Management of Proximal Interphalangeal Joint Fractures and Dislocations

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ABSTRACT: Proximal interphalangeal joint (PIP) injuries are among the most common in the hand and their severity is often underestimated. These injuries often lead to prolonged disability, pain, and stiffness. Appropriate treatment includes a thorough assessment, physical examination, and directed imaging. Such an approach should lead to a rational treatment plan that focuses on the rehabilitation of all damaged components, including osseous, articular, and soft tissue structures. This article reviews all elements in the management of PIP injuries and introduces an assessment method for PIP injuries based on the mechanism of injury rather than primarily on the basis of radiographic findings.


The proximal interphalangeal joint (PIP) is the most commonly injured joint in the hand, despite its inherent articular and ligamentous stability. The PIP joint is exposed to significant forces during vocational, avocational, and athletic endeavors. Injuries often are labeled as “finger sprains,” and their significance is underestimated. Adequate diagnosis of the extent of damage to the joint is hampered because bystanders at the time of injury relocate displaced joint injuries before radiographic investigation, and appropriate medical attention often is delayed after these “treatments in the field.” PIP joint fractures and dislocations now are being recognized as complicated joint injuries requiring careful attention to address static and dynamic bone and soft tissue disruption. The existing classifications of PIP joint injuries divide injuries according to their anatomic site and as being stable and unstable and have been augmented by several classifications that quantify joint articular surface involvement and static and dynamic joint subluxation, taking soft tissue disruptions into consideration. This article reviews the concept of classifying PIP injuries according to their causative mechanism and their biomechanical consequences for the joint. We correlate the mechanism of injury to many existing classifications and discuss the principles of our treatment approach.

ANATOMIC CONSIDERATIONS

The PIP joint is classified as a hinge joint. The asymmetric congruity of the condyles and the opposing articular surfaces of the base of the middle phalanx in their specific ligamentous arrangements also provide a helicoid motion, allowing the fingers to converge toward the tubercle of the scaphoid. The adaptability of the hand to grasp a variety of shapes and sizes not only arises from the flexion-extension curve, but also from its execution along an equiangular spiral. This adaptability of the hand may be significantly lost after injury to the PIP joint, if normal or near-normal convergence and range of motion (ROM) are not achieved.

The PIP joint is completely encapsulated by joint capsule. In addition, stability is provided dorsally by the extensor tendon central slip and lateral bands; ulnarly and radially, by collateral, accessory collateral ligaments and the conjoined lateral bands; and volarly, by the volar plate, flexor tendons, and the fibro-osseous flexor tendon sheath. All of these structures serve as static stabilizers of the joint in extension and lead to proper seating of the condyles of the proximal phalanx in the mirrored concave surfaces of the base of the middle phalanx. The volar plate and the accessory collateral ligaments act as a dynamic restraint to extension, also contributing to the lateral stability. The ligamentous and tendinous structures, bony configuration, and muscular forces across the joint give the joint a strong dynamic stability throughout the arc of motion. Ligamentous disruption, volar plate avuls-
DIAGNOSIS OF PROXIMAL INTERPHALANGEAL JOINT INJURIES

The goal of treatment of PIP joint injuries is to obtain a strong, stable, and pain-free joint with an optimal ROM and convergence. To institute appropriate treatment, a complete history and thorough physical examination are paramount to establish the extent of damage to the joint. The spectrum of PIP joint injuries ranges from mild ligamentous sprains to unstable irreducible joint fracture-dislocations. A history of a severe deforming force at the time of trauma, particularly if accompanied by an account of an abnormal angulation or deformity, strongly suggests ligamentous damage associated with the more severe fractures and dislocations.

Careful observation and physical examination with an emphasis on the presence and location of swelling and particular areas of tenderness localize the areas of anatomic pathology. Testing of joint stability, sometimes requiring the use of local anesthesia, should be performed actively and passively. Active testing of joint stability determines the functional ROM of the damaged joint and gives a good impression of the primary structures that determine joint stability on the palmar and dorsal aspects of the joint. Subluxation with active motion suggests major ligament disruption or a significant intra-articular fracture of the joint. Passive testing of joint stability is useful to assess volar plate and collateral ligament damage.

True anteroposterior and lateral x-rays complemented by two oblique views of the joint delineate subluxation or dislocation of the joint as well as the extent of involvement and displacement of the articular surface in intra-articular joint fractures. Stress x-rays rarely are required to confirm the diagnosis of collateral ligament instability when paying attention to the angulatory deformity after varus or valgus stress and the quality of the end point while stressing the joint.

