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Complications of Proximal Interphalangeal Joint Injuries: Prevention and Treatment

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SYNOPSIS

Proximal interphalangeal (PIP) joint injuries are one of the most common injuries of the hand. The severity of injury can vary from a minor sprain to a complex intra-articular fracture. Due to the complex anatomy of the joint, complications may occur even after an appropriate treatment. This article provides a comprehensive review on existing techniques to manage complications and imparts practical points to help prevent further complications after PIP joint injury.

Keywords

Proximal interphalangeal joint; complications; prevention; treatment

The ability to flex and extend the proximal interphalangeal (PIP) joint is crucial for adequate grip strength. Estimates show that the PIP joint accounts for approximately 85% of the motion required in functional grip.¹ As a hinge joint, it is extremely stable in the sagittal plane, but has limited tolerance to angular, axial, and rotational stress. Thus, the PIP joint is one of the most susceptible joints to injury. The vulnerability of the PIP joint stems from its unprotected position in the digit and its long moment arm. Out of potential injuries to the

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hand, PIP joint injuries are common among the general population and are especially pronounced in athletes.²⁻⁴

Because injury type can range from minor sprains to complex intra-articular fractures, classifying PIP joint injuries can be a complex task for therapists and surgeons. PIP joint injuries are often overlooked by patients or even athletic trainers or coaches; thus, improper treatment occurs regularly. Necessary treatment and rehabilitation techniques may be delayed and lead to permanent deformities of the digit. For example, prolonged immobilization of the PIP joint can cause stiffness and may subsequently result in irreversible loss of motion in the digit.^{5,6} Given that this joint has a predilection for stiffness, pain, arthritis, and residual deformities caused by soft tissue imbalance or adhesions, timely and accurate diagnosis and appropriate treatment is critical for all PIP joint injuries. Certain complications may be more easily prevented than treated. Therefore, concerted measures promoting prevention of further complications following PIP joint injuries are needed.

Relevant Anatomy

The PIP joint is comprised of a delicate balance of bony and soft tissues. The combination of the tongue-in-groove articulation of the intercondylar eminence at the base of the middle phalanx and the bicondylar head of the proximal phalanx permits increased resistance of torque and translational displacements. Although the joint is commonly classified as uniaxial, some lateral movement and rotation may occur during flexion, facilitating rotation of the finger toward the scaphoid tubercle.^{1,7,8} This unique property results from slight anatomic differences in the radial and ulnar condyles of the proximal phalanx, as illustrated by the trapezoidal cross section at the head of proximal phalanx. Moreover, the index and middle fingers display a more prominent ulnar condyle, whereas the ring and little fingers possess a more prominent radial condyle.⁹ (Figure 1) Further discrepancies exist between the articular surfaces of the proximal and middle phalanxes at the PIP joint. Most notably, the articular facet of the proximal phalanx facilitates 210° of motion, whereas the middle phalangeal side encompasses approximately 110°. ¹⁰

Given the asymmetry among condyles, bony structure alone cannot effectively stabilize the joint during motion, and surrounding soft tissues play an important role in joint stability. A three-sided box analogy is useful to identify relevant soft tissue structures. The PIP joint is intrinsically supported along the volar, radial, and ulnar side but devoid of a stout dorsal restraint, as if it were surrounded by a three-sided box (Figure 2). The true and accessory collateral ligaments (ACLs) embrace the radial and ulnar walls of the box and prevent lateral deviation. Along the base, the volar plate functions to limit hyperextension of the joint.¹¹ In addition to the three primary stabilizers, the joint is further supported by the central slip, the lateral bands, and the flexor tendons, collectively referred to as secondary stabilizers. These secondary stabilizers determine the balanced posture and facilitate motion of the joint.¹² Dislocation of the PIP joint requires that the volar plate and at least one of the collateral ligaments be disrupted.¹³ However, small disruptions or incongruities to the intricate structure of the joint or its stabilizers may lead to abnormal wear, arthritis, or more extreme complications after injury.^{1,14}

Classification of PIP Joint Injuries

Because injuries of the PIP joint can affect many combinations of the bony structures and surrounding soft tissues, various classifications systems of PIP joint injuries are available. Individual fracture or dislocation patterns are affected by the characteristics of the specific mechanism of injury. The most common pattern of injury is observed when a force drives proximally along the middle phalanx against the dorsal lip of the head of the proximal phalanx. This can lead to fracture of palmar lip of the base of middle phalanx with dorsal subluxation of the PIP joint. The volar plate of the PIP joint may be avulsed (Figure 3). Occasionally, injury mechanisms are substantially more complex, with the direction and magnitude of a force determining a unique fracture location and pattern. To facilitate the best prognosis and treatment option for each injury, it is important to classify PIP joint injuries with a standard system according to the structural involvement, mechanism of injury, and joint stability.¹⁵⁻¹⁷ The classification systems used in this article are described below.

Collateral ligament injuries

Any laterally deviating force to the tip of the finger will affect the distribution of stress over the collateral ligaments. Significant injury may also disrupt the secondary PIP joint stabilizers. With enough force, the true collateral ligament will tear from its origin at the proximal phalanx. The disruption may also progress to the ACL and the attachment of volar plate at the middle phalanx.^{11,18} Bowers et al.⁸ developed the following grading system for classification of collateral ligament injuries:

- Grade 1: Asymmetric swelling and tenderness over the collateral ligament without instability on the lateral stress test.
- Grade 2: Complete disruption of the collateral ligament but the volar plate remains intact; Clinical exam displays a stable active arc of motion (AOM) and $<20^\circ$ of deviation with a firm end point on the lateral stress test.
- Grade 3: Total collateral ligament disruption and volar plate rupture; Clinical exam depicts evidence of subluxation or dislocation on active extension and $>20^\circ$ of joint laxity on a varus and valgus stress test with a firm end point.

