and lead to gross instability.

MECHANISM OF INJURY

PIP joint fracture dislocations can be divided most simply into volar, dorsal, and pilon fracture dislocations. Dorsal fracture dislocations occur far more often than their volar counterparts. As identified by Kiefhaber and Stern, volar and dorsal fracture dislocations result from either shearing or avulsion, or a combination of the 2, whereas pilon fractures are pure axial loading injuries.

Mechanism of Dorsal Fracture Dislocations

Dorsal fracture dislocations (Fig. 1) are commonly produced by axial load with the joint held in a mild degree of flexion. The longitudinal force causes the volar lip of the middle phalanx to shear off as it impacts the head of the proximal phalanx. Patients often describe a jammed finger occurring when a ball impacts the tip of an outstretched finger. Unfortunately, these patients often reset the finger themselves and do not seek treatment until the resultant stiffness and swelling becomes unbearable, weeks to months after the initial injury.

Dorsal fracture dislocations can also occur following hyperextension injuries at the PIP joint. Rapid hyperextension leads to separation of the distal volar plate from its insertion on the middle phalanx, often with a bony avulsion. However, disruption of the volar plate is not sufficient to produce dorsal dislocation unless the proper collateral ligament is also disrupted.

Mechanism of Volar Fracture Dislocations

Volar fracture dislocations (Fig. 2) occur far less frequently than dorsal dislocations. In these cases, the dorsal lip of the middle phalanx is sheared off by axial force applied to an extended finger, as opposed to the flexed position that leads to volar lip fractures in dorsal dislocations. The mechanism of volar fracture dislocations is thought to include...
an element of rotatory force, as well as axial and volar-directed load, onto the middle phalanx. Just as disruption of the volar plate and at least 1 collateral ligament is necessary for a dorsal fracture dislocation, disruption of the central slip and at least 1 collateral ligament is necessary to produce a volar fracture dislocation.

Mechanism of Pilon Fractures

Pilon fractures occur due to longitudinal force placed on the PIP joint sufficient to split the middle phalanx articular surface as it is driven into the head of the proximal phalanx (Fig. 3). Both the volar and dorsal lips of the middle phalanx are disrupted. The central articular surface of the middle phalanx may be impacted with metaphyseal compression. The PIP joint is almost always unstable following a pilon fracture.

CLASSIFICATION

Classification systems are most useful when they guide treatment. Because the ultimate goal in treating fracture dislocations of the PIP joint is to provide a mobile, stable, and congruent joint, these injuries are best classified by their stability and by the size of the articular fracture fragment in the sagittal plane. Stability should thus be assessed immediately following closed reduction of the joint.

The size of the middle phalanx articular involvement can be thought of as a surrogate for stability. Increasing size of the fracture fragment leads to compromised bony and soft tissue constraints and thus decreased stability. A commonly used classification system (Table 1) categorizes

Fig. 1. Dorsal fracture dislocation.

Fig. 2. Volar fracture dislocation. (From Meyer ZI, Goldfarb CA, Calfee RP, et al. The central slip fracture: results of operative treatment of volar fracture subluxations/dislocations of the proximal interphalangeal joint. J Hand Surg Am 2017;42(7):572.e3; with permission.)

Fig. 3. Pilon fracture.
fracture dislocations based on the percent of the middle phalanx articular surface involvement on a lateral radiograph. Understanding the mechanism of injury and potentially traumatized structures is of paramount importance when developing a treatment plan. Thus, fracture dislocations of the PIP joint can also be classified by the direction of the dislocation (dorsal vs volar). Dorsal fracture dislocations should alert the surgeon to assess both the volar plate and the collateral ligaments, and volar dislocations should prompt an assessment of the central slip and collateral ligaments.

### Classification of Dorsal Fracture Dislocations

Volar lip fractures occur with dorsal fracture dislocations. According to the Kiefhaber and Stern classification scheme, those that involve 30% or less of the articular surface are generally stable and can be treated with progressive splinting. Fractures involving 50% or more are unstable and will require fixation to provide stability. Those involving 30% to 50% of the joint surface are tenuous and significant consideration should be given to operative fixation.