INDICATIONS AND CONTRAINDICATIONS

A discussion about rehabilitative principles of PIP joint injuries is facilitated by an injury classification according to the direction of injury-deforming forces and their resulting displacement patterns. The displacement patterns suggest the involvement of particular anatomic structures. Despite the fact that most injuries to the PIP joint are impure and a combination of damaged anatomic structures may be present, an understanding of the potential injury patterns (supplemented by a thorough physical examination and appropriate radiographic investigations) can lead to a rational rehabilitation protocol.

Milder PIP injuries all are associated with partial ligament damage, whereas more severe injuries result in complete ligament rupture, fracture, or more severe fracture-dislocation injuries of the joint. The extent of damage depends on the direction of force, joint position at the time of trauma, and eccentric muscular contraction at the time of injury, which determine how actively the tendons and ligaments were under load at the time of impact. The vectors of the flexors, extensors, and intrinsic structures further magnify the initial displacement. Based on radiographic examination, the injury can be classified further according to the fracture or dislocation of the joint. The extent of soft tissue trauma may impose as great a limitation in joint ROM as bony incongruence. Effective restoration of joint mobility and stability equally should address treatment of soft tissues and bone. Excursion and gliding of the encapsulating ligamentous and tendinous structures surrounding the PIP joint is paramount in treatment. Prolonged immobilization or limited joint motion has an adverse effect on joint hydrodynamics. These physiologic changes in the joint may cause pain, degenerative changes, and arthofibrosis and ultimately lead to joint stiffness.

After determining the extent of bony and soft tissue involvement, rational rehabilitative treatment of PIP joint injuries should address the following questions: How can a complete correction of associated joint subluxation be achieved and maintained? How does swelling around the joint affect early mobilization? When should early mobilization be initiated? What is the safe arc of motion without causing redislocation and loss of reduction? When are bony consolidation and soft tissue healing strong enough to allow for unrestricted loading? What are the consequences of the treatment protocol on the long-term sequelae, such as the development of degenerative arthritis?

MECHANISM OF INJURY, CLASSIFICATION, AND ITS THERAPEUTIC GUIDELINES

Laterally Directed Proximal Interphalangeal Joint Dislocation Forces

An abduction- or adduction force to an extended digit results in stress on the collateral ligaments of the PIP joint. The most commonly affected digits are the border digits, and radial damage occurs more frequently than ulnar-sided damage. Disruption of the collateral ligaments most frequently starts at the origin of the ligament on the proximal phalanx, progressing in more severe injuries to the secondary lateral restraints of the joint, the accessory collateral lig-
aments, and the volar plate (Figure 1). Disruption of these structures occurs through the junction of the true collateral and the accessory collateral ligaments toward the insertion of the volar plate on the volar lip of the middle phalanx. Variations include midsubstance disruptions or avulsion of the collateral ligament at its insertion on the middle phalanx.\(^6\)\(^,\)\(^7\) Bowers\(^4\)\(^,\)\(^8\) classification of these collateral ligament injuries is a useful guide to treatment. Grade I injuries are identified by asymmetric swelling and tenderness over the collateral ligament, without instability on stress testing. Grade II injuries are associated with complete disruption of the collateral ligament, but the volar plate remains intact. These injuries are characterized by a stable active arc of motion and <20° of deviation with a firm end point on varus or valgus stress. Grade III injuries are characterized by total collateral ligament disruption and volar plate rupture. Clinically, this type of injury may exhibit subluxation or dislocation on active extension and >20° of joint laxity on varus/valgus stress without a solid end point.\(^7\)

Application of a laterally directed force to the PIP joint held in slight flexion may result in a unicodylar fracture of the PIP joint (Figure 2). In these fractures, accurate bone reduction with restoration of articular congruence is crucial; and usually there are no additional primary soft tissue considerations present that dictate specific therapy.

