Fractures of the proximal interphalangeal joints of the fingers

C. Y. Ng, C. W. Oliver

From the Royal Infirmary of Edinburgh, Edinburgh, Scotland

Injuries to the proximal interphalangeal joint (PIPJ) of the fingers are common. They occur most often following an axial impact on an extended finger. This article reviews the anatomy of the PIPJ and the clinical evaluation and management of these fractures.

Anatomy

The PIPJ is a synovial joint. The base of the middle phalanx carries a facet that is divided by a central ridge into two concavities. The head of the proximal phalanx is correspondingly trochlea-shaped, with the facets on the distal and flexor surfaces.1 This congruence affords intrinsic stability to the joint, especially in an axially-loaded finger.2

The collateral ligaments, the accessory collateral ligaments, the volar plate, the capsule and the central slip of the extensor mechanism form the capsuloligamentous structures of the PIPJ. The collateral ligaments originate from the concavities of the lateral aspects of the proximal phalanx and insert into the volar and lateral aspects of the middle phalanx, creating a course which is slightly palmar to the mid-axis of the finger. The volar fibres are taut in extension, whereas the dorsal fibres are taut in flexion. The accessory collateral ligaments originate volar to the collateral ligaments proper. They fan out volarly to attach on to the volar plate and the flexor tendon sheath. The fibres are taut in extension and relaxed in flexion (Fig. 1).2

The volar plate inserts onto the base of the middle phalanx. Proximally it has slender extensions, the checkrein ligaments, which are firmly attached to the periosteum of the proximal phalanx and to the sides of the flexor sheath at the distal end of the A2 pulley. It thus forms the floor of the flexor sheath at the PIPJ. The proximal extension becomes membranous in the midline and a hiatus is formed by the bridging checkrein ligaments, permitting a nutrient artery to supply the joint and the flexor tendon.2

Functionally, the PIPJ is a pure hinge joint.1 Its stability results from the articular congruence and the surrounding soft-tissue structures. The volar plate limits hyperextension, whereas the collateral ligaments contribute to varus-valgus stability.3 For dislocation to occur, the volar plate and at least one of the collateral ligaments must be injured.4

Clinical assessment

After acquiring the basic information including handedness and occupation of a patient, the history following an injury to the PIPJ should focus on the mechanism of injury, the occurrence of any subluxation or dislocation, and whether it was reduced at the time of injury. The timescale of each event is important in influencing the degree of swelling and stiffness. Examination begins with inspection of the finger, noting any swelling, bruising, laceration and deformity. Palpation should be performed, paying attention to the exact site of tenderness. The neurovascular status should be clearly documented.

Radiographs should be taken if there is swelling, pain or restriction of movement of the joint. In the presence of an obvious deformity or a history of attempted reduction, radiographs should be taken before assessing the range of movement (ROM) and stability. A simple dislocation may be reduced closed in the emergency department using a ring block and/or Entonox. Post-reduction films are important to confirm congruency of the joint and to exclude iatrogenic fracture. A true lateral radiograph is particularly important and a divergence of the articular surfaces, giving a
The initially undisplaced fractures had a tendency to displace during immobilisation. If overlooked, this may result in angular deformity and articular incongruity. The standard posteroanterior and lateral radiographs will often need to be supplemented by oblique views to exclude such injury. Fixation of these fractures by multiple wires or miniscrews was recommended. Nonetheless, some degree of flexion contracture appeared inevitable.11,12

**Fractures of the base of the middle phalanx**

**Avulsion fractures.** Lateral forces applied to the PIPJ can result in an avulsion fracture of the base of the middle phalanx. The bone will fail in tension at the site of attachment of the ligament if the latter is strong enough to withstand the tensile strain. Provided the fragment involves less than 25% of the articular surface, it is minimally displaced and the joint remains stable, this injury can be treated with neighbour strapping for two to three weeks and then mobilised as symptoms allow.9

Dorsal avulsion fractures are often the consequence of a volar dislocation of the PIPJ. The central tendinous attachment to the base is preserved, but the middle phalanx has the potential to subluxate volarly. A boutonnière deformity may develop in the presence of persistent displacement.9 If the avulsed fragment is large enough it may be amenable to fixation with a lag screw. However, additional comminution of the fracture can compromise fixation.