The implications of an open approach for ligament repair must be considered because open repair can aggravate the injury and further induce fibrosis. Furthermore, the collateral ligament may spontaneously heal itself over time and does not always require surgical correction. Eaton et al. demonstrated this process through the formation of a “neocollateral” ligament after total ligament excision for treatment of PIP stiffness in 10 PIP joints over a 3-month period.¹⁹ Thus, open ligament repair should be preserved for only Grade 3 collateral ligament injuries that require restoration of the volar plate integrity.^{5,20}

Proximal phalanx articular fractures

Condylar fractures of the proximal phalanx result from strong lateral deviation forces or forceful axial loading. They are classified into three types:

- Type 1: stable fractures without displacement

- Type 2: unicondylar, unstable fractures
- Type 3: bicondylar or comminuted fractures

For lateral deviation injuries of the PIP joint, an applied force may lead to avulsion fracture of the condyle or rupture of the collateral ligament. This is particularly relevant for a joint that exhibits slight flexion because joint stability is maintained solely by the soft tissue stabilizers, making the joint vulnerable to stress. Type 1 and 2 injuries are referenced by subtle comminution or displacement. A Type 3 injury pattern is usually the result of aggressive force and high-energy axial loading at the fingertips. Such injuries are vastly comminuted and displaced. Most of these fractures, including Type 1 non-displacement fractures, will require fixation. Considering the substantial force and torque exhibited during joint movement and minimal periosteal sleeve surrounding the fracture site, restoration of an appropriate bicondylar morphology through adequate fixation is necessary to maintain lateral and rotational stability (Figure 4). Various techniques of fixation have been described including the use of K-wires, lag screws, or an external fixation device.²¹⁻²⁴

Base of the middle phalanx fractures

The most common type of PIP joint injury is a volar lip fracture at the base of middle phalanx with PIP joint dorsal dislocation.^{25,26} This type of injury is typically the result of hyperextension or axial loading at the tip of finger during joint flexion.²⁷ Classification is not only defined by fracture morphology and stability, but also dependent on the involvement of the articular surface of the base of middle phalanx. The amount of articular surface involvement can be used to determine post-reduction joint stability (Table 1). The main goals of any treatment plan for fracture-dislocation injuries should focus on maintaining concentric reduction of the subluxated or dislocated joint, restoring stability to achieve a normal AOM, facilitating early range of motion (ROM) exercises, and, if feasible, performing an anatomic reduction of the articular surface. Nonetheless, existing evidence shows that imperfections to the joint articular surface are not correlated with clinically relevant posttraumatic arthrosis of the PIP joint and will not worsen clinical outcomes.²⁸⁻³¹ In other words, if a smooth articular surface cannot be obtained technically, the outcomes may not suffer as long as alignment and concentric reduction is achieved.

Available treatment options include immobilization, protected motion, traction, open reduction and internal fixation, buttress reconstruction, joint arthroplasty, or arthrodesis.³²⁻³⁸ By principle, stable PIP joint fracture dislocations can be treated non-surgically if closed reduction can restore a normal AOM. However, surgical treatment is indicated for injuries that are unable to achieve concentric joint reduction or cannot maintain stability after reduction.³⁹ Whenever possible, the selected treatment should permit early-protected motion with a stable AOM. Early motion exercises enhance cartilage healing and promote remodeling of the injured articular surface to a great congruency.⁴⁰

Complications of PIP Joint Injuries

Various complications are possible after treatment for a PIP joint injury. Although joint stiffness and flexion contracture are most common, other complications include re-dislocation, posttraumatic arthritis, chronic swelling, or even permanent functional loss.

Given the precise anatomy of the joint and its soft tissue stabilizers, even minor injury can afflict adhesion or misalignment among the delicate structures and lead to abnormal wear and stiffness. Nevertheless, underestimation of the severity of the injury by patients, health care providers, or coaches can delay treatment and increase the chances of complication.

There is no consensus for the best treatment avenue for PIP joint injuries. In addition, evidence suggests that post-treatment outcomes rarely return a full AOM.³⁹ However, studies indicate that outcomes are significantly improved when the injuries are tackled early (within 4 weeks of injury), regardless of treatment modality used.⁴¹⁻⁴⁴ To further diminish complications, evidence recommends early diagnosis and restoration through concentric reduction to facilitate early motion exercises, if feasible, for every injury.^{25,39,45,46}

Joint stiffness or flexion contracture

Although many patients can tolerate around 15-20° of flexion contracture without any functional deficit, more severe contractures typically require corrective treatment.⁴⁷ Achieving a full AOM and stability of the joint, as well as harmonization of the complex structures surrounding the joint, is essential. PIP joint stiffness may be attributed to a combination of structures, including the bony parts, articular surface, joint capsule, collateral and retinacular ligaments, tendons or their sheaths, and the skin. Similarly, flexion contracture may be caused by a lack of extensor power at the PIP joint, decreased excursion of flexor tendons, capsular or ligamentous contractures, or bony blocks or exostoses resulting from malunited fractures.^{48,49} Therefore, it is often extremely difficult to delineate the root cause of the contracture, especially in cases that also involve chronic stiffness.

Because joint stiffness and flexion contracture are the most common complications after PIPJ injury, it is important to understand the pathogenesis of the disease. Following acute injury of the PIP joint, the inflammatory processes of healing and hemarthrosis increase the joint's relative volume. In response, the PIP joint will accommodate up to 30-40° of flexion to maximize its volume. In conjunction with pulling forces from the flexor tendons, the finger is maintained in a flexed posture.^{50,51} During the inflammatory period, scarring and fibrosis are initiated, causing adhesions along the tendons and underlying bony parts or the surrounding soft tissue. The adhesion forming zone is not necessarily confined within the injury zone, and it may extend further beyond the affected area.⁵² When the PIP joint remains in this position for an extended period of time, dense fibrotic scarring can occur. This process causes increased stiffness of the joint and difficulties with digit manipulation. To ensure the best outcomes, the surgeon should evaluate all potential causes and initiate treatment before the formation of dense fibrosis had begun.

Clinical Evaluation

Surgeons should focus their evaluation on defining the precipitating cause of stiffness and delineating the causative structure of stiffness. Details on injury mechanism, severity, duration of injury, prior treatment and rehabilitation, global function of hand, and occupation must be considered. Greater severity injuries will create more extensive scarring and adhesions.⁴⁶ Detailed history taking will guide the surgeon in determining a prognosis and facilitate the appropriate intervention technique. Because patient compliance plays a crucial

role in the treatment process for PIP joint stiffness, it must be addressed in the evaluation stage. Patients should be educated on the treatment protocol and possess an appropriate understanding of the treatment plan to ensure optimal healing.⁵³

A stiff finger is characterized into one of the following groups: ⁵⁴

1. Skin/fascia related problems
2. Muscle/tendon injuries or lesions
3. Capsule/joint ligaments contractures
4. Damage of articular bone

The affected finger is palpated and the pliability, consistency, and mobility of skin are evaluated. If surgical intervention is deemed necessary, incisions should be planned and any skin defect after contracture release should be estimated. Additionally, local tissue rearrangement or skin flap should be planned, if indicated, to achieve tension free coverage.

