Management of Proximal Interphalangeal Joint Dislocations in Athletes

Randy R. Bindra, MD, FRCS*, Brian J. Foster, MD

KEYWORDS

- Proximal interphalangeal joint
- Dislocation • Fracture • Pilon • Volar plate

Proximal interphalangeal joint dislocations are common injuries in athletes. These injuries may be associated with fractures of the base of the middle phalanx. Principles of management include achieving and maintaining a congruent joint, early mobilization to prevent stiffness, and restoration of the joint articular surface, which is the least important issue. An athlete or coach may minimize injury to the proximal interphalangeal joint, especially dislocations that are reduced on the field; therefore, it is the responsibility of the treating orthopedic surgeon to fully and carefully evaluate and treat these injuries. In the following sections, basic anatomy, injury pathology and characteristics, clinical assessment, radiological findings, and treatment principles are reviewed.

ANATOMY

The proximal interphalangeal (PIP) joint is a hinge joint that accounts for 85% of the motion required to grasp an object.[1] The PIP joint is formed by proximal and middle phalanges and derives its stability from its bony architecture and soft tissue restraints. The majority of joint motion is in flexion-extension, with a normal range of motion between 100° and 120°. The proximal phalanx head has two concentric condyles that are separated by an intercondylar concavity or notch. The condyles articulate with corresponding concavities on the broad base of the middle phalanx. These concavities are separated by a saddle-shaped median ridge; the ridge fits into the corresponding intercondylar notch of the proximal phalanx for bony stability. This congruence offers stability in flexion-extension while limiting lateral and rotational movements.[2]

A collateral ligament on each lateral aspect of the PIP joint limits radial and ulnar deviation and offers side-to-side stability (**Fig. 1**). The ligaments arise from a notch distal to the epicondyle of the proximal phalanx and run in an oblique and volar direction to insert onto the middle phalanx in its volar lateral aspect. Each collateral ligament has two parts: a dorsal component that tightens during flexion and a volar component that tightens in extension.[3] A separate accessory collateral ligament runs with each proper collateral ligament; however, this accessory collateral ligament runs in a more volar direction to insert on the lateral edge of the volar plate and flexor tendon sheath. The primary function of the accessory ligament is to tension the volar plate and pull it proximally to provide clearance during finger flexion.[4]

Spanning the volar aspect of the joint is the volar plate, which primarily prevents hyperextension of the joint.[4] The volar plate is secured proximally to the proximal phalanx through thick lateral extensions (checkrein ligaments) that attach to the bone within the distal aspect of the second annular pulley. The proximal edge of the plate remains free so that it can move proximally during digital flexion. Its proximal origins are also confluent

Department of Orthopaedic Surgery, Loyola University Medical Center, Maguire Center Suite 1700, 2160 South 1st Avenue, Maywood, IL 60153, USA
* Corresponding author.
E-mail address: rbindra@lumc.edu (R.R. Bindra).

Hand Clin 25 (2009) 423–435
doi:10.1016/j.hcl.2009.05.008
0749-0712/09/$ – see front matter

hand.theclinics.com

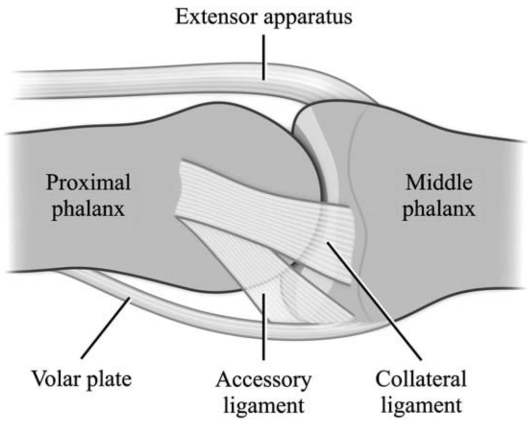

Fig. 1. Key anatomic structures surrounding the PIP joint.

with the proximal origins of the first cruciate pulley. The volar plate's central distal attachment is to the base of the middle phalanx where it blends with the periosteum just volar to the articular surface; its lateral distal attachment is thicker and blends with the insertion of the collateral ligaments. The volar plate and collateral ligaments form a strong boxlike design that stabilizes the PIP joint and resists joint displacement. PIP joint displacement occurs when the ligament-box complex is disrupted in at least two planes.[3,5] The volar plate and accessory collateral ligaments maintain joint stability in the extended PIP joint whereas the proper collateral ligaments maintain stability in flexion.[3]

The flexor and extensor tendons provide additional stability. The central slip of the extensor mechanism crosses over the PIP joint before it attaches to the dorsum of the middle phalanx. The lateral bands of the extensor mechanism (composed of the lumbrial and dorsal interossei tendons) travel on both sides of the PIP joint; they are held in place over the PIP joint by the transverse retinacular ligament. The flexor tendons are held close to the volar aspect of the joint by the third annular pulley, which attaches to the volar plate. In addition, the flexor digitorum superficialis tendon directly inserts on either side of the volar lateral edge of the middle phalanx through two lateral slips.