Volar avulsion fractures are much more common and are often observed after a hyperextension injury to the PIPJ. The palmar plate is placed under tension and may avulse a small articular fragment. In the absence of instability, the injury may be treated with neighbour strapping and mobilisation.9

**Pilon fractures.** Axial compression can lead to impaction and comminution of the base of the middle phalanx. These fractures are challenging to reconstruct. The surgical options are either ORIF or external fixation and traction. An open reduction may require a bone graft to support the articular fragment before fixation with a screw. The bone graft can be harvested from the distal radius. In the more complex cases, ORIF may be combined with external fixation.

Allison11 reported reasonable results using a spring-loaded dynamic traction device to treat a series of 14 patients with pilon fractures or dorsal fracture-dislocations. The spring is made of stainless steel with a ferrule at either end. A pair of the springs together with two K-wires placed transversely proximal and distal to the fracture form the construct (Fig. 2). Johnson et al14 later proposed a modification of the system using acrylic instead of stainless steel ferrules. The device permits active and passive mobilisation while maintaining traction across the joint. Improvement in the initial reduction with mobilisation was observed in the patients with pilon fractures, although no centrally depressed fragments were reduced openly.13 Closed reduction was also employed by Hynes...
and Giddins,\textsuperscript{15} who described a simple traction device using two K-wires only (Fig. 3).

In contrast, Seno et al\textsuperscript{16} emphasised the importance of the stability and joint congruity achieved by open anatomical reduction of the articular surface, rigid internal fixation and bone grafting if necessary, to ensure an optimal outcome. In their series of 140 fingers with fractures of the base of the middle phalanx, 45\% were treated surgically. The surgical group were then reviewed at a mean of 94 months. A few fingers achieved good clinical results despite poor radiological findings. No single radiological predictor of a poor clinical outcome was identified, a combination of tilting, incongruity and step-off tended to correlate with poor clinical results.

Stern et al\textsuperscript{17} reviewed the results of treatment of pilon fractures in 20 patients with splintage, skeletal traction or open reduction and stabilisation with K-wires. They advised against treatment by immobilisation and concluded that skeletal traction and open reduction produce comparable results. Caution should be exercised when considering open reduction because of its potential complications.\textsuperscript{17}

**Fracture-dislocations**

These result in articular damage, which is further compounded by injury to the soft-tissue constraints of the joint. The patterns of injury are variable. Schenck\textsuperscript{18} has proposed a classification of fractures and fracture-dislocations of the PIPJ to help guide the management of these injuries. He describes four grades of fracture (I to IV) and four grades of subluxation/dislocation (A to D), giving rise to 16 possible combinations of fracture-dislocation. In the absence of subluxation, the injury is graded as 0. The majority of literature available is on the fractures of the volar lip of the base of the middle phalanx with dorsal subluxation or dislocation, which will be the focus of this section.

The main concern of management is the stability of the joint. It is determined by the size of the volar fragment of the base of the middle phalanx and the degree of impaction of the remaining dorsal articular surface.\textsuperscript{19} If the volar fragment constitutes more than 40\% of the joint surface as seen on a lateral radiograph, it is likely that all or most of the lateral collateral ligaments are attached to it, thus leading to dorsal instability of the middle phalanx.\textsuperscript{19} Various surgical techniques have been described to treat this injury, reflecting the lack of a method that would predictably produce a satisfactory outcome.

McElfresh, Dobyns and O’Brien\textsuperscript{20} described the use of extension-block splinting as a treatment for dorsal fracture-dislocation of the PIPJ. They recommend the technique when the volar fragment involved is less than 30\% of the total articular surface. The angle at which the joint subluxates or dislocates is determined. A dorsal splint is incorporated in a forearm cast such that the PIPJ cannot extend to within 10° to 15° of the subluxation/dislocation angle (Fig. 4). Active flexion is allowed from the beginning. Serial reviews with radiographs are necessary to ensure that the reduction is maintained. Strong\textsuperscript{21} later described a modified splint based on the same principle. An alternative method using a K-wire effecting an extension block has also been employed with satisfactory outcomes\textsuperscript{22,23} (Fig. 5).
the central slip but proximal to the conjunction of the two lateral slips, and is then passed proximally across the PIPJ and into the head of the proximal phalanx. The finger is also protected with a splint. Newington et al recently reported the long-term results of ten patients who had undergone this operation. After a mean period of follow-up of 16 years, the average ROM was 85°, but a mild fixed flexion deformity was common. Radiographic examination showed subchondral sclerosis and minor narrowing of the joint space in some cases, but no advanced post-traumatic osteoarthritis was seen. Septic arthritis was not encountered.