**Treatment**

Grade I collateral ligament injuries may be treated by a short period (1 to 3 days) of immobilization during the inflammatory phase and period of greatest discomfort. Edema control using Coban wrapping and application of cold packs is a useful adjunct to reduce swelling and pain about the injured joint. When swelling and pain have been reduced, the joint should be actively remobilized by active flexion and extension exercises protected by buddy tapes. Isolated distal interphalangeal (DIP) joint blocking exercises stimulate gliding of the lateral bands and the profundus tendon and prevent tightness of the spiral oblique retinacular ligament (SORL), preventing a pseudoboutonniere deformity. Ligamentous injuries such as these may take several weeks to months to consolidate, and a gradual return to unprotected motion over this course should be anticipated.

In grade II PIP collateral ligament injuries, operative repair of the avulsed collateral ligament has been suggested in the past; however, these injuries can be treated conservatively. In the acute phase, these joints can be immobilized similar to a grade I injury. Because the palmar structures on the lateral aspect of the PIP joint are more severely affected, it is usually more comfortable for the patient to splint the joint in slight flexion in the acute phase of the injury. When the inflammatory phase has subsided and swelling is
reduced, a prolonged period of protected remobilization in an extension block splint ranging from 10° to 45° of flexion depending on the stability of the joint assessed under image intensifier, with a gradual increase of the arc of motion to full extension over 3 to 4 weeks allows for healing of the accessory collateral ligament and the possibly partially damaged volar plate. During this period, active flexion and extension exercises are instituted with buddy tapes protecting the healing ligament within the constraints of the extension block splint. After discontinuation of the extension block splint, gradual return to full function over 6 to 8 weeks with the use of buddy tapes is allowed. Throughout the mobilization period, an emphasis is placed on the excursion of the lateral bands and profundus tendon and maintaining the SORL length by performing DIP joint blocking exercises. Continuous monitoring for the development of PIP joint flexion contracture is an essential component of therapy.

The treatment of the most severe grade III PIP collateral ligament injuries is addressed primarily toward the disrupted volar plate. Their treatment is dictated by the extent of volar plate or volar lip rupture.

Injuries to the PIP joint after laterally directed stress while the joint was held in flexion may result in unicondylar fractures (Figure 2). The treatment of unicondylar fractures is aimed primarily at accurate articular reduction. Unicondylar fractures may be stable initially but may become unstable over time. The angular displacement may increase when unrestricted ROM exercises are permitted. These fractures may not be apparent on posteroanterior views, and oblique x-ray views are important to assess the degree of displacement. If not treated with appropriate fracture reduction and early motion, angulation at the joint, arthrofibrosis, and loss of motion are common complications. Open reduction and internal fixation (ORIF) using transverse Kirschner wires (K-wires), tension band wiring, lag screw, and mini-condylar blade plates has been reported. The condyles receive their vascular supply from the articular branch of the digital arteries through the collateral ligaments, however, and avascular necrosis of the condyle may arise if the surgical reduction is extensive. For this reason, closed reduction under image intensifier may be preferred, followed by limited open reduction with lag screw fixation. On reduction of the fracture, the primary goal is to restore the joint mobility. Because of the location of the fracture, a greater emphasis should be placed on gliding of the lateral bands and the central slip. Early active motion with buddy taping to the adjacent digit facilitates return of PIP joint motion. Considering the anatomic arrangement of the collateral ligament complex and the vascularity of the condyles, the PIP joint should be mobilized actively between 30° and 60° arc of motion on the first postoperative day, with weekly increases in 10° increments.

Because of the inherent problems with stiffness after ORIF, undisplaced or minimally displaced unicondylar fractures may be treated better with traction splinting in extension. It is necessary to monitor displacement of the fractured condyle with x-rays on a weekly basis and to be prepared to proceed to ORIF if the reduction of the articular surface is not satisfactory. If the joint remains congruent, short arc ROM exercises in the traction splint are started at 2 to 3 weeks with discontinuation of the traction splint at 6 weeks. If ORIF of unicondylar fractures is instituted, it is imperative to treat these injuries with early ROM exercises. In cases in which the type of fixation is not adequate to allow unrestricted motion, the use of traction splinting may prevent loss of reduction.