### Classification of Volar Fracture Dislocations

Dorsal lip fractures are associated with volar fracture dislocations. Again, the amount of articular surface involved guides treatment, as well as an assessment of stability. Generally, those that involve less than 50% of the articular surface tend to be stable, whereas a fracture fragment of greater than 50% of the articular surface tends to be unstable.

### Classification of Pilon Fractures

Pilon fractures disrupt the entire articular surface and are thus not classified according to the amount of middle phalanx involved. Classification is based solely on stability: fractures that maintain joint congruency throughout the entire arc of motion are deemed stable, whereas any subluxation or instability renders the fracture pattern unstable.

### EVALUATION

The evaluation of a suspected PIP joint fracture dislocation begins with a thorough history. The mechanism of injury and the position of the finger at time of the insult will help to guide diagnosis and treatment. Examination of the finger should be directed at assessing the soft tissue envelope, as well as the neurovascular status of the finger. A significant amount of swelling about the PIP joint is to be expected. Any bleeding necessitates ruling out an open fracture.

### Radiographs

After physical examination, imaging is the next most useful adjunct. Generally, posteroanterior and lateral views of the finger will provide enough information to make the diagnosis. The lateral view should be scrutinized not only to assess the approximate percentage of articular involvement but also to assess for avulsions of either the volar plate or the central slip. A V-sign (Fig. 4) in which...
gapping of the marginal joint space is noted indicates subluxation of the middle phalanx and thus instability. Similarly, coronal deviation on the posteroanterior view or bony avulsions from either side of the joint implies disruption of the collateral ligament complex.

**Advanced Imaging**

In the acute setting, computed tomography (CT) scans are rarely necessary. If there is a question about the amount of articular incongruity, a CT scan may provide more information; however, ultimately, the stability of the joint will provide the most guidance with regard to treatment. MRI is not typically used in the setting of an acute injury.

**Joint Reduction**

After obtaining imaging studies, the joint should be reduced. This can be performed effectively under digital blockade. Although the single subcutaneous injection technique for digital blockade has been shown to provide superior results in comparison with transthecal or dorsal injection techniques, volar injections may not provide adequate analgesia to the dorsum of the PIP joint. Therefore, it is recommended that 1 mL of 2% lidocaine be injected into the dorsal web space on either side of the digit, at a depth of 3 to 4 mm. The use of epinephrine has been shown to be safe in the finger and provides longer duration of analgesic relief.

After successful digital blockade, the joint is reduced based on the direction of dislocation. In the event of a dorsal dislocation, the volar plate may be entrapped in the joint space. Additionally, the use of isolated longitudinal traction will cause the checkrein ligaments of the volar plate to close down, preventing adequate reduction. The middle phalanx should be hyperextended with application of gentle proximally directed force. Longitudinal traction is then applied while holding the middle phalanx in this hyperextended position. Significant soft tissue swelling may make reduction difficult.

When reducing a volar dislocation, the surgeon should keep in mind that the middle phalanx may have button-holed through the flexor tendon sheath. Additionally, the central slip of the extensor tendon may be interposed in the joint space. The reduction technique is analogous to that for dorsal fracture dislocations, with the middle phalanx being flexed instead of extended.

**Assessment of Stability**

Once the joint is reduced, it should be splinted and reduction confirmed with radiographs. On successful reduction, the joint is then assessed for stability. The patient is asked to actively flex and extend the joint through a full range of motion. The surgeon then observes the joint for evidence of subluxation or dislocation. Fluoroscopy is helpful, as is adequate digital blockade.

While the patient slowly takes the PIP joint through a full range of motion, the surgeon inspects for any signs of instability. Any areas of articular incongruity are noted. The long axis of middle phalanx should always intersect the axis of rotation in the head of the proximal phalanx. The presence of a V-sign indicates some degree of instability.