The PIP joint dorsal capsule has a small synovial lining and is separate from the overlying extensor mechanism.[6] The volar capsule consists of the volar plate, the proximal extension of which is continuous with a band of connective tissue that extends to the proximal phalanx neck.[2] The radial and ulnar aspects of the joint capsule can each be divided into three components: the collateral ligament and the two fan-shaped areas dorsal and volar to it. The fibers of the dorsal fan-shaped area blend distally with the extensor expansion; the fibers of the volar fan-shaped area blend distally with the collateral ligament, volar plate, and flexor sheath.[2]

INJURY CHARACTERISTICS

Due to its unprotected location, long lever arm, and low lateral and rotational mobility, the PIP joint is susceptible to injury in athletes.[7] Athletes who participate in sports involving catching or hitting a ball are especially susceptible to PIP injuries. Many of these injuries occur from the athlete "jamming" or "catching" their finger while catching a ball or falling, resulting in hyperextension or angular deformity to the PIP joint. Compounding the actual injury, the PIP joint has a propensity for stiffness after trauma or immobilization, especially immobilization of longer than 3 weeks.[8] This stiffness is likely due to pain, swelling, and fibrosis/scar tissue formation.

PIP injuries include sprains, dislocations, and fracture-dislocations. PIP dislocations are identified by the direction of the middle phalanx in relation to the proximal phalanx. If associated with fractures of the base of the middle phalanx, they are classified as fracture-dislocations. Increasing instability is associated with increased size of fracture fragments. The three types of PIP dislocations are dorsal (most common), volar, and lateral. The volar plate and at least one collateral ligament must be injured for PIP dislocation to occur.

PROXIMAL INTERPHALANGEAL JOINT DORSAL DISLOCATIONS

By far the most common type of PIP dislocation, dorsal dislocations, occur secondary to hyperextension of the PIP joint; there is usually also an axial load component to the deforming force. In these injuries, the volar plate is avulsed from the middle phalanx base and the middle phalanx rests on the dorsum of the proximal phalanx. The middle phalanx is dislocated dorsally and the volar plate is avulsed from its distal insertion, thus helping to prevent the plate from incarcerating within the joint. The volar plate usually retains its proximal and lateral attachments to the proximal phalanx and accessory collateral ligament, respectively.[4]

Dorsal PIP dislocations occur along a spectrum of injuries to the PIP joint. As a result of hyperextension injury, most injuries result in avulsion of the volar plate at its distal attachment with or without a small bony fragment. The collateral ligaments remain intact and joint congruity is maintained; clinically this presents as a "sprained" joint. With more severe applied force, in addition to volar plate avulsion, the collateral ligaments split longitudinally allowing dorsal dislocation of the middle phalanx (**Fig. 2**). The most severe form of injury is one resulting from hyperextension and axial loading, resulting in dorsal PIP dislocation with a shear fracture of the volar lip of the middle phalanx as it makes contact with the head of the proximal phalanx. With larger fracture fragments involving more than 40% of the articular surface of the middle phalanx, the dorsal fragment is bereft of any stabilizing soft tissue attachment as the volar plate and collateral ligaments remain with the volar fracture fragment (**Fig. 3**).[5,9] The additional loss of bony congruity creates an extremely unstable situation whereby it is difficult to maintain joint reduction.

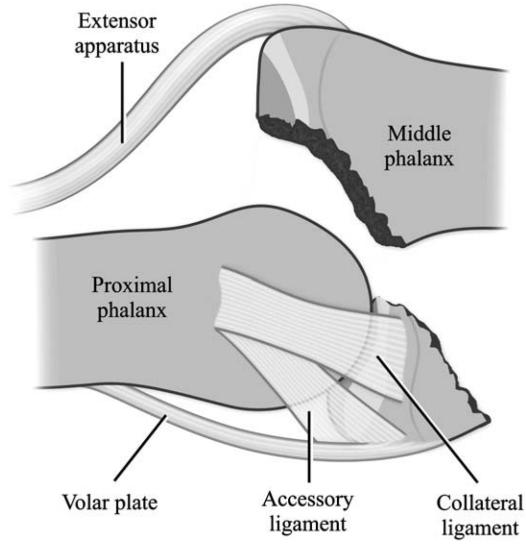

Fig. 3. Anatomic features of a dorsal PIP fracture-dislocation with a fracture fragment consisting of more than 40% of the middle phalanx base. The loss of bony congruity along with disruption of all ligamentous stabilizers creates an extremely unstable configuration.

PROXIMAL INTERPHALANGEAL JOINT LATERAL DISLOCATIONS

A laterally directed force to the PIP joint results in avulsion of the collateral ligament from its proximal attachment on the side of the applied force (**Fig. 4**).[7,10] With continued force the volar plate eventually tears on the side of injury, resulting in lateral dislocation.

PROXIMAL INTERPHALANGEAL JOINT VOLAR DISLOCATIONS

Volar PIP dislocations are rare and unlike the more common dorsal or lateral dislocations, are sometimes irreducible due to soft tissue interposition.[11] In uncomplicated cases the central slip of the extensor mechanism ruptures or avulses from the dorsal lip of the middle phalanx (**Fig. 5**).[10] The intact lateral bands initially can perform joint extension even though the central slip is ruptured. Failure to immobilize the joint in extension to allow central slip healing can eventually lead to stretching of the triangular ligament holding the lateral bands, resulting in their volar subluxation. The subluxated lateral bands can no longer extend the PIP joint and the tightening of the terminal extensor slip leads to hyperextension of the distal interphalangeal (DIP) joint: the classic boutonniere deformity.