Dorsally Directed Proximal Interphalangeal Joint Dislocation Forces

Dorsally directed PIP joint dislocation forces result in PIP joint hyperextension, volar plate rupture, and dorsal dislocation with rupture of the collateral ligaments (Figure 3). Most commonly, damage to the volar plate occurs at its insertion into the base of the middle phalanx, but in about one third of cases, there is fracture of the volar lip of the middle phalanx; this is referred to as a volar lip fracture-dislocation. Eaton and Littler classified these injuries into three classes. Type I (hyperextension) injuries are defined by a partial volar plate avulsion with intact collateral ligaments. These injuries clinically do not exhibit hyperextension instability on active extension or passive hyperextension. Type II (dorsal dislocation) injuries are characterized by total volar plate rupture and complete collateral ligament split. These injuries exhibit instability on active extension or hyperextension deformity on passive dorsally directed stress testing. Type III (fracture-dislocation) injuries include a fracture of the insertion of the volar lip of the middle phalanx. Several classifications have been used to subcategorize this Eaton type III fracture-dislocation further, and these introduce several measurable parameters.

Hastings and Carroll introduced a subcategorization into three classes based on volar articular involvement, and this classification was refined further by Kiefhaber and Stern on the basis of the stability on stress testing. Stable (type I) injuries involve <30° of the articular surface at the base of the middle phalanx and on stress testing the joint remains congruent. Tenuous (type II) fracture-dislocation injuries of the volar lip involve 30% to 50% of the joint surface at the base of the middle phalanx (Figure 4A). Congruent reduction is possible with <30° of flexion because the dorsal portion of the collateral ligament is still intact. Passive extension stress testing may dorsally sublux the base of the middle phalanx. Unstable (type III) fracture-dislocation injuries of the volar lip...
of the base of the middle phalanx involve >50% of the joint surface of the base of the middle phalanx. These injuries are accompanied by total disruption of the collateral ligaments, making congruent reduction often impossible. Included in this category are fractures that involve 30% to 50% of the joint surface but require >30° of flexion to maintain joint congruity.

Schenck\textsuperscript{14} introduced a further subclassification of Eaton's type III fracture-dislocations based on the extent of fracture involvement and on the grade of subluxation and dislocation. He introduced four grades of fractures as followed: Grade I involves <10% of the articular surface, grade II has 11% to 20% of articular surface involvement, grade III has 21% to 40% involvement, and grade IV has >40% involvement. Schenck added four grades of subluxation. Grade A has <25% subluxation, grade B has 25% to 50% subluxation, grade C has >50% subluxation, and grade D has total dislocation. Schenck arrived at a 16-class classification of the Eaton type III fracture-dislocation (e.g., IA, IIB, IVD). In Schenck’s classification, exact fracture classification in grade I to IV remains difficult in such a small joint, and most combinations in his classification are relatively rare (e.g., IVA). In addition, a dorsal dislocation without a fracture (Eaton’s type II) perhaps should be classified as a Schenck type ID; however, in Schenck’s own words, his classification was designed only to divide Eaton’s type III into a larger number of degrees of fractures and dislocations. The use of a simpler classification system, such as that of Kiefhaber or Hastings, for the Eaton Type III fracture-dislocations may be preferable.

\textit{Treatment}

Closed treatment is uniformly regarded as the treatment of choice for stable hyperextension and dorsal dislocation injuries of the PIP joint (Eaton class I and II type).\textsuperscript{15} Dorsal block pinning or dorsal block splinting with a buddy tape to the adjacent digit for 4 to 6 weeks is sometimes necessary.\textsuperscript{16,17} Immobilization of the PIP joint is not recommended.\textsuperscript{18} To achieve mobility of the joint, periodic ROM exercises within the dorsal blocking splint should be performed several times a day. Motion at the PIP joint encourages gliding of the joint and excursion of the extensor mechanism. Critical attention should be given to the excursion of the flexor digitorum profundus because it is likely to tether at the site of injury. Active DIP joint blocking exercises allow excursion of the flexor digitorum profundus and the extensor lateral bands. It also maintains the length of the SORL. Early detection of SORL tightness and treatment with dynamic splinting maximizes the digital ROM. On completion of the PIP joint dorsal blocking period, a PIP joint flexion contracture may be evident. If so, dynamic, static progressive or serial static splinting (based on the tissue end-feel) should be considered. In the event that the joint remains painful and limited in ROM, a continuous passive motion machine at night, in conjunction with splinting and ROM exercises during the day, produces favorable results.

In the more severe Eaton type III injuries, one should consider the stability of the joint. Stable injuries (Hastings type I) often can be treated similar to Eaton class I and II injuries. The treatment of Hastings type II tenuous injuries is controversial, however, and treatment options include splint or K-wire fixation in flexion, extension block splinting within the range in which the joint remains congruent (i.e., >30° of flexion), traction splinting, external fixators, and open treatment such as volar plate arthroplasty\textsuperscript{19} or ORIF of the fracture fragments.\textsuperscript{20,21} Treatment should be aimed at maintaining the joint...
congruency within the safe arc of motion until fracture healing has occurred. Most often, this can be achieved adequately by extension block splinting the joint in >30° of flexion and gradually bringing the joint out to full extension over 3 to 4 weeks.