Wilson and Rowland were the early proponents of ORIF. Their lateral approach involved routine detachment of the collateral ligament and the volar plate from their distal insertions. Only K-wire was available for fixation, and post-operative immobilisation was prescribed for at least three weeks. McCue et al similarly advocated the use of ORIF with the use of a transarticular wire to maintain reduction at 30° of flexion. At three weeks, the transarticular wire is removed and the finger splinted for another fortnight. In selected cases where there are large fracture fragments amenable to interfragmentary screw fixation (Fig. 6), ORIF may be employed early. It aims to restore articular congruence and achieve rigid fixation, thereby allowing immediate mobilisation. However, this is obtained at the price of further soft-tissue trauma, which may lead to adhesions and joint stiffness. Generally, a better ROM is achieved following acute ORIF than after delayed fixation. There is also a risk of persistent instability, especially when the ORIF is delayed.

An alternative to ORIF is volar plate arthroplasty, popularised by Eaton and Malerich. With this technique, small avulsion fragments are discarded, the subluxation/dislocation is reduced and the joint stabilised by attaching the volar plate to the volar lip of the distal articular surface (Fig. 7). Eaton and Malerich described their experience of the use of this technique over ten years in treating both acute and chronic fracture-dislocations of the PIPJ. A satisfactory outcome was usually achieved, but greater mobility was achieved in the acute cases. Remarkably, remodelling of the distal articular surface was often observed radiologically, and long-term follow-up of the patients showed satisfactory maintenance of pain-free function.

Numerous external fixators have been designed, but none has proved superior to the rest. These devices can be used to treat pilon fractures or any unstable injury of the PIPJ. Any dynamic external fixator relies on two key principles for its functioning, namely traction and mobilisation. Traction facilitates reduction of the fracture by capsuloligamentotaxis and simultaneously prevents shortening of the collateral ligaments, which can lead to joint stiffness. Likewise, mobilisation reduces the formation of intra- and peri-articular adhesions, and has been shown in an animal model to promote cartilage healing.

In 1946, Robertson, Cawley and Faris described the use of multiple skeletal traction maintained on a Banjo splint. The device uses three wires and three rubber bands to effect dorsal traction through the neck of the proximal phalanx, volar traction through the base of the middle phalanx, and axial traction through the neck of the middle phalanx (Fig. 8). All seven fractures treated were said to have united satisfactorily, achieving a good pain-free ROM. However, the device was in effect a static traction fixator. A year later, Quigley and Urist described the use of digital skeletal traction, in which a wire is fashioned into a fish hook and inserted into the dorsum of the middle phalanx. They realised the importance of mobilisation and insisted on active movement of the fingers during traction. The modern design by Schenck affords both traction and early passive mobilisation (Fig. 9). He treated ten patients and reported an average range of movement...
of 87° at a mean follow-up of 16 months. The Banjo system is effective, but has been criticised as cumbersome. The force couple splint, described by Agee, uses a linkage of three K-wires activated by a single rubber band. The base of the middle phalanx is levered volarly and the distal end of the proximal phalanx is lifted dorsally, achieving reduction (Fig. 10). It maintains concentric joint reduction while allowing early active movement. In Agee’s series of 16 patients the group obtained a mean range of movement of 83° after a mean follow-up of 21 months.

Fahmy described the Stockport Serpentine Spring System, commonly known as the ‘S’ Quattro. Distraction is achieved by two parallel or divergent wires connected by two serpentine springs (Fig. 11). Some degree of movement of the injured joint is possible because of the inherent elasticity of the system. Of the original series of 20 patients, 19 were said to be satisfied with their outcomes. Inanami et al designed a fixator consisting of a pair of rhomboid outriggers with two pulleys at both ends and a pair of arms with a pulley in the middle (Fig. 12). In their initial series of four acute and three malunited fractures, the former group achieved a mean active ROM of 95°, whereas the latter obtained 80° of movement. Only one patient experienced mild pain.