Complex volar dislocations involve rotary displacement with a collateral ligament tear secondary to lateral stress combined with an anteriorly directed force. In complicated cases the central slip, lateral band, or torn collateral ligament may be interposed within the joint, thereby necessitating open reduction.[12]

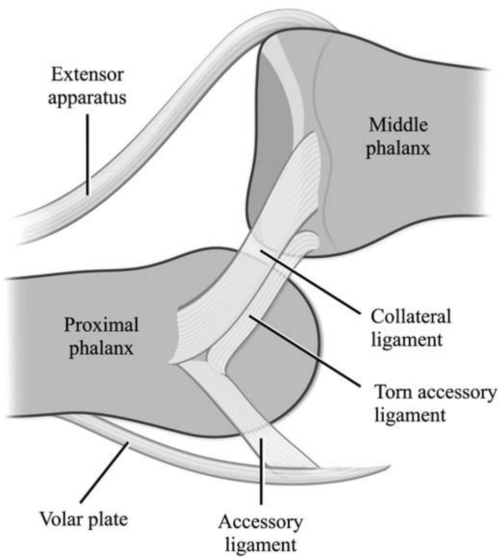

Fig. 2. Ligamentous injuries associated with a simple dorsal PIP dislocation. Apart from the volar plate and part of the accessory collateral ligament, other important structures and hence joint stability is preserved.

PROXIMAL INTERPHALANGEAL JOINT FRACTURE-DISLOCATIONS

These injuries result in PIP dislocation with a fracture of the proximal base of the middle phalanx. Hyperextension or hyperflexion loads result in avulsion fractures, whereas axial loading in varying positions of PIP flexion/extension leads to

Fig. 4. Anteroposterior and lateral radiographs of a lateral dislocation of the PIP joint.

impaction shear fractures.[9,13] The fractures are located at one of three locations on the middle phalanx: volar lip, dorsal lip, or central (pilon fracture).

Avulsion fractures are either volar or dorsal and can involve varying amounts of the middle phalanx articular surface, although they generally involve less than a third of the articular surface. Tiny volar avulsion "chip" fractures are more common, represent an avulsion of the volar plate, and are secondary to a hyperextension injury. Dorsal avulsion fractures are less common and are secondary to an axial force flexing an extended digit, thereby avulsing the central slip of the extensor mechanism. Impaction shear fractures have more comminution than avulsion fractures and occur when an axial stress is applied to the PIP joint in varying angles of flexion or extension. Axial stress in flexion produces a volar impaction shear fracture and stress in extension results in a dorsal impaction shear fracture.[13] Pilon fractures are comminuted fractures that result in fractures of the volar and dorsal cortices with compression of the central articular surface. These are secondary

Fig. 5. Clinical and radiographic appearance of a volar PIP dislocation.

to axial load in neutral or hyperextension. The multiple small fracture fragments are often too small for fixation of all the fragments.

Because there is a correlation between the amount of articular surface that is fractured and PIP joint stability, PIP fracture-dislocations are generally classified based on the amount of articular surface involvement (ie, Grade I = 0%, Grade II = 0%–20%, and so forth).[5,9,14] However, their prognosis and treatment are best evaluated by simply labeling them as "stable" or "unstable" based on clinical and radiographic assessment. "Stable" volar lip fractures generally involve less than 30% of the articular surface and maintain joint reduction through a full arc of motion. "Unstable" volar lip fractures usually involve 40% to 50% of the articular surface and redislocate as the digit is moved into extension. More severe injuries generally are only stable in extreme degrees of flexion.

CLINICAL FEATURES

As with any sports injury, a thorough physical examination is important in a patient with a PIP joint injury. In addition to the physical examination, a detailed history including handedness, specific position or activity in sport, level of competition, status of the current sport season, and patient expectations and goals are important considerations. It is generally advisable to examine the unaffected digits, hand, and wrist before examining the PIP joint in question. Swelling, skin integrity, areas of tenderness, active and passive range of motion (ROM), and scissoring when the patient makes a fist should be noted. A dislocation can easily be determined clinically, but a minor subluxation may be more subtle and is suggested with severe restriction of PIP joint motion or scissoring. Although neurovascular injuries are uncommon in PIP injuries, capillary refill and two-point discrimination should be examined in the affected digits. Integrity of the central slip, flexor superficialis, and flexor profundus must be examined individually. Finally, ROM and stability of the adjacent joints in the same digit must be tested so that additional injuries in the same digit are not missed.

Further examination of joint stability is performed after closed reduction under local anesthetic is achieved. Stability testing should include taking the PIP joint through a full ROM of flexion-extension and side-side stressing. Radiographs should be obtained before any reduction, manipulation, or stability testing. Testing side-side joint stability with the joint fully extended and in 30° of flexion assesses collateral integrity. A laxity of 10° in extension and 20° in flexion indicates proper collateral ligament rupture; 15° laxity in extension and 30° in flexion indicate additional accessory collateral ligament rupture.[3] The joint is then moved through flexion-extension and the position of any recurrent subluxation or dislocation is recorded.

Some PIP joint dislocations may have been already been treated on the field and present after closed reduction. It is important to determine the direction of the previous deformity and perform a thorough physical examination, specifically assessing joint stability. Stability should be assessed after radiographs, as nondisplaced fracture fragments may move when manipulated under anesthesia. It is not uncommon to have associated injuries to the distal interphalangeal joint, especially mallet injuries as they have a common mechanism of injury. Clinical and radiographic evaluation must exclude associated injury to the DIP joint (**Fig. 6**).