In severe unstable cases of volar plate injuries or dorsal fracture-dislocations (Hastings type III), the main goal of treatment is to restore the palmar buttress function of the volar lip of the middle phalanx. The management of these injuries should focus on reduction of the fracture and restoration and maintenance of joint congruity while allowing motion. For these injuries, a variety of therapeutic approaches, including extension block splinting, extension block...
pinning, the “S” Quattro technique, force coupled methods, external fixators, volar plate advancement arthroplasty, and ORIF methods, have been suggested. The traction and motion combination method as advocated by Schenck 22–24 may be the preferred treatment option (see Figure 4). In late cases or if the fracture is not reducible with traction alone, osteoclasis or ORIF along with traction and early mobilization may be required. Volar plate arthroplasty with resection of the palmar lip and advancement of the volar plate 25 is a difficult procedure that often results in a disappointing outcome.

**Palmarly (Volarly) Directed Proximal Interphalangeal Joint Dislocation Forces**

Volar dislocation of the PIP joint is a rare injury and usually arises from a rotatory longitudinal force on a semiflexed digit. 26 No universally accepted classification of these injuries exists, probably because these injuries most commonly involve a combination of damaged structures. To rehabilitate these injuries rationally, one should consider the injuries to the soft tissues and to the osseous structures. The rehabilitation of these injuries should combine the principles that are applicable to each of the damaged structures individually, and treatment guidelines can be found in the previous sections. The anatomic disruption includes unilateral rupture of a collateral ligament and partial avulsion of the volar plate (see section on laterally and dorsally directed stresses), accompanied further by herniation of the head of the proximal phalanx through the extensor mechanism (Figure 5). Occasionally an in-substance rupture of the central slip is associated with this injury (boutonniere injury) or, in its most severe form, a dorsal lip fracture of the base of the middle phalanx at the insertion of the central slip (boutonniere fracture). 26 The severity of the bone and soft tissue damage manifests itself in the degree of subluxation, the size of the associated fracture and the pattern of displacement of the fracture fragments. 27,28 To help in treatment of these dorsal lip fractures, we use the following classification: grade I, associated dorsal lip fracture of <25% of the articular surface, no subluxation of the base of the middle phalanx (Figure 6A); grade II, associated dorsal lip fracture of <50%, with minimal subluxation of the base of the middle phalanx and may have frank boutonniere deformity (Figure 6B,C); and grade III, any size dorsal lip fracture, with complete palmar dislocation of the base of the middle phalanx (Figure 6D).

In grade III fractures, there is often a physical separation of the collateral and accessory collateral ligaments because of the volar translation of the middle phalanx. These injuries virtually always are accompanied by a complete avulsion of the central slip insertion. Clinically, there is an absence of the classic boutonniere hyperextension at the DIP joint, however, because of the redundancy of the conjoined lateral bands.

Paradoxically, in the less extensive injury when the central slip remains intact, reduction of the joint may become difficult because of trapping of the head of the proximal phalanx in a noose formed by the lateral band and the central slip, interposing parts of the lateral band or the central slip in the joint space behind the condylar flare of the proximal phalanx. 28,29 Closed reduction of this type of dislocation may be achieved by extending the wrist and flexing the metacarpophalangeal (MCP) and PIP joints, relaxing the volarly displaced lateral bands and the extensor mechanism. With a rotatory motion, the intra-articularly trapped lateral band can be disengaged from the condylar flare. Sometimes, closed reduction of these fractures is not possible, and open reduction of the dislocation should be undertaken. Indications for open reduction are an inability to achieve a fully congruent relocated joint, suggesting soft tissue joint interposition, or failure to return the dorsal lip fracture-dislocation fragment to ≤1 mm of its anatomic position. Surgery is performed most easily through a dorsal approach, extracting interposed soft tissue from the joint and, if necessary, repairing the central slip or fixing the dorsal fracture fragment. Post-reduction radiographs should be taken to confirm congruent reduction, and active testing of the extensor mechanism reveals the extent to which the central slip is damaged.
Treatment