Dorsal fracture dislocations are generally stable in some degree of flexion along the arc of motion. Stable injuries exhibit concentric reduction without subluxation in full extension. In unstable cases, gradual stability is obtained with increasing PIP joint flexion. Grossly unstable joints will typically demonstrate instability at 30° or more of PIP joint flexion. Volar fracture dislocations and pilon fractures are more binary; they either exhibit stability in full extension or they do not. Those that are stable in extension can be considered stable joints, whereas any instability in extension indicates a globally unstable joint.

The collateral ligaments should also be assessed. Minamikawa and colleagues recommend that lateral stability be assessed in both extension and 30° of flexion to prevent false-negatives; 10° and 20° of angulation, respectively, in full extension and in 30° of flexion indicate proper collateral ligament disruption. Lateral deviation in extension of 15° or 30° in flexion implies additional disruption of the accessory collateral ligament.

**TREATMENT**

**Goals of Treatment**

Successful treatment of PIP joint fracture dislocations includes restoring a concentric stable joint while allowing for early range of motion. Delay in diagnosis and/or treatment will predictably lead to stiffness of the PIP joint, greatly compromising the normal function of the hand. Any treatment algorithm must strike a balance between providing adequate stability of the joint while allowing for early mobilization.

In addition to fixation of articular fracture fragments, soft tissue injuries must be recognized and treated. Collateral ligament damage results in coronal plane instability. The volar plate is commonly disrupted in dorsal fracture dislocations; failure to recognize and manage these injuries can lead to a swan-neck deformity. Central slip avulsions, seen with volar fracture dislocations, will progress to boutonniere deformity.
Treatment Algorithm

Treatment of fracture dislocations is based on stability of the joint, the size of the fracture fragment, and associated soft tissue injuries. Stable injuries can be treated in a closed manner, whereas unstable joints can be treated in a variety of fashions, including closed treatment, dynamic traction, external fixation, open reduction and internal fixation, advanced joint reconstruction, or arthrodesis. Any treatment should achieve joint stability and articular congruity, allowing early mobilization when possible. Figs. 5–7 outline treatment algorithms for dorsal, volar, and pilon fracture dislocations.

Treatment of Stable Dorsal Fracture Dislocations

Buddy taping
Stable dorsal fracture dislocations generally disrupt less than 30° of the middle phalanx articular surface and are stable in extension. Because stability is present throughout the full range of motion of the PIP joint, buddy taping or strapping (Fig. 8) to an unaffected neighboring finger is the preferred treatment. This allows for early active range of motion while limiting the risk of hyperextension. The fingers are taped together for 3 to 4 weeks, at which time passive flexion and strengthening can begin.

Treatment of Tenuous Dorsal Fracture Dislocations

Extension block splinting
Tenuous fracture dislocations generally involve 30% to 50% of the middle phalanx articular surface and are stable between 0° and 30° of flexion. The goal of treatment is to take advantage of the stable range of motion between 30° and 90°. Extension block splinting (Fig. 9) allows for immediate active range of motion while preventing extension that could separate the volar lip fragment from the remainder of the middle phalanx. Repeat radiographs are required for the first 2 to 3 weeks to ensure no subsequent loss of reduction. The splint should be initially fabricated in the least amount of flexion that exhibits joint stability (maximum of 30°). The splint should be serially adjusted to decrease flexion by about 10° weekly, with a goal of full extension at 3 to 4 weeks.

Treatment of Unstable Dorsal Fracture Dislocations

Unstable dorsal fracture dislocations generally involve greater than 50% of the middle phalanx articular surface. Treatment focuses on providing concentric reduction and stability to the fracture fragment, allowing early range of motion while the fracture unites. The various surgical procedures described, as well as the lack of strong level-of-evidence studies, make surgical decision-making difficult.