IMAGING

Evaluation of PIP joint injuries demands thorough examination of accurate posteroanterior (PA), lateral, and oblique radiographs centered on the injured digit. It is important to obtain radiographs before reductions or stability testing. Postreduction radiographs should be carefully reviewed to ensure concentric joint reduction and look for any displaced or interposed fracture fragments. A true lateral view should reveal a congruent joint space with two parallel surfaces. PIP joint subluxation may be difficult to appreciate but can be represented on the lateral view by a "V" sign, which is divergence of the posterior articular surfaces from the central aspect of the joint (**Fig. 7**).[15] It is essential to confirm joint congruency on posteroanterior and lateral views immediately after reduction and serially during treatment.

MANAGEMENT OF PROXIMAL INTERPHALANGEAL JOINT DISLOCATIONS AND FRACTURE-DISLOCATIONS

The primary goal for treatment of PIP dislocations and fracture-dislocations is to restore joint alignment and maintain joint stability so that the patient can perform early ROM exercises. Early ROM has a positive effect on cartilage and soft tissue healing, and decreases adhesions. The middle phalanx must glide around the head of the proximal phalanx during flexion instead of hinging at the fracture margin; joint subluxation prevents gliding.[9] The secondary goal of treatment is to maintain articular congruity, although this can be sacrificed to achieve joint stability and early ROM.

Fig. 6. Radiographs demonstrating concurrent PIP and DIP joint injuries. The radiograph on the left shows a dorsal PIP fracture-dislocation with bony mallet finger. On the right the finger shows a PIP pilon fracture associated with a DIP dislocation.

Most dislocations and stable fractures can be treated conservatively with closed reduction and early ROM. Anatomic studies have shown that on reduction of dorsolateral PIP dislocations, the injured volar plate and collateral ligaments return to their anatomic positions.[16] Injuries that fail conservative treatment or are unstable require more aggressive management, such as percutaneous fixation or traction. Open reduction internal fixation (ORIF) is not frequently required and is usually used in the treatment of injuries that present late. Athletes must be treated in the context of their sport. It is vital to take into account the athlete's specific sport, level of competition, position/role, future requirements, and goals/expectations.

CONSERVATIVE MANAGEMENT

Dorsal Proximal Interphalangeal Dislocations

If seen within a few days of injury, most dorsal PIP dislocations can be treated with closed reduction. Closed reduction of dorsal PIP dislocations is performed after digital block is administered. Gentle longitudinal traction is applied followed by flexion at the PIP joint. Joint stability is tested after reduction and while the digital block is still in effect. As long as the PIP joint is stable, small volar lip avulsion fractures do not require specific management and the digit is mobilized with buddy taping to an adjacent digit to prevent hyperextension for 3 weeks. There is no need to splint in flexion, as this can lead to flexion contractures. Athletes may return to their sport with buddy tapping as symptoms allow. Active and passive ROM should be started as soon as possible.

If a dorsal PIP dislocation is unstable, it will dislocate as the digit is brought into extension. Further treatment varies with the position of redislocation. If closed reduction is easily achieved, the joint is stable in 30° or less of flexion, and the volar avulsion fragment is less than 40% of the articular surface, then extension-block splinting may be used (**Fig. 8**).[17] A dorsal aluminum splint is made to run across the length of the finger with the PIP joint flexed just past the position of stability. The splint is hand-based and uninvolved digits are left free. Full active flexion is allowed immediately. The amount of PIP flexion in the splint is reduced every week by 25% with full extension being achieved at 4 to 6 weeks. Maintenance of reduction must be confirmed by weekly radiographic evaluation. Once full stable extension is obtained, athletes may return to sport with buddy taping used for an additional 3 weeks.

Fig. 7. Radiograph demonstrating the "V" sign (*dotted lines*) that signifies incomplete PIP joint reduction.

Lateral Proximal Interphalangeal Dislocations

Closed reduction is usually successful in restoring joint congruency. Lateral PIP dislocations are reduced under digital block through gentle longitudinal traction followed by radial or ulnar-directed force, depending on the direction of dislocation (ulnar-directed force for radial dislocation and vice versa). Stability is assessed after closed reduction, and if stable, the digit is mobilized with buddy taping to the digit that is adjacent to the injured collateral ligament. Early motion is initiated within buddy taping and can be continued for 3 weeks. Ice and compression are used intermittently to minimize swelling and facilitate movement.

Surgical repair of the torn collateral ligament does ensure joint stability and must be considered in an athlete.[18–22] Indications for surgical repair include postreduction lateral instability of more than 20° on stress testing, involvement of the index or small finger, or high demands placed on the finger by the athlete (eg, baseball pitcher).

Volar Proximal Interphalangeal Dislocations

Volar PIP dislocations are reduced under digital block through gentle longitudinal traction followed by extension at the PIP joint. These injuries usually reduce easily, but must be immobilized in full extension for 3 to 4 weeks to allow the central slip to heal. The DIP is left free and movement is encouraged. DIP motion promotes gliding of the terminal slip, takes tension off the injured central slip, and helps to prevent volar subluxation of the lateral bands. The initial immobilization is followed by dynamic extension splinting that permits active flexion for an additional 2 weeks; this is then followed by passive flexion and strengthening. Irreducible volar PIP dislocations require operative reduction and are likely due to volar-rotatory dislocations with extensor mechanism interposition.