Acute volar dislocations not associated with a dorsal lip fracture usually are stable. These injuries should be immobilized in full extension during the inflammatory and fibroplasia healing phases of the tendon, lasting for 6 to 8 weeks. If there is an associated fracture of the dorsal lip (grade I injuries), the period of immobilization may be shortened to 4 to 6 weeks because bony healing of the middle phalanx occurs at a more rapid rate than tendon healing. The distal phalanx is left free and should be mobilized actively. DIP joint flexion and extension motion, with the PIP joint held in full extension, allows retention of the lateral bands dorsal to the joint axis. In addition, the anatomic length and movement of the SORL and a balance between transverse retinacular and the triangular ligament are maintained, preventing the development of a boutonniere deformity. After 6 to 8 weeks of PIP joint immobilization, active PIP joint flexion and extension exercises are performed. As greater flexion at the PIP joint is achieved, loss of extension commonly is observed. This loss may be caused by (1) reduced strength of the extensor mechanism compared with the flexors and (2) subtendinous adhesions causing inadequate extensor excursion proximally. As PIP joint extension is lost, compensatory MCP joint hyperextension may ensue. This abnormal MCP joint hyperextension further increases the flexion deformity at the PIP joint, causing volar migration of lateral bands and producing a boutonniere appearance. This kinematic chain imbalance may be treated successfully with a MCP blocking splint in 30° of flexion. Our observations in treating these conditions suggest that a gradual remodeling of subtendinous adhesions, with an MCP extension block splint, increases the force transmission at the PIP joint, restoring normal kinematics. This process of remodeling may take 9 to 12 months and correlates to the third and final remodeling phase of wound healing.

PIP joint extension lag also may be due to an excessively stretched triangular ligament. This lag can occur when the triangular ligament is incapable of maintaining the lateral bands dorsally, despite the use of DIP joint blocking exercises aimed at retaining the lateral bands dorsal to the PIP joint axis and maintaining the SORL length. The classic PIP joint flexion with DIP joint hyperextension is noticed. To allow tightening (shrinkage) of the triangular ligament, the DIP joint is held statically in slight flexion with a splint. This produces a tension on the lateral bands translocating these structures closer to the central joint axis. The patient is asked to perform active PIP joint motion exercises with the DIP joint held in flexion with a splint. This exercise enhances the gliding of the central slip and the lateral bands, restoring the extension at the PIP joint. As the PIP joint extension is restored, the DIP joint splint can be weaned gradually. Critical attention should be given to the possibility of a swan-neck deformity developing. If a swan-neck tendency is beginning to occur, the DIP joint splint should be discontinued.

Dorsal lip fractures with subluxation or dislocation (grade II and III of our classification) require complete articular reduction. In grade II injuries, this can
be achieved most commonly by closed reduction, whereas grade III injuries may require open reduction. Lag screws, tension band wiring, or interosseous K-wire or combination of any of the three methods may be used depending on the size of the fragment. After the surgical procedure, a safe arc of motion at the PIP joint can be determined using an image intensifier. The PIP joint having difficulty moving or exhibiting tilting or hinging during flexion postoperatively preferably is treated with dynamic traction and short arc early mobilization. If the joint glides congruently, the joint may be treated by PIP joint extension splinting and a short arc motion program without traction. In grade II and III injuries, the central slip is virtually always intact and flexion and extension exercises are initiated earlier at 3 to 4 weeks. Because all volar dislocation injuries involve collateral ligament disruption, the treatment should address the issues that were raised in the section earlier on laterally directed PIP dislocation forces. When instituting flexion and extension exercises, the collateral ligaments need to be protected with buddy tapes. Effective rehabilitation of injuries requiring ORIF may be achieved by early mobilization with traction to restore the joint mobility.