Closed reduction and transarticular pinning
Perhaps the simplest method of surgical fixation is closed reduction and transarticular percutaneous pinning. The PIP joint is held in 30° to 60° of flexion while reduction of the fracture fragment is confirmed under fluoroscopy. A Kirschner (K)-wire is driven either retrograde or anterograde across the PIP joint, from the dorsum of the proximal phalanx to the dorsum of the middle phalanx. The wire is left in place for 4 weeks, at which time progressive extension block splinting is performed to a goal of full extension at 6 weeks. At that time, the splint is removed and therapy is begun for range of motion and strengthening.

de Haseth and colleagues retrospectively reviewed the results of 9 patients with unstable dorsal PIP joint fracture dislocations treated with transarticular K-wires. Their patients had an average articular involvement of 36%. By the end of their 6-month follow-up, the patients achieved a mean PIP joint flexion of 104° and an extension lag of 4°.13 Barksfield and colleagues14 performed a similar review of 12 patients treated with transarticular pinning of unstable dorsal PIP joint fracture dislocations. Their series included an average 40% articular fracture fragment and 3-month follow-up. The patients had considerable loss of PIP joint range of motion, with a 56° arc of motion and a 15° flexion contracture. The endpoint of flexion was 73°. However, they note that their study included a relatively short follow-up period.

Closed reduction and percutaneous pinning
A variation of closed reduction and percutaneous pinning published by Vitale and colleagues15 involves direct fixation of the fracture fragment to the middle phalanx (Fig. 10). The fracture is reduced with a towel clip under fluoroscopic guidance. After adequate reduction is achieved, a K-wire is driven from volar to dorsal (through the flexor tendon) to secure the fragment to the middle phalanx. The K-wire can be used to elevate the central impaction, and is then driven across the phalanx and out the dorsum of the finger. The wire is withdrawn from the dorsal side until the volar aspect is flush with the volar cortex of the fracture fragment. A second K-wire is inserted on the opposite side of the phalanx, resulting in 2 dorsal-to-volar pins, 1 in the radial half of the phalanx and 1 in the ulnar half. The K-wires are then...
Fig. 5. Treatment algorithm for dorsal PIP joint fracture dislocations. CRPP, closed reduction and percutaneous pinning; ORIF, open reduction and internal fixation.
Fig. 6. Treatment algorithm for volar PIP joint fracture dislocations.
bent and cut and a dorsal blocking K-wire is inserted dorsally to prevent extension of the PIP joint. The pins are kept in place for 4 weeks, at which time therapy is started. The Vitale and colleagues series on 6 subjects treated in this manner demonstrated an 89° arc of motion (4°–93°), a Disability of the Arm, Shoulder, and Hand (DASH) score of 8 and a visual analog (VAS) score of 1.4 out of 10.

**Dynamic external fixation**

Several K-wire–based dynamic external fixation devices have been developed that take advantage of ligamentotaxis to provide joint reduction. Concentric articular congruity must be achievable via a combination of longitudinal traction and translation to obtain a successful outcome. In 1987, Agee devises a 3-pin force couple splint that uses rubber bands to correct the sagittal plane deformity while allowing for full range of motion of the PIP joint. His series of 16 subjects followed for an average of 21 months had an average of 42% articular involvement. Although his cohort included chronic subluxations in addition to acute unstable fracture dislocations, the acute injuries averaged a 95° PIP joint arc of motion. Although he noted that only 6 subjects regained full extension, it is not clear whether those were chronic or acute cases.

Ruland and colleagues devised an external fixator using 3 0.045-in longitudinal K-wires and dental-grade rubber bands (Fig. 11). The wires are placed

![Fig. 8. Buddy strapping. (From Jensen C, Rayan G. Buddy strapping of mismatched fingers: the offset buddy strap. J Hand Surg Am 1996;21(2):317; with permission.)](image-url)
1. Through the center of rotation of the proximal phalangeal head
2. Through the middle phalanx just distal to the fracture
3. Through the center of rotation of the middle phalangeal head.

The wires are bent and rubber bands applied such that the proximal pin acts to pull the finger out to length and reduce the fracture via ligamentotaxis.

Ellis and colleagues published the outcomes of 8 unstable PIP joint fracture-dislocations treated with the external fixator described by Slade. Subjects were allowed to perform immediate limited range of motion of the PIP joint after surgery. In their admittedly small treatment group, the investigators were able to achieve an average 88° PIP joint arc of motion (range: 1° to 89°), grip strength 92% of the unaffected side, and a pain VAS of 0.6.