The examiner must also evaluate the mobility of the joint. Any discrepancy between the active and passive AOM is measured. If the passive AOM is preserved but there is a limited active AOM, musculotendinous adhesion or injury exists. If both the passive and active AOMs are equally limited, there is a clear indication of joint involvement or bone block. However, examiners should be cautious because tendon involvement is often masked and may remain unknown with physical examination alone. Radiograph tests such as x-rays or a computer tomography (CT) scan are suggested to illustrate the articular congruency and identify the bone block. In cases of chronic stiffness and contracture, intrinsic tightness must also be evaluated. Intrinsic tightness is confirmed if there is less PIP flexion when the metacarpophalangeal (MCP) joint is extended than when it is flexed. Furthermore, the physician should check for abnormal posture of digit during posing and motion. Hyperextension of the distal interphalangeal (DIP) joint combined with a flexion stance at the PIP joint suggests a chronic central slip injury. A summary of the classification system for PIP joint stiffness, created by Jupiter et al.⁵⁵ and modified by Kaplan⁵³, is presented in Table 2.

Prevention

Regardless of treatment type, it is generally difficult for one to regain a full ROM after stiffness or contracture has started to develop. Thus, prevention of joint stiffness or flexion contracture is often easier and may provide better outcomes than treatment. Stiffness and contracture of the PIP joint may be attributed to prolonged immobilization and low levels of patient participation owing to pain or edema.^{53,56} To ebb the chance of fibrosis and stiffness, early and effective treatment protocols are imperative. Appropriate fracture stabilization, maintenance of joint stability, and restoration of the soft tissue envelope permit early motion and can limit edema, thus lessening the chance of contracture.³⁹ Furthermore, the physician should initiate adequate pain control, edema control, and patient counseling measures simultaneously with treatment.

In addition, the patient should initiate tendon-gliding exercises during the first 4 weeks of injury to minimize tendon adhesion. Gaining 5 millimeters (mm) of tendon excursion and

upwards to 30-40° in PIP joint motion are favorable prognostic signs.⁵¹ Immobilization of the joint for longer than 3 weeks should be avoided.⁴⁷ Prolonged immobilization will not only facilitate stiffness of the PIP joint, but may escalate stiffening of the DIP joint and even nearby digits, which may not have been directed injured.⁵⁷ Similarly to most other injuries in which a short immobilization period is required, the hand can be safely splinted with the wrist positioned in 30° of extension, the MCP joints flexed at 70°-90°, and the PIP joints fully extended. Safe positioning places the MCP and PIP collateral ligaments with maximum tautness and strengthens the volar plate, subsequently minimizing post-immobilization stiffness. Although this splinting technique may produce a slight degree of extension contracture at the PIP joint, correction of the extension contracture is considerably easier than flexion contracture.⁵⁸

Non-operative treatment

Given that most patients can tolerate slight contractures without any functional deficit, treatment for PIP flexion contractures is not indicated until the degree of contracture is >20°. However, some patients may seek treatment for a stiff finger or slight contractures to best suit their aesthetic preferences. Non-operative treatments, such as serial casting or dynamic/static extension splinting, should be the primary treatment avenues in most cases.^{46,47,55,59} Serial casting is preferred if the contracture is long standing or the degree of contracture is >45°. On the other hand, splinting is suitable if examination reveals some joint mobility and a contracture of <45°. Previous research has reported that aggressive forces from a wire splint can produce pressure ulcers on the underlying skin when applied in cases of severe contracture (>45°).⁶⁰ Further studies report that the success rate of non-operative treatment is highly dependent on the amount of time spent in the splint, as well as patient compliance rates.⁶¹⁻⁶³

Surgical treatment

A surgical release operation may initiate an inflammatory cascade that promotes additional fibroses and adhesion. Therefore, surgery is only indicated after all non-operative protocols have been attempted without evidence of improvement. Moreover, there is not a restricted time window in which surgery must be initiated. Some reports have shown that surgical intervention can aid a patient to achieve an AOM between 65° and 90°; however, slight flexion contractures (<25°) typically remain.⁴⁷ Nonetheless, others have reported unimpressive results or worsening outcomes.^{13,64-66}

Open release of the PIP joint can be conducted using local, regional, or general anesthesia. However, a wide awake local anesthesia technique is recommended because it permits the surgeon to directly observe the mobility of the PIP joint throughout the operation.⁶⁷ In cases involving multiple fingers or extensive scarring that require a more extensive tendon release to the hand and forearm, use of regional or general anesthesia is indicated.

When considering appropriate surgical techniques, the cause of the stiffness or contracture should first be classified as a bony abnormality or soft tissue imbalance. Bony pathologies, such as bony blocking or ankylosis, should be corrected before addressing the soft tissue

contracture.⁶⁸ Three main techniques to release the soft tissue of the PIP joint commonly practiced today.

Percutaneous surgical release—In 1985, Stanley and colleagues were the first to propose percutaneous surgical release for treating PIP joint flexion contracture.⁶⁹ The authors aimed to lessen the extent of surgery inflicted to the joint by using a limited incision to release the underlying ACL. A long-term study of 30 joints after a follow-up period averaging 34 months reported better outcomes among patients with osteoarthritis and post-immobilization stiffness, as opposed to those with inflammatory arthritis. Although approximately half of the study participants demonstrated improved outcomes and long lasting results (average PIP joint flexion deformity angle improved from 78° to 34°; average AOM improved from 17° to 39°), outcomes in the other half remained unchanged or deteriorated.⁷⁰ Thus, the authors concluded that percutaneous ACL release is properly indicated in stiff joints affected by capsuloligament disease that have not undergone previous surgery.⁷⁰ This operation is not always a suitable alternative for an open release but can be attempted before adoption of a more extensive technique.

