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Invited Hand Article: Current Concepts in Treatment of Fracture-Dislocations of the Proximal Interphalangeal Joint

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Abstract

Background—Proximal interphalangeal joint fracture-dislocations are common injuries that require expedient and attentive treatment for the best outcomes. Management can range from protective splinting and early mobilization to complex operations. In this review, the current concepts surrounding the management of these injuries are reviewed.

Methods—A literature review was performed of all recent articles pertaining to proximal interphalangeal joint fracture-dislocation, with specific focus on middle phalangeal base fractures. Where appropriate, older articles, or articles on closely related injury types were included for completeness. The methodology and outcomes of each study were analyzed.

Results—When small avulsion fractures are present, good results are routinely obtained with reduction and early mobilization of stable injuries. Strategies for management of the unstable dorsal fracture-dislocation have evolved over time. To provide early stability, a variety of techniques have evolved, including closed, percutaneous, external, and internal fixation methods. Although each of these techniques can be successful in skilled hands, none have been subjected to rigorous, prospective, comparative trials. Volar dislocations fare less well, with significant loss of motion in many studies. Pilon fractures represent the most complicated injuries, and return of normal motion is not expected.

Conclusion—The best outcomes can be achieved by (1) establishing enough stability to allow early motion, (2) restoring gliding joint motion rather than non-congruent motion, and (3) restoring the articular surface congruity when possible. Although the majority of literature on this topic consists of expert opinion and retrospective case series, the consensus appears to favor less invasive techniques whenever possible.

Keywords

proximal interphalangeal joint; PIP; fracture-dislocation

Introduction

Proximal interphalangeal joint (PIPJ) injuries are relatively common in most hand surgery practices. The annual estimated incidence of finger fractures is 67.9 per 100,000 persons per year in the United States, based on emergency department visits. Finger dislocations are estimated to affect 11.3 per 100,000 persons per year.¹

The spectrum of injury varies from minor strains to complex intra-articular fractures. Often, the severity of injury is underestimated by the patient, especially “jammed finger” injuries that do not lead to gross deformity or angulation. The management of these injuries must be proactive, restoring mobility as soon as feasible, to prevent stiffness and disability. Freiberg stated, “In general, when dealing with finger fractures and dislocations, one must always remember that for every case of delayed or nonhealing fracture, there are at least 100 permanently stiff fingers.”² This statement resonates with all experienced hand surgeons, underscoring the importance of correct management of these injuries, which must include early motion whenever feasible.

Although stable injuries typically require only proper hand therapy and a compliant patient to obtain a good result, many unstable fracture-dislocations require surgical intervention. As one reviews the existing literature, it quickly becomes evident that there are many surgical approaches advocated for these injuries, with a wide range of procedural invasiveness and technical skills required. Furthermore, as new approaches are developed, they are often rapidly and enthusiastically adopted without careful evaluation of outcomes. Indeed, comparative trials are rare for these techniques; most of the evidence available comes from retrospective case series. With this review, we will succinctly analyze the existing literature, to help the practicing hand surgeon decide on the best treatment for these injuries.

Anatomy and Biochemicals

The PIPJ is a stable joint in most respects, often described as a “box”, with the radial and ulnar proper collateral ligaments forming the box's sides, and the volar plate forming the bottom (Figure 1). In other texts, the PIPJ has been described as a “sloppy hinge” joint, because it does technically allow motion in more than just two dimensions. However, the small amount of rotational motion that can occur at these joints is minimal compared to the flexion/extension arc.³ The accessory collateral ligaments, though often portrayed in illustrations as hefty triangular structures, actually seem quite insubstantial under detailed anatomic scrutiny.⁴ The central slip of the extensor mechanism adds a “lid” to the PIPJ box, inserting at the dorsal base of the middle phalanx. Disruption of any one side of the box does not typically lead to dislocation; rather, at least two of these structures must be disrupted for the joint to dislocate.²

Even when completely disrupted, the collateral ligaments and volar plate usually do not require repair. Even after complete excision of the PIPJ collateral ligaments, the “neocollateral” ligaments that form in their place confer all the stability that the PIPJ requires.⁵