Axially Directed Forces

Pilon fractures, or centrally impacted fractures, are caused by axially directed high-energy forces while the digit was held in full extension. The central articular structures at the base of the middle phalanx are impacted by the head of the proximal phalanx, in a dye punch manner, producing a central defect. The entire soft tissue envelope collapses, and a redundancy of the ligamentous and tendinous structures is evident. The geometry of the joint concavity of the middle phalanx base is substantially lost. Management of these fractures is difficult. A PIP external fixator device for treatment of such fractures is complex and particularly difficult to apply to the central digits. Isolated DIP joint blocking exercises in a similar manner are performed hourly to maintain profoundus and lateral band gliding and SORL length. A dorsal blocking splint combined with traction splinting

DYNAMIC TRACTION SPLINTING

The goal of treatment of PIP joint injuries is restoration of joint congruity and stability and a pain-free normal anatomic arc of motion. To achieve this, one should minimize complications such as pain, flexion or extension contractures, extensor lag, digital scissoring, and arthrofibrosis. Schenck combined the concept of dynamic traction and early motion to treat intra-articular fractures. The application of longitudinal traction to the displaced articular fractures reduced the fragments of the fractures by ligamentotaxis through the encapsulating structures of the PIP joint. An additional benefit is the preservation of the anatomic length of the encapsulating tissues, preventing contractures. Salters work on continuous passive motion devices showed that early motion enhances the regeneration of articular cartilage, promotes healing, and prevents arthrofibrosis. The combination of traction and motion helps prevent adhesion formation at the tendons and preserves the motion at the joints. Many studies on traction methods to treat intra-articular fractures have detailed the benefits of this technique.

A prerequisite for treatment with traction is the ability of the device to reduce the articular congruency. Some intra-articular fractures are not reducible with traction alone. This situation may be due to the particular displacement of the fractures, collapse of the soft tissue envelope, or delay to treatment that has caused the soft tissues to undergo contracture or the bone to form interposing callus. Fractures that are not amenable to traction alone should be considered for osteoclasis or ORIF. Postsurgery treatment may be augmented by treatment with traction and an early motion program.

In our center, the therapist fabricates a thermoplastic splint with the traction apparatus. An image intensifier is used to determine the exact amount of traction force required to reduce the fracture. A Haldex tension gauge for measurement of the traction force is used. With the use of the image intensifier, fracture stability during motion and the safe arc of motion permissible within the traction splint are determined. Skin traction can be used for forces of ≤350 g, whereas transosseous K-wire traction is required for traction forces >350 g. Patients are required to perform active flexion and extension exercises with at least 15 to 20 repetitions in the traction device on an hourly basis. Isolated DIP joint blocking exercises in a similar manner are performed hourly to maintain profoundus and lateral band gliding and SORL length. A dorsal blocking splint combined with traction splinting
in unstable volar lip fractures may be required to prevent dorsal subluxation of the middle phalanx during active or passive extension of the joint. Contracture control splinting (dynamic or static) may be applied along with the traction device. Critical attention is given to the convergent arcs of the digits during flexion by adjusting the orientation of the tracks appropriately. The traction splint is used continuously for 6 weeks or until fracture healing is confirmed radiographically. On discontinuation of the traction splint, joint-specific active and passive ROM, tendon-gliding exercises, corrective splinting, and edema control methods are used to maximize digital ROM. Grip and pinch strengthening techniques are added when joint motion is relatively pain-free.

Traction splinting and early mobilization approaches also are beneficial for unicondylar and bicondylar and pilon fractures. Fracture reduction and restoration of articular congruency may be attainable with traction. Even in cases requiring ORIF for condylar, dorsal, and volar lip fractures, soft tissue recovery is improved by the application of traction. In these cases, the advantages of improved fracture stability achieved with surgical reduction and fixation are offset by the increased periarticular edema caused by the surgical trauma. Movement of the joint is often painful, and traction reduces the discomfort of motion programs. The dynamic traction increases the joint space, reducing the compressive forces acting on the joint, permitting friction-free mobility. The traction and early motion restores the soft tissue length surrounding the joint, allowing tissues to glide effectively. An added benefit of traction and motion in these situations is that it reduces pain because of the continuous stimulation of the proprioceptive end organs. Similar to the nonoperative cases, the traction splinting is used for 6 weeks or until fracture healing is confirmed radiologically. Static or dynamic corrective splinting also may be used in combination with the traction device in order to maximize digital motion.

COMPLICATIONS

The PIP joint is vulnerable to posttraumatic pain and stiffness because of its complex anatomy and biomechanics. The integrity of the soft tissue envelope around the PIP joint and the coordinated gliding motion of ligaments and tendons are critical and precise. Disturbance of any or part of the tendinous structures acting on the joint results in limited motion. The PIP joint being a central joint in the digit significantly influences the functioning of the proximal and distal joints. Articular congruity along with the motion of the soft tissues provides proper prehensile function to the digit. Because all the digits often work in unison, limited joint motion and adhesion of tendons has an adverse effect on noninvolved adjacent digits producing a quadrigia effect. Strength, prehension, and overall function of the entire hand may be compromised significantly without proper diagnosis and management of PIP joint injuries.