Badia and colleagues recently published a series in which they performed a modification of the dynamic external fixator popularized by Gaul and Rosenberg in 1998. This design does not involve rubber bands but uses longitudinal traction between the pins to induce ligamentotaxis and joint reduction. This frame is created by applying a 0.045-in K-wire transversely through the axis of rotation of the proximal phalanx. A second 0.045-in K-wire is driven transversely through the head of the middle phalanx. The proximal wires are bent 3 times to provide a cradle for the distal wires. This cradle provides the longitudinal traction necessary to maintain a congruent and reduced

Fig. 9. Extension block splinting. (From Williams CS. Proximal interphalangeal joint fracture dislocations: stable and unstable. Hand Clin 2012;28(3):413; with permission.)

Fig. 10. (A–E) Closed reduction and percutaneous pinning. (From Vitale MA, White NJ, Strauch RJ. A percutaneous technique to treat unstable dorsal fracture-dislocations of the proximal interphalangeal joint. J Hand Surg Am 2011;36(9):1455–6; with permission.)
joint through full PIP joint range of motion. The series by Badia and colleagues\textsuperscript{19} followed 6 subjects over 24 months with 48% middle phalanx articular involvement. The subjects demonstrated an average 89° PIP joint arc of motion with a 5° extensor lag. No instability was noted at final follow-up.

**Open reduction and internal fixation with interfragmentary screws**

Dorsal fracture dislocations with large fracture fragments and minimal comminution are amenable to open reduction and internal fixation. This can be performed with either lag screws or plate and screw constructs. Headless compression screws provide stable fixation with minimal tendon irritation and stability to start early range of motion (Fig. 12).

Open reduction and interfragmentary screw fixation can be performed from either a volar or dorsal approach, or with a combined approach. If using a dorsal approach alone, care must be taken to avoid disruption of the central slip of the extensor tendon. Subperiosteal dissection is performed to gain lateral exposure to the level of the deep flexor tendon, taking care to preserve the neurovascular bundle.

![Fig. 11. (A, B) Dynamic external fixator.](image)

![Fig. 12. (A) Open reduction internal fixation with (B, C) interfragmentary screws. (Courtesy of P. Blazar, MD, Boston, MA.)](image)
Once the volar aspect of the middle phalanx is exposed, a freer-elevator or hypodermic needle can be used to disimpact and reduce the fracture fragment. Cancellous autograft or allograft can be used to fill any void in the metaphyseal region. After reduction is achieved, a headless compression screw is inserted from dorsal to volar, taking care to limit the amount of screw penetrating the volar cortex to avoid flexor tendon irritation. A splint is applied with the fingers in extension; however, the patient can come out of the splint for daily range of motion exercises. Passive range of motion exercises can be started at 2 weeks and strengthening can begin at 4 to 6 weeks postoperatively.

Lee and Tech\textsuperscript{21} fixed 12 dorsal fracture dislocations in 10 hands with either 1.3-mm or 1.5-mm interfragmentary screws alone. All joints were unstable; 4 subjects had 21\% to 40\% articular surface involvement, whereas 8 had greater than 40\% involvement. Results were obtained at an average of 8 months of follow-up. All fractures achieved union with an average 85° PIP joint arc of motion. However, 7 subjects developed an extensor lag averaging 20°.

**Open reduction and internal fixation with plate and screws**

Open reduction and volar plating is an option for fixation of the volar lip fragment seen with dorsal fracture dislocations. A Bruner-style incision is made on the volar aspect of the middle phalanx, exposing the A3 and C2 pulleys. The A4 pulley can be vented for additional exposure. The flexor tendons are retracted laterally, which should provide access to the volar lip fragment. The volar plate is often still attached to the fragment and can be carefully retracted proximally to expose the fracture site.