PIPJ stability depends heavily on the amount of intact joint surface (Figure 2). Fracture-dislocations involving 30% or less of the volar lip are considered stable, whereas those involving more than 50% are unstable. Injuries in between these extremes are considered “tenuous”, and should be assessed carefully for stability during treatment. This “30-50 rule”, as it is sometimes known, was established partially by the early work of McElfresh et al. who showed that fracture-dislocations involving 10-30% of the joint surface could be reliably treated with extension block splinting, whereas more extensive fractures were uniformly unstable.⁶ This was validated in a recent cadaver biomechanical study by Tyser et al. showing that fractures of 20% of the surface were uniformly stable, fractures of 40% of the surface were variable, and fractures of 60-80% were always unstable.⁷ In practice, live lateral-view fluoroscopy, such as can be obtained with a mini C-arm, can be very helpful in determining post-reduction stability and position of splinting for these digits.

In the following sections, different injury patterns will be addressed, with guidelines for management of each injury type. Because stiffness and pain are the most common limitations after PIPJ injury, those outcomes will be emphasized for each technique discussed. Also, when available, validated patient-rated outcomes data will be summarized.

Dislocations without Fracture

The most common type of dislocation is dorsal (Figure 3); these are typically closed injuries and are usually easy to reduce.⁸ Early motion is the most important component of treatment, as prolonged immobilization leads to significant difficulty with stiffness. Although this concept is stressed in most review articles on this subject,^{2,9,10} there is little high-level evidence to support this. Arora et al. published a retrospective study comparing 4 weeks cast immobilization versus early active motion following reduction of PIPJ dorsolateral dislocations. The early active motion protocol produced significantly superior range of motion and pinch strength results.¹¹ Of note, the only Cochrane review on this topic pertains to treatment of PIPJ hyperextension injury, and did not focus on dislocations specifically.¹²

Volar dislocations are much less common, but are more difficult to reduce and carry a higher likelihood of morbidity (Figure 4). The attachment of the central slip is usually disrupted, and therefore early mobilization is avoided, maintaining the PIPJ in extension for 3-6 weeks to allow for healing. This type of treatment has led to disappointing results in many series.¹³ For open repairs of the central slip, there is evidence that rehabilitation with an early active short arc motion protocol may result in outcomes superior to immobilization.¹⁴ This may have some application for open reductions and/or repairs of these injuries.

Dorsal Fracture-Dislocation

These injuries are caused by a hyperextension mechanism, where the most common fracture pattern is a volar lip fracture of the middle phalanx (Figure 5). This fracture fragment is typically attached to the volar plate which has been avulsed off of the middle phalanx. As with simple dorsal dislocations, these injuries are usually easily reduced. The stability of the joint after reduction is directly related to the amount of joint surface disrupted, as mentioned above (Figure 2). Small fracture fragments can be safely ignored, and early range of motion

with extension-block splinting should lead to good results.⁶ However, as more of the articular surface is involved, dorsal subluxation of the middle phalanx becomes more likely. This is related to two factors: loss of the normal volar buttress and disruption of the insertion of the proper collateral ligaments where they attach to the middle phalanx.

Kiefhaber and Stern point out that subtle subluxation can be difficult to recognize on standard radiographs; the “V-sign” (Figure 6) is one telltale marker that can alert the clinician to this problem.¹⁵ During attempted PIP flexion, this dorsal subluxation of the middle phalanx can lead to “hinging” on the fracture line, rather than true gliding joint motion (Figure 7). These authors further stressed that restoration of joint stability and early motion were more important than re-establishing precise congruity of the articular surface.¹⁵

A wide variety of interventions can be considered for the unstable dorsal fracture-dislocation. In select cases, extension block splinting alone can be considered, provided that the flexion required to eliminate joint subluxation is neither too pronounced, nor sustained for too long, to avoid significant PIP flexion contracture.^{6,16,17} Although extension block splinting may be initiated at any degree of flexion (up to 80 degrees has been described), most injuries of this type are stable with 25-40 degrees of blocking. The goal should be to reduce the block by 25% each week post-injury, otherwise flexion contracture becomes more of a certainty.