PERCUTANEOUS MANAGEMENT

Percutaneous pinning is an excellent treatment alternative for reducible but unstable PIP dislocations. The pin may be inserted as a blocking pin to prevent full extension, or passed across the joint to immobilize it while soft tissue healing occurs. A blocking wire functions in a similar way to a dorsal extension-blocking splint.[23] The PIP is reduced with axial traction and flexed maximally. A 0.9-mm smooth K-wire is placed percutaneously through the center of the proximal phalanx articular surface. The K-wire is driven retrograde into the proximal phalanx at a 30° angle to its long

Fig. 8. Treatment of a PIP fracture-dislocation (*left*) with an extension-block splint (*right*).

axis until it engages the volar cortex. The K-wire is bent and left outside the skin and acts as a block to the last 30° of extension (**Fig. 9**). A protective splint is used and gentle active ROM is begun the day after surgery (**Fig. 10**). The K-wire is removed after 3 weeks at which time active and passive ROM are started to regain the remaining PIP extension. In cases of fracture-dislocations, the volar fragment may not be reduced anatomically by this technique; this is not critical as long as the joint is concentrically reduced. Athletes may return to sport after the pin is removed, but should buddy tape the digit until full ROM is achieved and they are asymptomatic.

Another option for unstable injuries is the placement of a transarticular pin after joint reduction. This technique can be applied to dislocations in all directions and does not require any patient compliance. The technique has been applied to unstable dorsal PIP fracture-dislocations involving up to 50% of the articular surface.[24] The PIP joint is reduced and stabilized in 20° to 40° of flexion. A smooth 0.9-mm K-wire is placed in retrograde fashion from the bare area on the dorsum of the middle phalanx, across the PIP joint, and into the head of the proximal phalanx. The pin is left in place for 3 to 4 weeks and an extension-block splint may be used for an additional 2 weeks after pin removal. The athlete should avoid sport during this time. After pin removal, active and passive ROM are initiated and the athlete may return to sport with buddy taping, which should be used until full ROM is achieved and he or she is asymptomatic. Although it may intuitively be expected to cause significant stiffness, the reported results in the setting of dorsal PIP fracture-dislocation are comparable to ORIF.[24,25]

SKELETAL TRACTION

For unstable PIP fracture-dislocations, various methods of skeletal traction, distraction, and dynamic external fixation have been used for treatment.[26–32] These methods are based on the concept of stabilizing the PIP joint and improving fracture alignment by distracting the soft tissues around the base of the middle phalanx, allowing reduction through ligamentotaxis. Use of skeletal traction is appropriate when the PIP joint reduces congruently and the middle phalanx cup-shape is restored. These treatment methods have shown good results in terms of postoperative ROM, return to activity, and patient satisfaction. The technique is especially useful in pilon fractures with fragments too small for internal fixation; the results are comparable to ORIF.[33] The advantages of this technique are avoidance of soft tissue stripping or dissection, early ROM, prevention of soft tissue contractures, and decreased postoperative swelling.

The disadvantages of skeletal traction include the need for pin care, risk of pin track infections, and residual articular incongruity, as skeletal traction does not elevate all depressed and impacted fragments. Reports on posttraumatic arthritis after the use of skeletal fixation have varied results, ranging from 0% to 30%.[29,30] Whereas articular reduction is a secondary goal to joint stabilization and early ROM, joint stability depends on restoration of the middle phalanx volar buttress. In addition, asymmetric fracture fragment depression can lead to unacceptable angulation. In cases that demonstrate asymmetric depression or loss of the middle phalanx cup-shape, additional intervention is required. Reduction can be

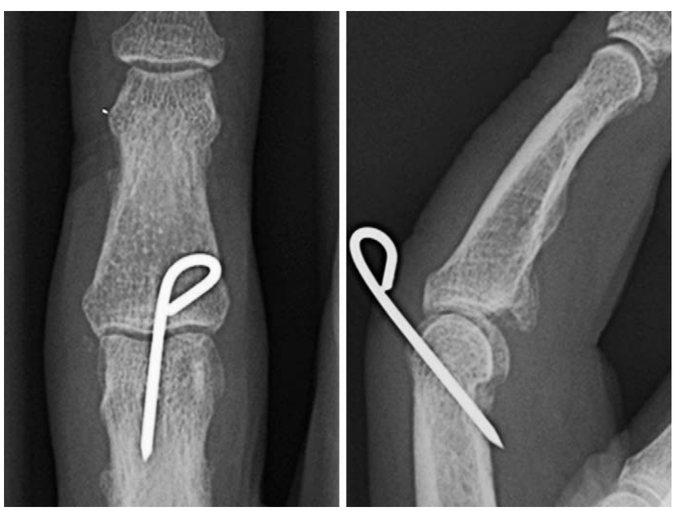

Fig. 9. Extension-blocking K-wire used for the treatment of an unstable PIP fracture-dislocation.

Fig. 10. Hand of a patient with an extension-blocking wire placed for a PIP fracture-dislocation. The patient is encouraged to move the joint through the permitted ROM.

accomplished through percutaneous elevation of impacted fragments with a K-wire or a freer dissector. If these problems cannot be corrected or the joint does not congruently reduce, formal ORIF should be considered.