The operation is performed using a Beaver knife insert through a dorsum 2 millimeters (mm) incision just lateral to overlying head of proximal phalanx. The blade is inserted between the head of the proximal phalanx and the collateral ligament, and is swung back and forth to unleash the ACL entirely (Figure 5). Blade direction is kept strictly in the sagittal plane to avoid inadvertent injury of the neurovascular bundles. The surgeon must use a moderate force to manipulate the joint, break remaining adhesions, and split the flexor tendon sheath. Occasionally, surgeons may be able hear the sound of the intra-articular adhesions breaking. Aggressive force should be avoided, because it may jeopardize the volar plate or result in iatrogenic phalangeal fracture.

Open surgical release—Similar to percutaneous release, the goal of open surgical release is to eliminate any structures that restrict joint motion, yet maintain sufficient joint stability. However, as previously mentioned, PIP joint stiffness or flexor contracture is usually caused by a combination of structures, and it is often impossible to delineate the prevailing causative structure in an individual finger through clinical evaluation alone. Previous literature has noted the benefits of a sequential release of involved structures; however, the order varies from author to author.⁷¹⁻⁷³ Most recommend progressively releasing from the proximal to distal ends and from extra-articular to intra-articular, checking for improvements after every structure released.^{56,65,71,73-75} Sequential releases are recommended in the following order:

1. Flexor tenolysis: This operation should be conducted under wide-awake local anesthesia, if feasible. In severe and long-standing contractures, the need for provisional soft tissue reconstruction using local tissue rearrangement or a flap should be considered and planned in advance (Figure 6). To begin, underlying structures can be exposed via a midaxial or Bruner incision, yet the midaxial approach is most common. One study of 45 fingers found that patients with a midaxial incision exhibited a better AOM 1.5 years postoperatively when compared to those receiving a Bruner incision.⁷⁶ Nonetheless, the midaxial exposure is limited and extending the incision beyond the proximal phalanx can be challenging. Given

that adhesions or fibrosis are not necessarily confined within the digit and there is a possibility for extensive scarring, a Bruner incision may be more appropriate (Figure 7).

After incision, the flexor tendons are released. Windows in the flexor tendon sheath are made proximal to A1 pulley, on the distal border of A2 pulley, and proximal to the A4 pulley. The A2 and A4 pulley are preserved to prevent bowstringing of the flexor tendons. The operator can use a traction force to break the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) from their adhesions. A Freer elevator is used to dissect the tendons from the pulley, surrounding tissue, and underlying bones (Figure 8). The FDS should be adequately freed toward its insertion site. If resistance of the flexor tendons remains proximally, a counter incision in the distal forearm is needed (Figure 9). The surgeon can then apply the traction force on the encountered tendon to facilitate adhesion lyses and tendon dissection.⁷³

When tenolysis is adequately performed, manual traction on the tendon will reveal full extension of the PIP joint, but the patient may not be capable of full active PIP joint extension. Extension lag is frequently observed after PIP joint injury, because sustained stretching of the extensor tendon from the flexion contracture can cause tendon lengthening. Tendon lengthening diminishes excursion of the extensor tendon and generates a lag in extension.^{77,78}

2. Volar capsular release: Volar capsular release can be initiated if a satisfactory extension arc still cannot be obtained after flexor tenolysis. The checkrein ligament is firstly released from the head of proximal phalanx. Take caution to avoid inadvertent injury to the transverse digital artery, which runs across the head of proximal phalanx, 2 mm proximal to the PIP joint and deep to the checkrein ligament (Figure 10).

Next, if the contracture is not improved, the insertion of the ACL is sharply divided (Figure 11). Additionally, the proximal portion of the volar plate is transected and freed from the underlying proximal phalanx. Afterward the PIP joint is gently manipulated until a functional AOM is obtained. Ultimately, if the flexor contracture still remains after release of the ACL and volar plate, the proper collateral ligaments may be progressively released until they are totally freed from their origin. The proper collateral ligaments should first be released from the volar origin and then, if necessary, released from the dorsal origin. Using this tactic, stability of the PIP joint is maintained by the lateral retinacular fascia.^{46,53,73} Once the final functional AOM is obtained, surgeons must then ascertain normal circulation of the finger. If there is a possibility of circulation being compromised, the surgeon and patient should be accepting of a lesser motion arc because the viability of the digit is most important.

Existing literature suggests that it may be impossible to achieve a full AOM after open surgical release. Normally, the functional AOM for the PIP joint is between 36° to 86°, with an average of 61°. ⁷⁹ Open release typically shifts the AOM, such that 25° to 30° of extension is gained, yet there is a concomitant amount of flexion loss.^{46,47} Nonetheless, an open release procedure should provide enough motion at the PIP joint for daily hand usage. Ghidella et al. found that outcomes of open surgical release are most favorable in younger

patients with a less severe diagnosis or a preoperative contracture of less than 45°. ⁶⁴ Conversely, adverse surgical outcomes are more commonly seen in patients who are older, have had a large number of operative procedures, extensive extracapsular release, or those with severe joint deformity. ^{48,49,64}

Dynamic traction device application—In 1986, Schenck proposed dynamic traction splinting and early passive movements as a viable treatment option for comminuted intra-articular fractures of the PIP joint. ⁸⁰ Dynamic traction splinting applies the ligamentotaxis principle, in which one gradually extends and distracts the PIP joint to overcome the deformation force. The benefits of this method have been generously demonstrated in the literature. ⁸¹⁻⁸⁴ Avoiding the possibility of added injury from open release, application of a dynamic distraction device diminishes the extent of soft tissue dissection to prevent further fibrosis or stiffness. Moreover, this method transmits force directly to the phalangeal bone, avoiding the development of pressure sores that frequently accompany serial casting or splinting. Treatments utilizing a distraction device have grown in popularity throughout the last decade and a wide variety of designs have been developed. However, all distraction devices can be principally classified into one of two types: extension correction or distraction correction devices (Figure 12). ⁸⁵