Closed Treatments

Extension-block pinning, in which the PIPJ is prevented from fully extending with a blocking Kirschner wire (K-wire) placed in the head of the proximal phalanx, accomplishes much the same ends as extension-block splinting, but eliminates some of the human factors, such as compliance with splint wear. The pin should be placed while the PIPJ is held in full flexion, to avoid tenodesis of the central slip which could limit early active motion of the PIPJ. The pin should block the PIPJ arc of motion about 30° from full extension.¹⁸ Maalla et al. reported on a retrospective series of 36 patients treated with this technique, of which 22 were available for follow-up at 2.6 years. Most of these patients had fractures of between 21-40% of the joint surface. Mean arc of PIP motion was 85°, with an average extension lag of 11.8°. Only 12 of the 22 patients were pain-free.¹⁹

Waris and Alanen combined extension-block pinning with percutaneous intramedullary fracture reduction to restore better joint surface congruency in cases of dorsal fracture-dislocation with depressed articular fragments.²⁰ At final follow-up, mean active motion was 83°, with extension lag of 3°, and visual analog score (VAS) for pain was 1/10. Postoperative DASH scores of 4 indicated very minimal impairment at final follow-up.

Osteosynthesis is another method that can be used to help restore both stability and a congruent joint surface. Toward this goal, various techniques of closed reduction and pinning as well as open reduction and internal fixation have been reported. Closed reduction can be difficult for small articular fragments; percutaneous wires may be used as levers²⁰ or tamps¹⁹ to accomplish this (Figure 8). Percutaneous fixation is accomplished with small K-wires, typically placed transversely across the base of the middle phalanx to capture the small fragments.²¹ Vitale et al. reported on a series of percutaneously-treated dorsal

fracture-dislocations using a volar-to-dorsal pinning technique, combined with extension-block pinning in 6 patients with fractures of 40% or more of the articular surface of the PIPJ.²² At 18 months follow-up, mean arc of motion was 89°, with an extension lag of only 4°. VAS pain score was 1.4 out of 10, and mean DASH score was 8.

Open Treatments

Open reduction techniques add another level of complexity to the treatment of this injury. Often, the fractures are more comminuted than suspected. Once the fracture is fully exposed, the stability afforded by the intact periosteum and other soft tissues is lost. Although the earliest reports of open treatments of dorsal fracture-dislocations utilized K-wires,²³ modern options for internal fixation include screws, mini-plates, and cerclage wiring.

Screw fixation is most applicable to cases where there is one large volar lip fragment. Both dorsal,²⁴ volar,²⁵ and lateral²⁶ approaches have been described, using screws between 1.1-2.0 mm in size. Although an early report of two cases by Green et al. reported PIPJ arcs of motion of 85° and 105°,²⁴ other studies have not been as favorable. Hamilton et al. reported on a series of 9 patients repaired with the volar approach, with a mean final arc of motion of only 70°. Seven of the nine were pain-free, with two patients reporting pain with heavy activity.²⁷ Using a primarily dorsal approach, Jonathan Lee et al. achieved slightly better results, with a mean PIPJ arc of 85°; pain was not evaluated in this study.²⁵ Jay Jun Lee et al. reported on the use of the lateral approach to fix small fracture fragments with absorbable suture, but on review of this study, it appears most were stable reductions, and might have done just as well without surgery.²⁶

Weiss proposed cerclage wiring of these dorsal fracture-dislocations as an alternative to mini-screws, and performed the procedure in 12 patients who had persistent subluxation after reduction. His series included patients with variable levels of fracture comminution, and some patients with depressed articular fragments. At 2.1 years follow-up, he reported active range of motion of 89° at the PIPJ, with extensor lag of 8°.²⁸ No patients complained of pain at follow-up, but one perceived a “click” in the joint. This technique requires careful planning and execution, and is technically more difficult than some of the other options available.