The fragment is reduced and a 3-hole plate is applied with cortical screw fixation. The plate can be a cut-down T-plate or a mini-hook plate (Fig. 13) can be created by cutting a 3-hole plate in the middle of the distal hole and bending the remaining prongs. Care must be taken to select the correct plate length that provides buttress fixation of the volar lip fragment, while not being so long as to create flexor tendon irritation. The volar plate provides an element of protection over the proximal aspect of the plate. The rehabilitation protocol is similar to that of independent lag screw fixation. Early motion is important to prevent flexor tendon adhesions, progressing to passive motion at 2 weeks and strengthening at 4 to 6 weeks.

Ikeda and colleagues\textsuperscript{22} reported on a series of 18 subjects with unstable dorsal fracture dislocations involving greater than 40\% of the articular surface. They used a T-plate cut to 3 holes and applied the plate in buttress fashion. At 16 months of follow-up, they identified no major complications or nonunions. PIP joint arc of motion averaged 85° with a 5° flexion contracture. They emphasized that early passive and active extension is important to prevent tendon adhesions. Additionally, they identified that screw length must be carefully chosen such that the screws gain purchase in the dorsal cortex to prevent the screws from backing out, while not being proud so as to irritate the extensor tendon.

Cheah and colleagues\textsuperscript{23} retrospectively reviewed volar plate fixation of 13 subjects over an average of 25 months. The volar lip fractures involved a mean 44\% of the articular surface. Following volar plate fixation with a mini-hook plate, the study group exhibited an average 75° PIP joint arc of motion with 10° of flexion contracture. The investigators identified the need to place the plate distal enough that the hooks do not interfere with joint function but not so distal as to irritate the flexor tendon.
Volar plate arthroplasty
Comminuted volar lip fractures are not amenable to interfragmentary screws or plate fixation. Restoration of the buttressing effect of the volar lip is necessary to preserve concentric reduction. Volar plate arthroplasty was first described by Eaton and Malerich in 1980 to solve this problem (Fig. 14). The premise behind this procedure is to use the volar plate to resurface the PIP joint. The indications for this procedure are acute and chronic PIP joint dorsal fracture dislocations in which congruous reduction is not possible due to loss of the volar buttress.

The PIP joint is approached through a standard Bruner incision. The neurovascular bundles are mobilized and protected, and the A3 pulley is reflected laterally, exposing the flexor tendons that are, in turn, reflected laterally. The volar plate is reflected proximally and any comminuted fracture fragments are debrided away. A trough is made in the volar aspect of the middle phalanx to accept the volar plate as it is advanced.

Stout nonabsorbable sutures are placed through the distal volar plate both radially and ulnarily. Keith needles and a wire driver are used to pass the sutures through the middle phalanx, emerging dorsally. The sutures can be passed through the skin in the case of a tie-over button, or an incision can be made to tie the sutures over the periosteum. Under fluoroscopic guidance, the volar plate is advanced to the middle phalanx until the joint is concentrically reduced, at which time the sutures are secured dorsally. Concentric reduction is again confirmed under fluoroscopy before final suture tying. Care must be taken to not overtighten and create a flexion contracture. An extension block splint or pin is placed to maintain the volar plate position and is removed after 2 to 3 weeks.

The initial account of volar plate arthroplasty by Eaton and Malerich described 7 subjects treated for acute unstable dorsal PIP joint fracture dislocations. These subjects achieved a 95° PIP joint arc of motion and a 6° flexion contracture at a follow-up of 38 months. Twenty years later, Dionysian and Eaton reported on 11 acute dorsal fracture dislocations treated with volar plate arthroplasty. These subjects demonstrated an 85° arc of motion with 100° of flexion and 15° of extensor lag. It is unclear why this second group had less motion with greater flexion contracture.

Lee and colleagues reported a modification of this procedure, using a suture anchor in lieu of transosseous sutures. Fourteen subjects were treated for acute unstable dorsal fracture dislocations. At 25 months postoperatively, the subjects had a 100° of flexion and 11° of extensor lag. It is interesting that this study showed similar range of motion, considering that their protocol seemingly involved immobilization of the digits (including the DIP joint) for 2 weeks postoperatively.