A simple and economical method of traction uses K-wires to create a low-profile frame.[26] A small, 1.2-mm smooth K-wire is placed transversely across the proximal phalanx condyles, close to the axis of PIP motion. A second K-wire is placed transversely across the distal shaft of the middle phalanx, distal to the fracture. The distal wire is first bent 90° proximally, and this is followed by an S-shaped bend into the wire that allows it to loop around the proximal transverse wire. The configuration generates tension and distracts the PIP joint. Early active motion is allowed and the wires are removed at 3 weeks. Buddy taping should be used until full ROM is achieved and the athlete is asymptomatic. Radiographic widening of the middle phalanx base does occur but has little clinical significance.

OPEN REDUCTION INTERNAL FIXATION

ORIF has a limited but important role in the treatment of unstable dorsal PIP fracture-dislocations. Open reduction is not widely used due to the risk of stiffness, the generally good results of closed and percutaneous treatment, and unstable fracture patterns generally having small, comminuted fracture fragments that are too small for screw fixation. The indications for ORIF include displacement of a large volar fragment from the middle phalanx that does not reduce, failure to reduce the joint by previous treatments, and cases of late presentation. ORIF has the advantage of restoration of immediate stability that allows early protected ROM with the potential for good to excellent results in selected cases.

Dorsal, volar, and midlateral approaches have been described for dorsal PIP fracture-dislocations.[34–37] The volar approach allows direct visualization of the fracture fragment and permits lag screw fixation and restoration of the volar buttress of the middle phalanx. This procedure uses a volar Bruner approach that extends from the proximal digital crease to the DIP joint crease (**Fig. 11**). The digital neurovascular bundles are mobilized from the flexor sheath. The flexor tendon sheath is opened like a trapdoor between the A2 and A4 pulleys and is reflected laterally. The flexor tendons are retracted to one side to expose the damaged volar plate, which is mobilized by releasing its lateral attachments to the collateral ligaments, and the plate is then reflected proximally. The collateral ligament attachments to the middle phalanx are partially released in a volar to dorsal direction, which allows the digit to be gently hyperextended until it is fully doubled over like a shotgun, exposing the volar fracture.

Small comminuted fracture fragments are removed and the major volar fragment is elevated and reduced provisionally with K-wires. The

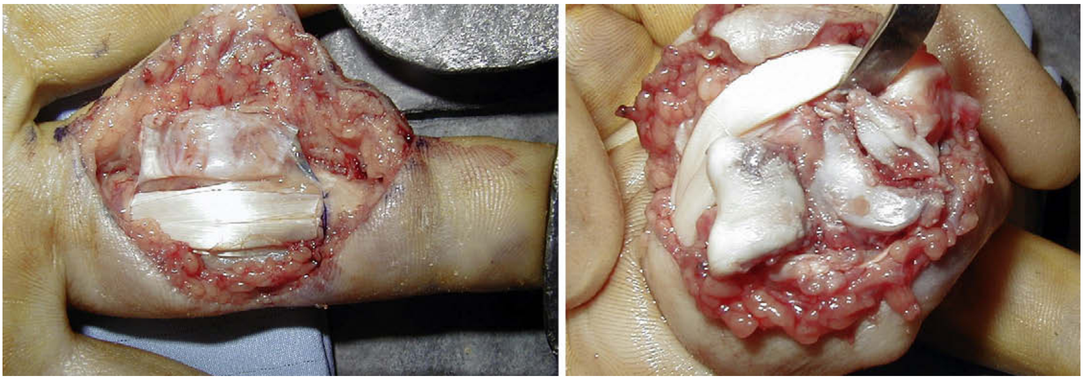

Fig. 11. Intraoperative photos of the volar "shotgun" approach to the PIP joint. The photo on the left demonstrates reflection of the flexor sheath between A2 and A4 pulleys. The final appearance is shown on the right, after the joint is mobilized and dislocated dorsally to allow the middle phalanx to lie parallel to the proximal one. The volar bone fragment can now be fixed easily.

fracture is temporarily stabilized with K-wires that are replaced with two lag screws passed from volar to dorsal (**Fig. 12**). In fractures that are too small or comminuted for screws, one can consider fixation with a circumferential wire loop.[38] Alternatively in small, comminuted fractures, an osteochondral graft from the dorsal lip of the hamate can be used to reconstruct the volar lip of the middle phalanx.[39]

ORIF is also useful as an adjunct to external fixation or as the primary treatment for pilon fractures of the middle phalanx.[40] Considerable care must be taken to avoid soft tissue stripping and devascularization of the fracture fragments. These

Fig. 12. Pre- and postoperative radiographs of internal fixation of PIP fracture-dislocation using the volar approach.

fractures are best treated through a midlateral approach using an incision defined by the line jointing points formed by the flexion creases of the interphalangeal joints when the digit is fully flexed. The dorsal skin flap is elevated, exposing the extensor mechanism lateral band, which is retracted dorsally after dividing the transverse retinacular ligament. The collateral ligament is identified and a longitudinal capsulotomy is made just dorsal to it. Provisional reduction may require K-wires. Definitive fixation is then performed with the use of lag screws directed laterally or from dorsal to volar as needed. The bare area between the lateral bands distal to the central slip insertion is a good location for screw insertion (**Fig. 13**).