A poor outcome after PIP joint injuries may be due to adhesions. The dorsal skin and the extensor tendon apparatus are the most vulnerable to the development of adhesions. Prolonged immobilization results in stiffness. If short-term immobilization is required or if adhesions around the PIP joint are developing, it is important to induce distal gliding of the extensor system by placing a mechanical load (DIP blocking exercises). In addition, because proximal excursion of the extensor apparatus depends on the control of the patient’s muscle, adhesions of the extensor system limit force transmission at the joint, producing a PIP extensor lag. Contrary to flexion contractures of the joint, extensor contractures are difficult to treat by means of splinting. The dorsal skin and subcutaneous tissues on the hand have a limited ability to withstand prolonged pressures of the splints, and these structures are much more susceptible to pressure-related necrosis. Prevention of contracture formation should be considered during the early stages of injury treatment. Flexion or extension contractures that are not amenable to serial casting or dynamic or static progressive splinting over a maximum of 8 to 12 weeks should be considered for surgical management.

Chronic hyperextension of the PIP joint secondary to volar instability may lead to a swan-neck deformity because of the dorsal migration of the conjoined lateral bands and increased load at the DIP joint produced by the profundus tendon. In contrast, development of a PIP joint flexion contracture may lead to a pseudoboutonniere deformity. This deformity develops because of increased forces of the lateral bands and a contracture of the SORL. The dorsal joint capsule along with the above-mentioned structures produces an irreducible extensor contracture of the DIP joint.

Restriction by a PIP joint hyperextension tendency or a flexion contracture also may have a mechanical effect on the MCP joint leading to a kinematic chain imbalance. Hyperextension posturing at the MCP joint and attenuation of the sagittal bands commonly is observed in PIP joint flexion contractures. PIP joint flexion contracture at the small finger PIP has an additional abduction and rotational tendency because of the combined vectors of extensor digitorum communis, extensor digiti minimi, and abductor digiti minimi. Contracture correction with splinting, strengthening of intrinsics and extensors, and the use of dorsal MCP joint blocking splint in 30° of flexion reduces this tendency.

Loss of flexion at the PIP joint secondary to a swan-neck deformity may produce a hyperflexion at the
MCP joint. This excessive flexion at the MCP joint is due to the increased forces of transverse fibers of the intrinsic tendons, which reduces the excursion of the profundus flexor tendons. Corrective splinting to gain intrinsic length, figure-eight splints to maintain thePIP in slight flexion, and a volar MCP joint blocking splint to maximize flexor tendon excursion are some treatment options to restore the imbalance. The long-term effects of PIP joint dysfunction on the kinematic chain disturbance have not been studied well. Early management and prevention of kinematic chain imbalance would improve the outcome of PIP joint injuries, however.

Pain is reported to be the most troublesome complication of PIP joint injuries. Usually, it steadily decreases after the first 6 months following injury. O’Rourke et al.35 reported that 34% of patients had mild ache with heavy use of the hand or owing to the cold intolerance, whereas 66% reported no pain in this retrospective series. Occasional use of anti-inflammatory medication, a light compressive Coban wrap, or intra-articular cortisone injections are often useful if the pain affects hand function. Persistence of pain with limitation in hand function >1 year suggests the possibility of degenerative posttraumatic arthritis and requires further investigations and management. Reports of posttraumatic degenerative arthritis secondary to PIP joint fracture-dislocations are limited because the PIP joints have a remarkable ability to regenerate and remodel if early motion after an injury is instituted.

**SUMMARY**

PIP joint injuries are the most common and most undertreated joint injuries of the hand. Careful therapeutic management of these injuries is paramount in regaining complete and pain-free hand function. Because certain trauma-deforming forces result in predictable injury patterns, a rational treatment approach may be directed by a thorough history of the trauma-deforming forces, complemented by a directed physical examination. Expected injury patterns have been reviewed within the framework of existing joint injury classifications. We have discussed rational treatment modalities of fractures and dislocations of the PIP joint, including their most common complications. We also have presented new classification of dorsal lip fractures of the PIP joint. The use of injury classification on the basis of the deforming forces helps in directing rational rehabilitation.

**REFERENCES**