Hemihamate autograft
Unstable, comminuted volar lip fractures can be treated with hemihamate resurfacing arthroplasty. The PIP joint is approached volarly as described in the volar plate arthroplasty technique. Once the fracture site is exposed, the volar and distal margins of the recipient site are prepared with a saw or rongeur (Fig. 15). The size of the defect is measured, taking note of the location of the interarticular ridge.

The wrist is then pronated to harvest the autograft. A transverse incision is made over the dorsum of hand, overlying the base of the 4th and 5th metacarpals. The extensor digiti minimi and extensor digitorum communis are retracted to expose the carpometacarpal capsule, which is then reflected off of the metacarpals distally. The
donor bone is taken from the distal articular surface of the hamate, where it articulates with both the 4th and 5th metacarpals. A ridge exists between the 2 carpometacarpal articulations, which will be used to recreate the proximal articular surface of the middle phalanx. The donor tissue is harvested with a saw or osteotome, taking slightly more donor tissue than measured. The capsule is reaproximated and the wound is irrigated and closed. The graft is then placed into the recipient bed and fixed with 1.1-mm or 1.3-mm interfragmentary screws (Fig. 16). The joint is reduced and range of motion assessed. The originators of this technique highlight that the hamate has thicker articular cartilage than the middle phalanx, so imaging may give the appearance of an articular stepoff; articular congruity is assessed with direct visualization. Once satisfied with the concentric reduction in full range of motion, the wound is closed and the joint is rehabilitated as for open reduction and interfragmentary screw fixation. The hamate donor site does not require any rehabilitation over and above the brief immobilization for the PIP joint.

Williams and colleagues evaluated the outcome of hemihamate autograft resurfacing on 11 subjects for unstable volar lip fractures averaging 60% of the articular surface. At an average of 16 months, average PIP joint arc of motion was 85° with 9° flexion contracture. Two subjects developed a recurrent dorsal subluxation of the PIP joint without functional complaints. All autografts went on to union.

**Treatment of Volar Fracture Dislocations**

**Extension block splinting**

Stable volar fracture dislocations can be treated with extension block splinting. Kang and colleagues advocated that only dorsal lip fractures with less than 2 mm of fragment separation be treated closed because those with greater than 2 mm are at increased risk of developing an extensor lag. When applying the splint, the PIP joint must be held in full extension to allow the central slip to scar down to the middle phalanx. The DIP joint should be left free to allow for tendon gliding and minimization of tendon adhesions. The PIP joint is immobilized for 3 weeks, followed by dynamic extension splinting, which allows for active flexion for another 2 weeks. Afterward, passive flexion and strengthening exercises are started.

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**Fig. 15.** Hemihamate arthroplasty harvest and inset. (A) The joint is shotgunned open and the recipient site prepared. (B) The hemihamate is harvested. (C) The hemihamate is inset to recreate the articular surface. (Courtesy of P. Blazar, MD, Boston, MA.)
Closed reduction and transarticular pinning
Unstable joints and stable joints with greater than 2 mm of fragment separation are at risk of extensor lag due to the inability of the central slip to reliably heal to the middle phalanx. If the fracture fragment can be reduced and the dorsal aspect of the middle phalanx is restored so as to allow the central slip to heal to it, closed reduction and transarticular pinning is an option. Rosenstadt and colleagues\textsuperscript{6} published a series on 9 subjects with acute volar fracture dislocations treated with transarticular pinning. Although the final range of motion of the PIP joints was 87% of the unaffected side, there was a considerable amount of extensor lag seen at the DIP joint, presumably due to tendon adhesions secondary to prolonged immobilization of the DIP joint.

Dynamic external fixation
Volar fracture dislocations that exhibit articular congruity with longitudinal traction and translation can be treated with a dynamic external fixator, as described for dorsal fracture dislocations. Abou Elatta and colleagues\textsuperscript{31} treated 13 volar PIP joint fracture dislocations with dynamic external fixation for 5 to 6 weeks. Their subjects achieved average PIP joint motion of 90° (range 80° to 100°) and total active motion averaging 256°. The investigators noted that the DIP joint had a tendency to hyperextend, possibly indicating an early boutonniere deformity; they recommended keeping the DIP joint flexed throughout the traction period.