Mini-plate fixation has only recently been applied to dorsal fracture-dislocations.²⁹ For most hand surgeons, it is not intuitive to place a mini-plate beneath the flexor tendons, given concerns for adhesions and tendon irritation. Cheah et al. reported on a series of 13 patients with dorsal fracture-dislocations involving an average of 44% of the joint surface. Mean PIPJ active range of motion at final follow-up was 75°, and average Quick-DASH score was 4. Most of the patients (12 of 13) reported no pain or mild pain, but 3 patients required hardware removal to try to improve motion.³⁰ Analysis of their data shows an average extension lag of 13°; similar deficits were reported by Kang et al. when they applied a small hook plate to this fracture.³¹

To summarize thus far, it appears that most studies show better overall motion with less invasive approaches. In one of the only comparative studies on this topic, Aladin et al. began to randomize patients between two groups: (1) closed reduction with transarticular K-wire

pinning and (2) open reduction with internal fixation.³² As the study progressed, difficulty with screw placement led to the adoption of cerclage wiring as the internal fixation of choice. However, due to concerns over the significantly greater morbidity in the open treatment group, the study was halted after randomization of only 19 patients. Range of motion, pain, sensory disturbances, and cold intolerance were all significantly worse in the open treatment group. Though it is clear that good results can be achieved in talented hands, there is clearly a significant risk of increased morbidity with open treatment of these injuries.

Dynamic External Fixation

In order to minimize morbidity, many techniques of external fixation have been developed (Figure 9)³³. Although the earliest reports were static devices,³⁴ most devices in current use allow for (1) distraction across the joint, (2) reduction of joint subluxation, and (3) early passive and/or active range of motion. Large, cumbersome devices as described by Schenck^{35,36} have largely been replaced by smaller devices. One of the more common constructs is the “pins and rubbers” system designed by Suzuki.³⁷

Suzuki's simple construct has been extensively studied and modified over the years.^{33,38-48} Most studies report a mean arc of PIPJ motion between 84-88°,^{38,41,46,47} although a significant learning curve is described, and some studies have reported mean arc of motion as low as 66°. ³⁹ Using a modification involving pre-loaded wires without rubber bands, Theivendran et al. reported a PIPJ arc of 64° at early follow-up (only 24 weeks); this study reported average Michigan Hand Outcomes Questionnaire (MHQ) scores of 90, which is an outstanding score.⁴⁸

Of the various commercial products designed for treatment of these injuries, few have been reported in the literature. Furthermore, each of these studies examines a very heterogeneous group of PIPJ injuries, so they should be interpreted with caution. Both Bain et al.⁴⁹ and Krakauer and Stern⁵⁰ studied the Compass PIP hinged fixator (Smith & Nephew, UK), reporting average arcs of motion of 73-74° after treatment of a wide range of acute and chronic PIPJ injuries. The Ligamentotaxor® device (Arex®, France) has been investigated by both Körting et al.⁵¹ and Damert et al.⁵² for treatment of various intra-articular PIPJ fractures. Results showed average arcs of motion between 73-76°, with extension lag of 13-20°. Damert et al. measured DASH scores at follow-up, which averaged 14.6 points; Körting et al. assessed Quick-DASH scores averaging 16.9 at final evaluation. Although some of the injuries treated in these series were quite complex, these results seem to compare less favorably to other methods.

Advanced Reconstruction

When dorsal fracture-dislocations cannot be stabilized by any of the above means, it may become necessary to proceed with more advanced reconstruction.