Volar PIP dislocations with dorsal lip fractures that are displaced greater than 2 mm or are irreducible require operative fixation. Anatomic reduction of the dorsal lip ensures secure healing of the central slip and restoration of the extensor mechanism. The dorsal fragment can be stabilized with percutaneous or open reduction and lag screw fixation from the dorsal to volar direction.[41] If open reduction is necessary, a curved dorsal skin incision is made over the PIP joint. The extensor mechanism is usually disrupted at the central slip, but additional exposure to reduce the fragment can be gained by making an incision between the lateral band and the extensor slip on one side. The joint is reduced and may be held with a temporary K-wire. Provisional reduction of the fragment is achieved with a small smooth K-wire, and one or two lag screws are placed dorsal to volar. In comminuted fractures, tension band fixation may be employed instead of screw fixation. Based on the size and stability of fixation, the transarticular pin may be removed after fixation or left in place for 2 weeks, at which time an external splint can be applied. The longitudinal incision in the extensor mechanism is repaired with a running nonabsorbable suture.

The joint is protected postoperatively in full extension with a splint. Protected motion is started around 1 to 2 weeks postoperatively using a Capener splint that provides passive extension of the PIP joint.[34] Protection of the PIP joint in full extension with a small volar splint must be maintained for 6 weeks. The athlete can return to sport as soon as 3 weeks after surgery with splint immobilization of the PIP joint.

RESULTS AND COMPLICATIONS

Stable joint reduction and early ROM positively influence outcomes for PIP fractures and fracture-dislocations. With simple dislocations, most athletes can expect to regain full flexion; however, a small flexion contracture is common and, fortunately, rarely symptomatic. With fracture-

Fig. 13. Pilon fracture of the middle phalanx (*left*) treated with open reduction and fixation with multiple lag screws using a lateral approach (*right*).

dislocations, long-term studies have shown radiographic degenerative changes in as many as 96% of patients treated with ORIF; however, the majority report little or no pain, do not have difficulty with work activities, and do not need modifications in their leisure activities.[42] The usual ROM averages from 12° of extension to 80° of flexion. Delaying ORIF of unstable PIP fracture-dislocations, and thereby delaying rehabilitation and ROM exercises, has been associated with decreased postoperative ROM.[38]

The results of ORIF are comparable to those of percutaneous pinning, which shows 90% good functional recovery and an average PIP ROM of 85° with an average flexion contracture of 8°.[25] The average PIP ROM after external fixation of PIP fracture-dislocations has been reported to be similar, between 74° and 88°.[26–29,31] Complications of ORIF include dislocation, reported in up to 11% of patients. Redislocations involve loss of fixation and are associated with a poor outcome; up to 67% of these patients require either arthroplasty or arthrodesis. Deep infection and stiffness requiring tenolysis are more common after surgical treatment and have been reported in up to 4% of patients.

ACKNOWLEDGMENTS

The authors acknowledge and thank Patrick Carrico, MAMS, who prepared the diagrammatic pictures used in **Figs. 1–3**.

REFERENCES

1. Leibovic SJ, Bowers WH. Anatomy of the proximal interphalangeal joint. Hand Clin 1994;10:169–78.
2. Kuczynski K. The proximal interphalangeal joint: anatomy and causes of stiffness in the fingers. J Bone Joint Surg Br 1968;50(3):656–63.
3. Minamikawa Y, Horri E, Amadio PC, et al. Stability and constraint of the proximal interphalangeal joint. J Hand Surg [Am] 1993;18:198–204.
4. Bindra R. Dislocations and fracture dislocations of the metacarpophalangeal and proximal interphalangeal joints. In: Ring DC, Cohen MS, editors. Fractures of the hand and wrist. New York: Informa Healthcare; 2007. p. 41–74.
5. Glickel SZ, Barron OA, Eaton RG. Dislocations and ligament injuries in the digits. In: Green DP, Hotchkiss RN, Pederson WC, editors. 4th edition, Green's operative hand surgery, vol. 1. New York: Churchill Livingstone; 1999. p. 772–808.
6. Bowers WH, Wolf JW Jr, Nehil JL, et al. The proximal interphalangeal joint. J Hand Surg [Am] 1980;5:79–88.
7. Kraemer BA, Gilula LA. Phalangeal fractures and dislocations. In: Gilula LA, editor. The traumatized hand and wrist. Philadelphia: W.B. Sanders; 1992. p. 105–70.
8. Blazar PE, Steinberg DR. Fractures of the proximal interphalangeal joint. J Am Acad Orthop Surg 2000;8:383–90.
9. Kiefhaber TR, Stern PJ. Clinical perspective: fracture dislocations of the proximal interphalangeal joint. J Hand Surg [Am] 1998;23:369–80.
10. Spinner M, Choi BY. Anterior dislocation of the proximal interphalangeal joint: a cause of rupture of the central slip of the extensor mechanism. J Bone Joint Surg Am 1970;52:1329–36.
11. Inoue G, Maeda N. Irreducible palmar dislocation of the proximal interphalangeal joint of the finger. J Hand Surg [Am] 1990;15:301–4.
12. Boden RA, Srinivasan MS. Rotational dislocation of the proximal interphalangeal joint of the finger. J Bone Joint Surg Br 2008;90(3):385–6.
13. Akagi T, Hashizume H, Inoue H, et al. Computer simulation analysis of fracture dislocation of the proximal interphalangeal joint using the finite element method. Acta Med Okayama 1994;48:263–70.
14. Schenck R. Classification of fractures and dislocations of the proximal interphalangeal joint. Hand Clin 1994;10:179–85.
15. Light TR. Buttress pinning techniques. Orthop Rev 1981;10:49–55.
16. Lutz M, Fritz D, Arora R, et al. Anatomical basis for functional treatment of dorsolateral dislocation of the proximal interphalangeal joint. Clin Anat 2004;17:303–7.
17. McElfresh EC, Dobyns JH, O'Brien ET. Management of the proximal interphalangeal joints by extension-block splinting. J Bone Joint Surg Am 1972;54:1705–10.
18. Redler I, Williams JT. Rupture of a collateral ligament of the proximal interphalangeal joint of the finger: analysis of 18 cases. J Bone Joint Surg Am 1967;49:322–6.
19. McCue FC, Honner R, Johnson MC, et al. Athletic injuries of the proximal interphalangeal joint requiring surgical treatment. J Bone Joint Surg Am 1970;52:937–56.
20. Ali MS. Complete disruption of collateral mechanism of proximal interphalangeal joint of fingers. J Hand Surg [Br] 1984;9B:191–3.
21. Isani A, Melone CP. Ligamentous injuries of the hand in athletes. Clin Sports Med 1986;5:757–72.
22. Brunet ME, Haddad RJ. Fractures and dislocations of the metacarpals and phalanges. Clin Sports Med 1986;5:773–81.
23. Viegas SF. Extension block pinning for proximal phalanx interphalangeal joint fracture dislocations: preliminary report of a new technique. J Hand Surg [Am] 1992;17:896–901.

