# PROXIMAL INTERPHALANGEAL JOINT

## Anatomy and its Clinical Implications

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The proximal interphalangeal joint (PIPJ) of the finger is a bicondylar hinge type of joint. Proper function of the PIP joint is important to normal hand function. Flexibility and stability of this joint are important in maintaining finger motion and hand function.

The PIPJ has the largest motion arc of the digital joints, normally from 0° to 120°. With a wide arc of motion, the PIPJ is responsible for 85% of total finger 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. Also, the unprotected position in the digit and its long moment arm make the PIP joint as one of the most susceptible joints to injury. PIP joint injuries are common among the general population and are more pronounced in sports persons especially those requiring catching a ball.

Normal PIPJ function depends upon adequate bony support, intact articular surfaces, and competent periarticular stabilizers. Damage to any of these critical structures resulting from trauma or other disease processes can lead to diminished joint motion and fixed contracture resulting in stiff fingers which will cause gross reduction in hand function. So, understanding of normal anatomy of PIP joint and its clinical implication is necessary in management of PIP joint injuries.

## Osseous anatomy

Osseous anatomy of PIPJ plays an important role in joint stability. It is composed of articulation between head of proximal phalanx and base of middle phalanx. The head of proximal phalanx has got trapezoidal configuration in axial plane (*fig.1*) divided by intercondylar groove that increases in depth from dorsal to volar. In sagittal plane the articular surface is tilted palmarly about 20 degrees[2]. On the lateral surface (*fig.2*) there is concave area proximo-dorsally from which the collateral ligament arise followed by flat area that extends to joint surface.

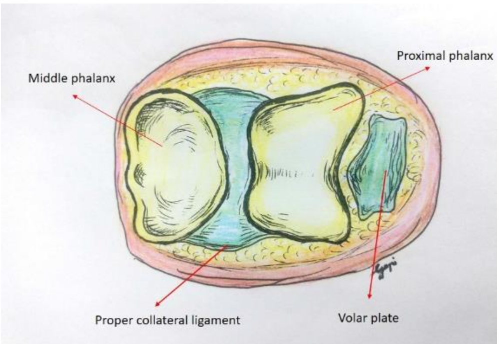


Fig 1. PIP joint anatomy as seen while performing a gunshot technique of exposure.

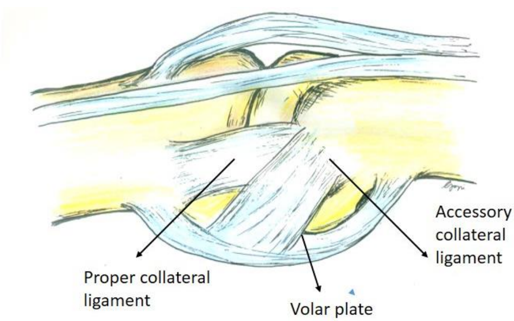


Fig 2. Lateral view of proximal interphalangeal joint.

The anatomy of middle phalanx shows imperfect congruence to that of proximal phalanx. In axial plane middle phalanx base is composed of two asymmetric concave ellipses separated by a median ridge that corresponds with the intercondylar groove of proximal phalanx (*fig.1*). This ***tongue-in-groove*** architecture provides resistance to axial rotation and translation forces acting on joint. The central slip of extensor mechanism is inserted to dorsal extent of median ridge. The rough surface on the volar side gives insertion to volar plate. The joint capsule gives its attachment to various small tubercles which are present on either side.

PIPJ is an inherently stable joint due to the anatomic structures that surround it.  The bony structure of the PIPJ permits flexion and extension in the sagittal plane behaving like a hinge[1]. However, due to asymmetry between the proximal phalangeal condyles, the middle phalanx rotates with flexion facilitating rotation of finger towards scaphoid tubercle[3] (*fig.3*). This characteristic property is due to slight anatomical differences in radial and ulnar condyles of proximal phalanx, i.e., index and middle finger ulnar condyle is prominent and ring, little finger radial condyle is prominent resulting in inclination of the articular surfaces of all the fingers in such a manner that the fingers point towards scaphoid when flexing (*fig.4*).

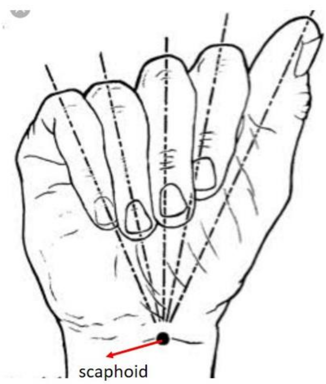


Fig 3.  Orientation of fingers on flexion pointing towards tubercle of scaphoid.

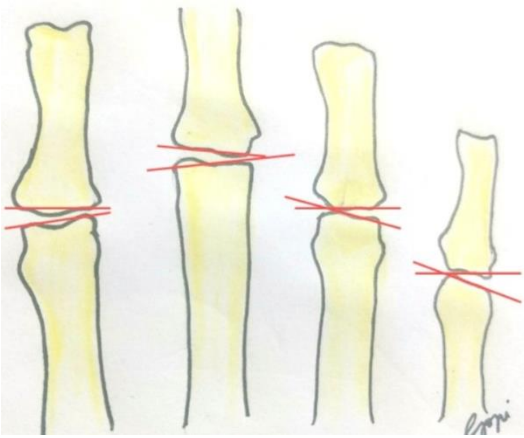

Fig 4. Dorsal aspect of right hand showing discrepancies in ulnar and radial condyles of proximal phalanx resulting in obliquity of joint line there by on flexion of joint result in rotation towards scaphoid.