Past studies have demonstrated favorable outcomes using various distractor models. On average, patients gain 42° to 62° of motion, and the distraction method has been shown to improve the degree of contracture even in highly resistant cases. ⁸⁶⁻⁸⁸ In 2013, Houshian et al. detailed the long-term outcomes of chronic post-traumatic PIP joint flexion contracture treated using a distraction device. During the distraction phase, the system was activated 1 mm each day. The distraction phase was terminated once a 5-mm joint opening or full extension of PIP joint was obtained; however, the device was kept in place for 1-week after successful distraction. Results showed that the average AOM had improved by 30° to 90° at an average of 54-months post device removal. Authors emphasized the use of a distraction device to correct flexion contractures, as opposed to an extension device, because a distraction device can circumferentially lengthen the periarticular tissue, whereas an extension device only creates pronounced effects on the volar soft tissue. Additionally, this study reported a combined complication rate of less than 15% for pin-tract infection, swelling, redness, temporary flexion deformity of the DIP joint, and pain, with all complications being completely resolved within a few weeks after the treatment period. ^{82,85}

When using a distraction technique, care must be taken if the flexion contracture is greater than 80° or if the joint is hypermobile, because there is an increased chance of asymmetrical joint opening or subluxation after treatment. Serial radiographs and close follow-up evaluations are recommended to prevent further joint subluxation. ⁸⁵ Patients with connective tissue diseases that affect the elasticity of the tissue, especially the neurovascular bundle, or delay healing require intensive monitoring during the distraction period or may be better suited for an alternate treatment method.

Extension contracture

Although less common than flexion contractures, extension contractures are another frequent complication following PIP joint injury. Kuczynski proposed that extension contractures result from adhesion between deep surfaces of the extensor apparatus and the retinacular ligament with the underlying bone.⁸⁹ In cases of long-standing contracture, the fibrosis and adhesion may also involve the collateral ligaments, causing a more profound stiffness of the joint. Around the same time, Egawa et al. presented their corrective technique of releasing the lateral band from the central band and dorsal capsule over the PIP joint in an effort to accomplish a greater flexion arc.⁹⁰ However, the authors predicted that the cause of extension contracture was the adhesion among the central band, dorsal capsule, and the lateral band. Because the lateral band had shifted dorsally from adhesion of the dorsal capsule and central slip, its release may restore the volar alignment and improve the extension arc. Long-standing extension contracture may also result from intrinsic contracture.⁹¹ Nonetheless, adhesions of the extensor apparatus are most commonly the cause of the contracture.⁷³ Illuminating the imperative cause of disease will aid the surgeon to determine an appropriate structural release sequence that avoids unnecessary surgical exposure and reduces opportunity for further inflammation or consequential fibrosis.

Prevention

The same measures described for overcoming flexion contracture can be applied to prevent extension contracture. Early mobilization after establishing concentric reduction with adequate joint stability is the most important preventive paradigm.

Non-operative treatment

There are several available modalities for non-operative treatment of PIP joint extension contractures. Two methods, taping and interphalangeal slings, follow a similar concept. Both mold the finger posture to achieve a specific position and are gradually adjusted to provide a gentle prolonged stretch. Oppositely, a dynamic flexion splint applies passive force across a joint in one direction while permitting active motion in the opposite direction. All of the non-operative treatment options facilitate plastic deformation, and, as a result of viscoplastic properties, tissue formation is permanently lengthened. Therefore, any type of static or dynamic splinting can correct the contracted joint.^{62,92}

Despite the high prevalence of extensor contracture, reports on outcomes after nonoperative treatment are limited. Existing literature does indicate that non-operative treatment can improve the arc of extension in cases where the cause of contracture was solely capsular or intrinsic muscle adhesion.^{61,93} Similarly to treatment of flexion contracture, any surgical procedure may add some intent of injury and promote further scar and adhesion. Therefore, nonoperative treatment should be the first line of treatment considered for all contractures. For rare cases, such as a patient who presents with a contracture with a chronic ulcer on the dorsum of finger or bony ankylosis, the non-operative phase can be skipped because open surgical correction is inevitable.

Surgical treatment

Surgical treatment is indicated when non-operative treatments are unable to improve the AOM. Given the risks of operative intervention, a non-operative regiment should be continued if it continuously reveals positive gains in ROM.⁷³

The literature contains only a few case reports to guide expectations, and results vary substantially. In one report, Mansat and Delprat investigated outcomes after surgical correction of extension contracture. Among the 246 contracture releases of the PIP joint performed, of which 45% were extension contractures, the degree of flexion improved by an average of 28°, whereas the PIP ROM improved from 19°-34° preoperatively to 8°-62° postoperatively.⁵⁶ There are two options used for surgical correction of a PIP joint extension contracture.

Extensor tenolysis—Extensor tenolysis is performed under wide-awake local anesthesia with or without tourniquet. If tourniquet is used, it should be placed at the forearm for a limited time period (no longer than 2 hours) to diminish pain. The wide-awake approach permits patient to maintain active control and move their hand throughout the operation. Active movement by the patient will provide an indication of the adequacy of surgical release and can be utilized to further break existing adhesion. Furthermore, the patient can participate throughout the progression of the surgery and observe the final results, which may encourage them to take a proactive role in the recovery process.

Egawa et al. were the pioneers who first presented open surgical release for correction of a PIP joint extensor contracture.⁹⁰ Their procedure involved extensor tenolysis and release of the lateral band from the central band. Inoue reported that, on average, the patients who underwent this procedure gained 56° of flexion but lost 9° of extension.⁹⁴

Surgeons have the option between a dorsal or dorsolateral approach. These approaches are pointed at the extensor apparatus, which is most commonly the structure responsible for the contracture. A curvilinear incision is made over the PIP joint. This incision design permits proximal or distal incision extension, which may be necessary for accurate determination of normal tissue planes. Skin flaps are meticulously elevated from the underlying tendon by sharp dissection. Care should be taken to preserve the paratenon of the extensor tendon. Next, the extensor apparatus and lateral bands are circumferentially freed using a scalpel or Freer elevator. The extensor tendon should be freed entirely from the base of proximal phalanx to the dorsal capsule or central slip insertion. Caution must be taken to avoid iatrogenic avulsion of the central slip, terminal tendon, or triangular ligament. In the scenario that there is some contracture of the DIP joint, tenolysis can be extended distally to reach the terminal tendon insertion. Afterward, the extensor tendon and lateral band are completely released. Longitudinal parallel incisions are made between the central tendon and the lateral bands at the level of PIP joint (Figure 13). These incisions will release the lateral band from the central tendon and can restore volar shift. The passive AOM should be assessed. If full passive flexion is achieved, the tourniquet is deflated. The patient is asked to actively flex the affected finger while, simultaneously, the surgeon gently manipulates the PIP joint. Further extensor tenolysis is required if the patient cannot obtain a functional flexion arc. In this case, proximal extension of the incision may be necessary.