The concept of volar plate arthroplasty (VPA) involves advancement of the volar plate into the joint to resurface the volar base of the middle phalanx. As such, this operation provides some stability, by helping the joint resist dorsal subluxation, and it furthermore resurfaces the middle phalanx where the articular surface is missing. Indications for volar plate

arthroplasty include acute fracture-dislocations where a stable volar lip cannot be satisfactorily reconstructed with other means, or in chronic injuries where the joint is not yet arthritic.⁵³ In one of the longest follow-up studies (11.5 years), Dionysian and Eaton showed that in cases of acute injury, arc of motion of 85° was maintained over time, with average extension lag of 15°. In the subset of chronic cases, arc of motion was only 61° and extension lag was 29°. No patient in either group complained of pain at rest or with activity in this series; all patients except one were completely satisfied.⁵⁴

In a retrospective comparative study, Deitch et al. compared the results of volar plate arthroplasty (17 patients) to open reduction and internal fixation with K-wires or screws (7 patients).⁵⁵ Within this small sample size, no significant difference was noted in final arc of motion between the two groups. Overall, extension lag averaged 12°, and PIPJ arc of motion averaged 68° at long-term follow-up (46 months); only half of the patients were pain-free at this time point. Of note, most of these patients were immobilized with transarticular pinning or external fixation for 3 weeks after surgery, which may reflect the severity of injury and may explain the long-term loss of motion.

Hemi-hamate arthroplasty is a technically demanding operation that replaces the volar buttress of the middle phalanx with an osteochondral graft harvested from the dorsal distal aspect of the hamate, where it abuts the fourth and fifth metacarpal bases (Figure 10).^{56,57} Several reports of this technique in small case series have had variable results, with arc of motion ranging from 67° to 96°. ⁵⁸⁻⁶⁰ In the largest series published to date, Calfee et al. report the results of hemi-hamate arthroplasty in 33 patients with comminution of at least 50% of the articular surface of the middle phalanx.⁶¹ PIPJ arc of motion for acute cases (71°) was similar to chronic cases (69°) at follow-up of 4.5 years. VAS for pain was 1.4/10, and DASH scores at follow-up averaged 5. This operation continues to evolve, with several helpful modifications and pearls available in recent technique articles.^{60,62}

Volar Fracture-Dislocations

Volar fracture-dislocations are much less common than their dorsal counterparts, but carry the potential for greater morbidity if not managed appropriately. Even though the fragment of bone may be small, the detached central slip will lead to a boutonniere deformity, which can cause more relative morbidity than a small volar plate avulsion fracture. These injuries can be treated non-operatively if the fracture fragments approximate adequately after PIPJ reduction and stabilization in extension. However, larger displaced fractures require some form of fixation (Figure 11).

Case reports have shown excellent range of motion without boutonniere deformity at up to 16-18 months follow-up.^{63,64} In a heterogeneous group of avulsion fractures (dorsal and volar) treated with mini-hook plate fixation, Kang et al. likewise reported good motion in all patients, with no boutonniere deformity in central slip avulsion fractures.³¹ In a larger series of 21 patients with bony boutonniere deformity treated with a wire loop repair, Zhang et al. reported mean PIPJ extension lag of just 6.4° at 13.5 months follow-up.⁶⁵ Of note, it appears that all patients had the wire removed at 9 months, although the investigators state it could

be left in routinely, since it is asymptomatic. Only one patient complained of moderate pain at final follow-up; the rest were pain-free.

Interestingly, treatment of volar fracture-dislocations seems to lead to better overall results than volar dislocations without fracture. This is perhaps due to the earlier mobilization facilitated with rigid fracture fixation, which leads to less long-term stiffness.

Pilon Fractures

In this context, the term *pilon fracture* refers to intra-articular fractures of the base of the middle phalanx in which both the dorsal and volar buttresses are compromised (Figure 12). Typically, these fractures also have depressed central articular fragments due to the axial load mechanism involved. With no significant joint congruity remaining, these fractures are particularly challenging for the surgeon to manage.

In a retrospective comparative study, Stern showed that external traction with a Schenck-style splint could deliver results superior to both splinting alone as well as open reduction and internal fixation in these cases.⁶⁶ Stern emphasized that anatomic restoration of the joint surface was often impossible, but perhaps also unnecessary in these cases, as extensive remodeling was evident in long-term follow-up.