Suzuki et al designed a pins-and-rubber band traction system consisting of two or three wires and rubber bands (Fig. 13). The locations of the pins are identical to those used in the Robertson frame, but it is more compact than the Banjo system. The wires are named hook, reduction and axial traction pins, respectively. The contraction force of the rubber band is converted to an axial traction force between the hook and the axial traction pins, resulting in
distraction and secondary reduction of the fracture. The reduction pin lies volar to the axial traction pin, which effectively prevents dorsal displacement of the middle phalanx. It is critical to insert the most proximal pin through the centre of rotation of the joint to facilitate a complete ROM. However, the wires interfere, to some extent with the excursion of the extensor apparatus regardless of their positions. The Suzuki frame appears to have gained popularity, and several other groups have subsequently published their experience of its use. The majority obtained a mean total ROM of over 80°. However, a meticulous surgical technique and close follow-up are paramount in producing optimal results. The Compass hinge is a commercially available dynamic external fixator. It is a unilateral, hinged device that has a worm gear to allow controlled passive movement. Typically it has been used in combination with other open procedures. In a series of 20 patients, two pin-track infections, one deep infection, one loose implant, four recurrent subluxations and one resorption of the head of the proximal phalanx were reported. In another series of 20 cases, four pin-track infections, two pin breakages, one dislocation and one septic arthritis were seen. These may be a reflection of the complexity of the injuries, but the complication rates appear to be unacceptably high.

More recently, a new technique using a hemi-hamate autograft to reconstruct the base of the middle phalanx has been described. The damaged volar lip of the middle phalanx is replaced with a size-matched osteochondral graft transplanted from the distal dorsal portion of the hamate between the fourth and fifth metacarpals. The suitability of the graft, and donor site stability after harvest have been confirmed by a subsequent cadaver study. In the initial series of 13 patients, the mean articular involvement was 60% (40% to 80%). After a mean follow-up of 17 months, the authors reported a mean ROM of 85° at the PIPJ with 100% union rate. There were however two recurrent dorsal subluxations. This technique should be considered when extensive articular damage occurs or when stability of the joint cannot be achieved with other techniques.

The studies discussed so far are case series of patients treated by a particular technique. The numbers are often
small, including a heterogeneous group with both acute and chronic injuries. To our knowledge, no prospective randomised trial has been carried out comparing different modes of treatment for complex intra-articular injury to the PIPJ. Deitch et al.\(^5\) carried out a retrospective review of patients with an acute dorsal fracture-dislocation of the PIPJ, treated by either volar plate arthroplasty or ORIF. Three redislocations occurred in each group. All had volar fragments involving more than half of the articular surface. Only 43\% of the original group were available for long-term review, making meaningful conclusion difficult. Another single-institution retrospective analysis of patients who had been treated with a Suzuki frame *versus* those treated with a modified Banjo frame showed no significant difference between the two groups in terms of ROM gained and rates of complication.\(^5\)

**Post-traumatic osteoarthrosis**

O’Rourke, Gaur and Barton\(^57\) published an 11-year review of intra-articular fractures of the phalanges. The majority were said to be fairly minor, and only four of the 59 fractures were treated surgically. The potential for improvement and articular remodelling over time was noted. Subluxation and depression of the joint surface appeared to predispose to radiological evidence of arthritis, which occurred in ten patients (17\%), but only seven of them had symptoms. Aching of the joint in cold weather appeared to be a frequent complaint.\(^57,58\)

Owing to the lack of comparative studies, the surgical treatment of fractures of the PIPJ is still largely based on the experience and personal preference of individual surgeons. For the dorsal fracture-dislocation with a volar lip, if the volar fragment is less than 30% of the articular surface, we volar plate arthroplasty. For the dorsal fracture-dislocation with a volar lip, if the volar fragment is less than 30% of the articular surface, we volar plate arthroplasty.

**References**