A finger that is stiff in extension also has a chance of developing flexor tendon adhesion, indicating the need for flexor tenolysis. Thus, it is crucial to test the excursion of the flexor tendons. Excursion of the flexor tendons can be tested by asking the patient to actively flex the finger during the operation or by directly pulling the flexor tendons via a volar stab incision. Because it is impossible to determine the necessity of flexor tenolysis preoperatively, the patient should be informed of the possibility of subsidiary flexor tenolysis prior to the operation.

Dorsal capsulotomy—If all previously described treatment methods have been attempted without restoration of passive flexion, dorsal capsulotomy is indicated. The dorsal capsules are exposed through the interval between the lateral band and central slip. An incision is made on the dorsal capsule while gently forcing the PIP joint in flexion. A Freer elevator is used to free any intra-articular adhesion and fibrosis around the volar plate. If flexion is limited after dorsal capsulotomy, partial or total collateral ligament excision can be safely performed without consequent PIP joint instability.⁶⁵ (Figure 14) The success of the open release is justified when the patient can actively reproduce the same amount of function that was achieved at the operating scene.

Redisplacement and Redislocation

Occasionally, a chosen treatment option cannot maintain sufficient joint stability, leading to redisplacement or redislocation. Redisplacement of a seemingly stable reduction may also arise from poor initial positioning, too rapid mobilization into extension, or hardware failure.

The prevalence rate of redisplacement varies within the literature, as it is highly dependent on the severity of disease and the mode of treatment. For example, redisplacement has been reported in up to 31% of patients who underwent volar plate arthroplasty for PIP dorsal fracture dislocation.^{27,44,82,95,96}

Prevention and treatment

Surgeons must carefully evaluate the pathology of the injury and select the best treatment to provide adequate stability. Complication rates are markedly high in patients who undergo a procedure that does not appropriately match the pathology, and previous research reveals that the major cause of complications is attributed to inappropriate treatment.^{27,44,96,97}

Preventing redisplacement is achieved through the appropriate initial treatment. Nonetheless, certain treatment types are associated with higher rates of redisplacement. For example, volar plate arthroplasty has a high reported rate of redisplacement because the head of the proximal phalanx can become embedded into the advanced volar plate.²⁷ Additionally, the bony defect depth at the volar lip of middle phalanx may be wider than the thickness of the volar plate. Consequently, the volar plate provides insufficient support to produce a buttress effect.⁸ To overcome this discrepancy, the bony defect can be augmented with a bone graft from the excised fragmented bone.⁹⁶ Alternatively, Wiley described a technique using one slip of the FDS tendon and attaching it to the base of the middle phalanx at the volar lip defect (Figure 15).⁹⁸ Although large-scale studies on the outcomes of this procedure have

not been performed, their small case series of three patients reported satisfactory results without redisplacement.⁹⁸

Maintaining an appropriate postoperative follow-up protocol is essential. Serial radiography should be performed periodically. Mangelson et al. recommend a follow-up visit every seven to ten days for four weeks with serial radiographic evaluation.⁴⁷ The appropriate interval for an individual's follow-up schedule is dependent on disease severity and patient compliance. In the case that there is increased potential for displacement and treatment may not provide complete stability, the follow-up schedule should be revised for more frequent visits.

Treatment of a redisplaced joint usually requires a more aggressive revision or salvage operation. A revision operation should be chosen based on three criteria; reduction achieved, stability maintained, and an acceptable condition of remaining cartilage. If the surgeon cannot satisfy all of three criteria with revision, a salvage operation such as arthrodesis or implant arthroplasty is recommended.⁴⁷ The most commonly selected revision operation is a hemi-hamate autograft. The literature reports favorable outcomes for this operation in patients with involvement of more than 50% of the articular surface of the middle phalanx and in cases of chronic dorsal fracture dislocation of the PIP joint. Additionally, the use of a hemi-hamate autograft operation has been shown to improve the AOM, reduce pain, and maintain stability of PIP joint.⁹⁹⁻¹⁰¹ In one example, Calfee et al. followed 22 patients who underwent hemi-hamate autograft for an average of 4.5 years postoperatively. Authors found that the postoperative AOM improved from 19° to 89°, and no patients reported significant postoperative pain.⁹⁹

Malunion

Neglect of a PIP joint fracture dislocation or inadequate prior treatment can further result in malunion. Malposition of the bony structures can facilitate abnormal wear or interference to the AOM. Consequently, arthritis or ankylosis may develop. Malunions of periarticular fractures of the PIP joint are scantily reported. Similar to the treatment of redisplaced joints, surgeons can use a revision or a salvage operation to correct a malunion. Various revision operations are commonly practiced, including corrective osteotomy with ORIF, volar plate arthroplasty, and hemi-hamate autograft. Acceptable results following corrective osteotomy with ORIF are demonstrated in the literature.¹⁰²⁻¹⁰⁶ For example, Del Pinal et al. examined outcomes using their osteotomy technique and ORIF with mini-screw and/or cerclage wire in 11 patients who sustained a malunited intra-articular fracture of the base of middle phalanx.¹⁰⁶ Using a modified Eaton and Malerich shotgun approach, the operator delineated cartilage-containing fragments by removing fibrous tissue and new bone. Next, articular fragments were disimpacted and elevated. Open wedge osteotomy of the volar lip fragment was performed to restore the volar buttress. They filled the void underneath the elevated fragments with cancellous bone graft from the distal radius, and fixation was performed, if necessary based on the number of fragments and degree of comminutions. At an average follow-up time of 28 months, the average visual analog scale had improved from 9.1 preoperatively to 0.8 postoperatively. The average arc of flexion improved from 77° to 84°. Because these results were similar between highly comminuted fractures (>3 fragments) and less comminuted fractures, the authors proposed that the amount of comminution does not

play a substantial role in predicting outcomes of osteotomy and internal fixation. Authors also emphasized that the quality of the remaining cartilage was the most crucial factor to undergo osteotomy and ORIF.¹⁰⁶

Despite reports of favorable outcomes after osteotomy and ORIF, many surgeons prefer to reconstruct the volar buttress of the middle phalanx with the volar plate or a hemi-hamate autograft. A malunion that has a high degree of comminution is technically demanding and surgical restoration of the concentric reduction is fraught with potential risks, such as loss of fixation, avascular necrosis, or loss of joint mobility.¹⁰⁷ Thus, surgeons may be more comfortable with the volar plate arthroplasty or hemi-hamate autograft procedure.