24. Newington DP, Davis TR, Barton NJ. The treatment of dorsal fracture-dislocation of the proximal interphalangeal joint by closed reduction and Kirschner wire fixation: a 16-year follow up. J Hand Surg [Br] 2001;26:537–40.
25. Aladin A, Davis TR. Dorsal fracture-dislocation of the proximal interphalangeal joint: a comparative study of percutaneous Kirschner wire fixation versus open reduction and internal fixation. J Hand Surg [Br] 2005;30:120–8.
26. Hynes MC, Giddins GE. Dynamic external fixation for pilon fractures of the interphalangeal joints. J Hand Surg [Br] 2001;26:122–4.
27. Majumder S, Peck F, Watson JS, et al. Lessons learned from the management of complex intra-articular fractures at the base of the middle phalanges of fingers. J Hand Surg [Br] 2003;28:559–65.
28. Ellis SJ, Cheng R, Prokopis P, et al. Treatment of proximal interphalangeal dorsal fracture-dislocation injuries with dynamic external fixation: a pins and rubber band system. J Hand Surg [Am] 2007;32:1242–50.
29. Ruland RT, Hogan CJ, Cannon DL, et al. Use of dynamic distraction external fixation for unstable fracture-dislocations of the proximal interphalangeal joint. J Hand Surg [Am] 2008;33:19–25.
30. Agee JM. Unstable fracture dislocations of the proximal interphalangeal joint: treatment with the force couple splint. Clin Orthop 1987;214:101–12.
31. Krakauer JD, Stern PJ. Hinged device for fractures involving the proximal interphalangeal joint. Clin Orthop 1996;327:29–37.
32. Johnson D, Tiernan E, Richards AM, et al. Dynamic external fixation for complex intraarticular phalangeal fractures. J Hand Surg [Br] 2004;29:76–81.
33. Stern PJ, Roman RJ, Kiefhaber TR. Pilon fractures of the proximal interphalangeal joint. J Hand Surg [Am] 1991;16:844–50.
34. Hamilton SC, Stern PJ, Fassler PR, et al. Mini-screw fixation for the treatment of proximal interphalangeal joint dorsal fracture-dislocations. J Hand Surg [Am] 2006;31:1349–54.
35. Lee JY, Teoh LC. Dorsal fracture dislocations of the proximal interphalangeal joint treated by open reduction and interfragmentary screw fixation: indications, approaches, and results. J Hand Surg [Br] 2006;31:138–46.
36. Wilson JN, Rowland SA. Fracture-dislocation of the proximal interphalangeal joint of the finger: treatment by open reduction and internal fixation. J Bone Joint Surg Am 1966;48:493–502.
37. Grant I, Berger AC, Tham SK. Internal fixation of unstable fracture dislocations of the proximal interphalangeal joint. J Hand Surg [Br] 2005;30:492–8.
38. Weiss AP. Cerclage fixation for fracture dislocation of the proximal interphalangeal joint. Clin Orthop 1996;327:21–8.
39. Williams RM, Kiefhaber TR, Sommerkamp TG, et al. Treatment of unstable dorsal proximal interphalangeal fracture/dislocations using a hemi-hamate autograft. J Hand Surg [Am] 2003;28:856–65.
40. Sarris I, Goitz RJ, Sotereanos DG. Dynamic traction and minimal internal fixation for thumb and digital pilon fractures. J Hand Surg [Am] 2004;29:39–43.
41. Tekkis PP, Kessaris N, Gavalas M, et al. The role of mini-fragment screw fixation in volar dislocations of the proximal interphalangeal joint. Arch Orthop Trauma Surg 2001;121:121–2.
42. Deitch MA, Kiefhaber TR, Comisar BR, et al. Dorsal fracture dislocations of the proximal interphalangeal joint: surgical complications and long-term results. J Hand Surg [Am] 1999;24:914–23.