Open reduction and internal fixation with interfragmentary screws
An alternative, if the fracture fragment is large enough, is to fix the fracture to the middle phalanx with a mini-fragment screw. Tekkis and colleagues\textsuperscript{32} reported on 2 cases in which a single 1-mm lag screw was used to fix each fracture. Range of motion exercises were started after 1 week postoperatively. At 16-month follow-up, subjects had greater than 100° of flexion but a 10° extension lag. This technique has the advantage of early motion; however, the fracture fragment must be large enough to hold a lag screw, and there is a risk of extensor tendon irritation.

Open reduction and internal fixation with plate and screws
Open reduction and internal fixation with a hook plate can be used to treat these injuries when the fracture fragment is too small to accept a lag screw. Komura and colleagues\textsuperscript{33} published a case report of a rugby player treated in this manner who had 100° of flexion at the PIP joint and no extensor lag at 4-month follow-up. Care must be taken to avoid screw penetration into the flexor
tendon sheath, as well as plate irritation of the lateral bands distally.

**Treatment of Pilon Fractures**

Pilon fractures can be treated with many of the modalities previously described. Open reduction and internal fixation is useful if the fracture fragments are large enough to accept interfragmentary screws. Stern and colleagues\(^1\) published a series on 9 subjects treated with open reduction and K-wire fixation for pilon fractures of the PIP joint. Seven of their subjects achieved 70° PIP joint arc of motion with 10° flexion contracture. Four subjects had pain with axial loading, 1 had pain with heavy lifting, and 2 had continuous pain. The investigators noted that the results of open reduction and internal fixation were inferior to their experience with dynamic external fixation.

Pilon fractures with severe comminution can be treated with dynamic external fixation. Hynes and Giddins\(^2\) presented a series of 8 pilon fractures treated with dynamic external fixation, albeit with a short follow-up averaging 7.5 months. Their cohort had a final average 88° PIP joint arc of motion with 12° flexion contracture. Ruland and colleagues\(^3\) reported on a series of 8 subjects with PIP joint pilon fractures treated in this manner. That study included unstable dorsal fracture dislocations, as well as pilon fractures, making it difficult to assess the results for pilon fractures alone; however, the subjects had a PIP joint arc of motion of 88° with extension from 10° of hyperextension to 25° of flexion contracture.

**SUMMARY**

PIP joint fracture dislocations threaten the normal use of the hand if not recognized and managed in a timely manner. The soft tissues that stabilize the uninjured joint are commonly disrupted, leading to significant pain, swelling, and instability. Fracture dislocations that present late are at very high risk of chronic stiffness and loss of motion that leads to loss of function of the hand.

The treating physician should be suspicious of a PIP joint injury whenever a patient presents with a swollen finger or complaint of a jammed finger. Plain films should be obtained to aid in diagnosis, with the knowledge that these injuries may self-reduce, and radiographs should be scrutinized for evidence of fracture dislocation.

An understanding of the anatomy, as well as the mechanism of injury, will help to guide treatment. Once the fracture pattern is recognized, it can be classified into either a volar or dorsal fracture dislocation, or a pilon fracture. Plain films as well as physical examination will help to determine the stability of the joint. The combined knowledge of the fracture pattern and the stability of the joint will guide treatment.

The goals of treatment are to preserve or restore stability to the joint to permit early range of motion. Early motion will help to prevent the adhesions that lead to contractures and loss of function. Buddy taping or extension block splinting are both tolerated well for stable injuries. Tenuous and unstable fractures with a high degree of articular involvement may benefit from open reduction and internal fixation, or even joint reconstruction with a hemihamate autograft. Regardless of the intervention, however, the goal should be early motion. It is incumbent on the treating physician to educate the patient on the guarded prognosis of this joint and the absolute importance of compliance with the therapy protocol.

**REFERENCES**