O'Rourke and colleagues published an 11-year review of 59 intra-articular fractures of the phalanges. Though 17% of joints showed radiological evidence of arthritis at the final follow-up visit, only one patient had persistent symptomatic pain.¹⁰⁸ Nevertheless, if the PIP joint becomes arthritic, a salvage operation is indicated. Salvage procedures can provide the patient with a painless joint and improve hand function. Arthrodesis is indicated for patients with intense hand usage, insufficient bone stock, or lack of stability to support an implant. Otherwise implant arthroplasty is typically selected to reduce pain and achieve functional motion. If arthrodesis is selected, the position of the fused PIP joint must accommodate the basic functions of the hand.

Prevention

Exemplary management of any PIP joint fracture can prevent malunion. Careful evaluation to determine the disease pathology, selection of the best treatment option, and intensive postoperative follow-up care are fundamental to avoid subsequent complication. Early intervention is encouraged to decrease the need for a salvage operation and preclude reconstruction.

Swan-Neck deformity

Hyperextension deformity of the PIP joint, regardless of subluxation, may develop secondary to an unhealed volar plate. Patients are unable to flex the PIP joint and afflict painful snapping of the lateral bands during forceful flexion. The deformity can lead to swan-neck deformity by the chronicity of tendon shifting. A treatment for swan-neck deformities should aim to relieve painful motion while maintaining joint stability. However, treating a chronic swan-neck deformity of the PIP joint can be a greater technical challenge owing to scar deformation. If the joint movement is supple and the PIP joint is well aligned with established stability, a swan-neck deformity can be treated using an extension block splint and buddy taping to initiate early motion exercises. Open surgical intervention is indicated if:

- the hyperextension deformity is persistent,
- the patient cannot tolerate splinting, or
- the underlying pathology requires surgical correction (e.g. malunion or redisplacement).

For open interventions, surgeons have the choice between volar plate reattachment or FDS tenodesis. Stiffness of the periarticular soft tissue may preclude the possibility of volar plate reattachment, in which case FDS tenodesis is the best option. Previous literature has demonstrated satisfactory operative outcomes with correction of the swan-neck deformity after FDS tenodesis.¹⁰⁹⁻¹¹¹ In one example, Catalano et al.¹¹⁰ reviewed their 15 years of experience treating patients with post-traumatic chronic hyperextension of the PIP joint using FDS tenodesis (Figure 16). Out of 12 total patients, 10 returned with a good or excellent outcome, and the average ROM improved from 31°-92° preoperatively to 12°-100° postoperatively. Nonetheless, several studies have reported that this technique will lead to inevitable flexion contracture.¹¹²⁻¹¹⁴ Most surgeons advocate 20° to 30° of PIP joint flexion to facilitate an adequate functional AOM.¹¹⁵ Considering the scar and adhesion of PIP joint that may arise by performing FDS tenodesis at the A2 pulley, the senior author has modified this operation by performing FDS tenodesis at the A1 pulley instead. (Figure 17)

Prevention

Owing to the nature of injury, preventing a volar plate injury is nearly impossible. Nonetheless, early detection is a key element to ensure adequate recovery. Chronic hyperextension deformity can lead to a fixed swan-neck deformity. Treatment protocols for the fixed deformity are more challenging and may require a more aggressive salvage operation.

Summary

PIP joint injuries are common. In particular, dorsal fracture dislocations continue to be the most prevalent pattern of injury. However, these injuries are frequently overlooked because they seem trivial in nature. Given the high rate of postoperative complications for PIP joint injuries, every injured finger should be carefully evaluated by a trained physician. All pathological findings must be addressed before pursuing a specific intervention. Current evidence supports that early treatment can improve surgical outcomes, regardless of the treatment method chosen. Despite selection of the proper treatment, complications may still arise because of the delicate anatomic structure of the PIP joint. The most prevalent complications, stiffness and flexion contracture, are more easily prevented than treated. To lessen the chance and severity of any complication, the chosen treatment should provide concentric alignment and facilitate early ROM exercises.

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KEY POINTS

- Proximal interphalangeal (PIP) joint stability is maintained through the congruency of the bony structures and its soft tissue stabilizers.
- Complications regularly arise after PIP joint injuries, yet they can often be prevented through early detection of injury and appropriate initial treatment protocols.
- The main goals of any treatment for a PIP joint complication are maintaining concentric reduction of the joint, restoring joint stability, and facilitating early range of motion exercises.

Figure 1. Illustration of the dorsal aspect of the right hand to demonstrate size discrepancies between the ulnar and radial condyles of the proximal phalanx in the fingers.

Courtesy of N. Fujihara, MD, Nagoya, Japan.

Figure 2.

(A) Anatomy of the soft-tissue stabilizers of the proximal interphalangeal joint. (B) A three-sided box analogy is useful to identify volar, radial, and ulnar restraints of the joint.

A: *From* Chung KC, Brown M. Capsulotomy for Proximal Interphalangeal Contracture. In: Chung KC, editor. Operative Techniques: Hand and Wrist Surgery, 3rd edition. Philadelphia: Elsevier; 2018; with permission.

B: *Courtesy of* C. Hokierti, MD, Bangkok, Thailand.

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Figure 3.

Volar plate avulsion injury. The dynamic forces across the PIP joint can lead to fracture of palmar lip of the base of middle phalanx with dorsal subluxation of the PIP joint.

Courtesy of C. Hokierti, MD, Bangkok, Thailand.

Figure 4.

(A) A unicondylar oblique fracture pattern is seen at the head of the proximal phalanx. (B) After fixation with 3 lag screws, restoration of bicondylar morphologic pattern was achieved to maintain stability.

Figure 5.
Percutaneous surgical release technique to treat flexion contracture of the proximal interphalangeal joint.
Courtesy of C. Hokierti, MD, Bangkok, Thailand.

Figure 6.