More recently, Hynes et al. published a series of 8 patients with pilon fractures treated with a simple dynamic fixator.⁶⁷ The mean arc of PIPJ motion was 72°, and the mean extensor lag was 12°; a few patients reported pain with heavy use, pain with cold weather, and pain with full flexion, but 5 patients were pain-free. This is consistent with the majority of reports; full return of finger motion is not expected after pilon fractures.

Conclusions

Review of the current literature on PIPJ fracture-dislocations reveals that most of the world-wide literature is Level IV evidence or lower. Only one randomized trial was discovered, and it was terminated early due to significant postoperative morbidity differences between groups.³² Many of the larger series pool together heterogeneous fracture patterns, which makes application to specific patients difficult.

Whichever approach is selected, the three fundamental guidelines put forth by Kiefhaber and Stern¹⁵ should be followed: (1) restore gliding joint motion and avoid fracture hinging due to joint subluxation, (2) impart enough stability to the joint, by means of fixation and/or traction, to allow early range of motion during rehabilitation, and (3) make reasonable efforts to restore joint surface congruity, so long as the overall morbidity of the operation is not dramatically increased. Furthermore, regardless of the treatment modality selected, clinicians should understand that return of normal PIPJ range of motion is typically not possible with many of these injuries, and should counsel their patients accordingly.

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Figure 1.

This lateral schematic of the proximal interphalangeal joint (PIPJ) emphasizes the structures important for stability, specifically the proper collateral ligaments, the volar plate, and the central slip of the extensor mechanism. P1 = proximal phalanx. P2 = middle phalanx.

Figure 2.

PIPJ stability depends on the amount of intact joint surface. Fractures involving 30% or less of the joint surface are almost always stable, whereas fractures of more than 50% of the joint surface are likely to be unstable. Fractures of between 30-50% of the joint surface are more variable, and stability may be tenuous. P1 = proximal phalanx. P2 = middle phalanx.

Figure 3.
Lateral radiograph showing dorsal PIPJ dislocation.

Figure 4.
Lateral radiograph showing volar PIPJ dislocation.

Figure 5.
Lateral radiograph showing dorsal PIPJ fracture-dislocation with small volar lip avulsion fracture.

Figure 6.

(A) This lateral schematic of the PIPJ shows a volar lip avulsion fracture and dorsal subluxation of the joint. The V-shaped gap shown in blue emphasizes the non-congruity of the dorsal portion of the joint, often referred to as a “V-sign.” P1 = proximal phalanx. P2 = middle phalanx. (B) This lateral radiograph demonstrates the “V-sign” due to PIPJ subluxation.

Figure 7.

This lateral schematic illustrates what can occur with PIPJ flexion after volar lip fracture.

(A) Normal gliding motion of the joint, with maintenance of congruity. (B) Abnormal “hinging” of the joint, as the middle phalanx pivots on the fracture line, rather than maintaining congruity. P1 = proximal phalanx. P2 = middle phalanx.

Figure 8.

This schematic shows the step-by-step technique to achieve percutaneous reduction of central articular fragments in PIPJ fracture-dislocations, with K-wire stabilization of the articular surface. (A) K-wire inserted dorsally, distal to impacted articular fragment, (B) K-wire used as a lever to reduce the articular fragment, (C) Articular surface can be stabilized with multiple K-wires placed just distal and parallel to the articular surface.

Figure 9.

Evolution of dynamic traction devices for comminuted PIPJ fractures and fracture-dislocations. From Agarwal et al. *Ann Plast Surg* 2007;58: 489–495, used with permission.

Figure 10.

Technique for design of hemi-hamate arthroplasty for the PIPJ. The dimensions A, B, and C, are measured from the defect in the middle phalanx (P2) and carefully plotted out on the dorsal, distal hamate to obtain a graft of the appropriate size. MC = metacarpal. CMC = carpometacarpal joint. PIP = Proximal interphalangeal joint.

Figure 11.
Lateral radiograph showing dorsal lip fracture with minimal volar subluxation.

Figure 12.
Lateral radiograph showing pilon fracture of the PIPJ (as well as an incidental mallet fracture of the distal interphalangeal joint).