This patient had a long-standing and severe flexor contracture of the right hand from Dupuytren disease. (A) The local tissue rearrangement incisions were designed. (B) At the end of the operation, the remaining incision was covered with a full-thickness skin graft from the forearm.

Figure 7. Flexor tenolysis using (A) a Brunner incision and (B) a midaxial incision. The neurovascular bundles should be identified to avoid inadvertent neurovascular injury during the operation.

Figure 8.

A Traction force is applied to profundus and superficialis tendons individually to facilitate breaking of adhesion between both tendons. (B) A Freer elevator is used to dissect the peritendinous adhesion.

B: From Kaplan FTD. The Stiff Finger. Hand Clin 2010;26(2):201; with permission.

Figure 9.
(A, B) Incisions designed for flexor tenolysis.

Figure 10.

Volar capsular release. (A) Relevant Anatomy. (B) Incision of periosteal attachments of the volar plate. (C) Volar plate dissected.

A: *From* Chung KC, Brown M. Capsulotomy for Proximal Interphalangeal Contracture. In: Chung KC, editor. *Operative Techniques: Hand and Wrist Surgery*, 3rd edition. Philadelphia: Elsevier; 2018; with permission.

Figure 11.

Arrows indicate where the true and accessory collateral ligaments are freed from the proximal phalanx.

Figure 12.
(A) Extension correction device. (B) Distraction correction device. *Courtesy of C. Hokierti, MD, Bangkok, Thailand.*

Figure 13.

Extensor Tenolysis. (A) Extensor structures approached via a curvilinear dorsal incision. (B, C) Lateral bands are separated from the central tendon by making bilateral longitudinal incisions along the border of the central tendon. (D, E) Dorsal capsulotomy and collateral ligament excision are performed through the interval of the lateral band and central tendon. (F) The arc of motion is evaluated.

C and Figure 13E: *From* Yang G, McGlinn EP, Chung KC. Management of the Stiff Finger: Evidence and Outcomes. *Clin Plast Surg* 2014;41(3):509; with permission.

Figure 14.

Dorsal capsulotomy. (A) Release of the dorsal capsule by making a transverse incision and using a Freer elevator to facilitate lysis of the intra-articular fibrosis. (B) Partial or total collateral ligament excision by insertion of a blade between the head of the proximal phalanx and the collateral ligament and swinging it back and forth.

From Kaplan FTD. The Stiff Finger. Hand Clin 2010;26(2):200; with permission.

Figure 15.

Diagram illustrating Wiley's technique of attaching one slip of the superficial tendon to the base of the middle phalanx at the volar lip defect.

Courtesy of C. Hokierti, MD, Bangkok, Thailand.

Figure 16.

Diagram illustrating the steps of flexor tenodesis. The ulnar slip of the FDS is identified at the cruciate pulley and transected. The end of the distal portion of the ulnar slip of the FDS is secured through the A2 pulley and sutured to itself. Not the slight degree of PIP flexion after FDS tenodesis.

Adapted from Wei DH, Terrono AL. Superficialis Sling (Flexor Digitorum Superficialis Tenodesis) for Swan Neck Reconstruction. J Hand Surg Am 2015;40(10):2071; with permission.

Figure 17.

Modified FDS tenodesis at the A1 pulley. (A) The FDS is identified just proximal to the A1 pulley. (B) Radial and ulnar slip of FDS are transected 1cm proximal to the A1 pulley. (C) The distal portion of the transected FDS is sutured to the cut edge of the A1 pulley. (D) Tension is set to maintain the PIP joint in 20° of flexion.

Table 1

Stability-based Classification of Proximal Inter phalangeal Joint fracture-dislocation

Fracture type	Articular surface involvement	Stability	Clinical stability
Volar lip	<30%	Stable	Stable with full active ROM
	30%-50%	Tenuous	Requires <30° of flexion to maintain reduction
	>50%	Unstable	Requires >30° of flexion to maintain reduction
Dorsal lip	<50%	Stable	Reduced in full extension
	Any percentage	Unstable	Volar subluxation/dislocation in full extension
Pilon	100%	Stable	Stable through full active ROM
	100%	Unstable	Grossly unstable

ROM, range of motion

Table 2

Stiff Finger Classification

	Motion Loss	Dorsal Disease	Palmar Disease	Possible Associated Conditions	Treatment
Type 1	Limited passive flexion Limited passive extension	Extensor adhesions Dorsal capsule–ligamentous contracture	A2 pulley insufficiency Palmar plate contracture Accessory collateral contracture Skin deficiency	Flexor tendon adhesions Flexor tendon disruption	Stage 1 • Extensor tenolysis • Dorsal capsulectomy • Flexor check Stage 2 • Flexor tenolysis, reconstruction • Palmar plate, checkrein release
Type 2	Limited passive flexion Limited active extension	Extensor adhesions Dorsal capsule–ligamentous contracture		Flexor tendon adhesions Flexor tendon disruption	Stage 1 • Extensor tenolysis • Dorsal capsulectomy • Flexor check Stage 2 • Flexor tenolysis, reconstruction
Type 3	Limited active flexion Limited passive extension		Flexor tendon adhesions Flexor tendon disruption A2 pulley insufficiency Palmar plate contracture Accessory collateral contracture Skin deficiency		Flexor tenolysis Flexor tendon reconstruction Pulley reconstruction Palmar plate, checkrein release Accessory collateral ligament release Skin contracture release, resurfacing
Type 4	Limited active flexion Limited active extension	Extensor subluxation Excessive length of extensor tendon	Flexor tendon adhesions Flexor tendon disruption		Stage 1 • Extensor rebalancing, reconstruction Stage 2 • Flexor tendon tenolysis, reconstruction
Type 5	Limited passive extension		Palmar plate contracture Accessory collateral contracture Palmar fibromatosis Palmar skin contracture		Palmar plate, checkrein release Accessory collateral ligament release Fasciectomy Skin contracture release, resurfacing
Type 6	Limited active flexion		Flexor tendon adhesions Flexor tendon disruption		Flexor tenolysis Flexor tendon reconstruction
Type 7	Limited passive flexion	Scar, burn contracture	Bone block		Skin contracture release, resurfacing Excision of bony block

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Motion Loss		Dorsal Disease	Palmar Disease	Possible Associated Conditions	Treatment
Type 8	Limited active extension	Extensor disruption			Splinting Extensor tendon repair, reconstruction

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