The depth of concavities of middle phalanx depends on height of corresponding condyles of proximal phalanx. Overall there is approximately 64 percent contact surface area among the articular surface in this plane[2].

The idea of PIPJ being a 'true' hinge joint was negated by subsequent observations which demonstrated the incongruities at the articulation between the proximal and middle phalanx. The mismatch between the radius of curvature of the middle phalanx and the proximal phalanx creates 2 points of contact which are located central to the condyles of the proximal phalanx. This brings to the concept of "instantaneous rotational axis"[5]which lies on the line between the two centers of rotation (*fig.5*). As a result of this PIPJ has potential for motion in abduction as well as adduction, axial rotation, and sagittal rotation around the center of rotation of the condyles of the proximal phalanx as well as the center of rotation of the concavity of the middle phalanx. This means to say that PIP joint moreover behaves like the knee joint.

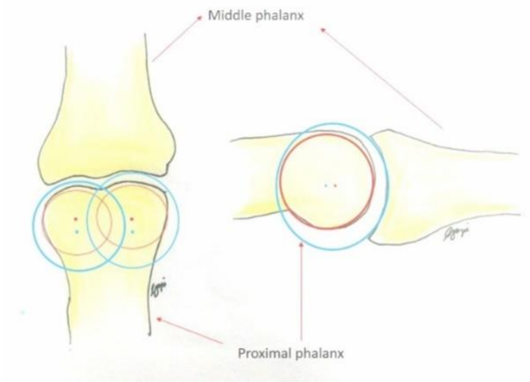


Fig 5. Showing differential centre of rotations of condyles of proximal and middle phalanx.

Further adding to the discrepancies the articular facet of the proximal phalanx facilitates 210 degrees of motion, whereas the middle phalangeal side encompasses approximately 110 degrees[4].
Due to asymmetry among condyles, bony structure alone cannot effectively stabilize the joint during motion. Hence, the surrounding soft tissues play an important role in joint stability.

## Soft tissue Anatomy

Soft tissue forms major stabilizer of PIPJ throughout its range of movement. A '3-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 strong dorsal support, as if it is surrounded by a 3-sided box (*fig.6*).

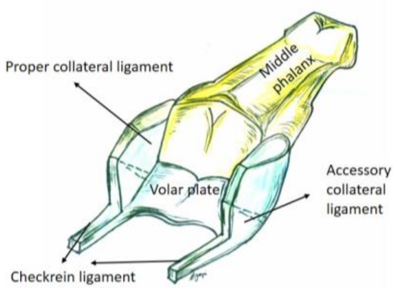


Fig 6. Showing '3- sided box analogy'.

The proper and accessory collateral ligaments (ACL) form the radial and ulnar walls of the box and prevent lateral deviation. The volar plate forms the base of the box and it mainly limit hyperextension of the joint. 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 provides the balance and facilitate motion of the joint.

Dorsal dislocation of the PIP joint requires that the volar plate and at least one of the collateral ligaments be disrupted and similarly volar dislocation of the PIP joint requires that the central slip and at least one of the collateral ligaments to be disrupted. Here, it is worth mentioning that the FDS tendon insertion is more distal on the middle phalanx when compared to volar plate, central slip and collaterals, thereby less prone to rupture. Any disruptions or incongruities to the intricate structure of the joint or its stabilizers may lead to abnormal joint mechanics resulting in wear and tear and eventually arthritis.

## Collateral Ligament Anatomy

The collateral ligament complex is composed of proper and accessory collateral ligament. It mainly contains type I and III collagen with type I predominating[3]. These laterally based ligaments span the proximal interphalangeal joint and form the main support against varus and valgus motion in different degrees of flexion.

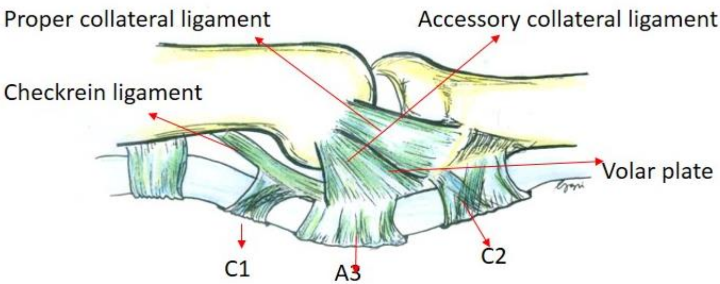


Fig 7. The orientation and anatomical details of collateral ligaments; checkrein ligament and its relation with the A3 pulley.

## Proper Collateral Ligament (PCL)

PCL is a cord like structure which has dorsal and volar fibers. Dorsal edge fibers are parallel to middle phalanx and volar edge are more oblique giving it a fan shape from origin to insertion (*fig.7*).

When viewed from superficial aspect the origin is broad, arising from the proximal and dorsal aspect of concave area (fovea). The insertion is into the entire lateral side of middle phalanx base. It does not insert on to the volar plate, but does extend close to it with clear separation between these two structures. Both origin and insertion is through Sharpey's fibers.

The dorsal and the volar parts of the PCL have differential gliding relative to each other, dorsal fibers become tauter during flexion and volar fibers are taut during extension. As a result of this, there is stability to joint against varus and valgus stress during entire range of motion (*fig.8*).

## Accessory Collateral Ligament

First described by Kaplan these are flimsy fibers that arises from volar aspect of PCL and oriented from dorsal to volar in oblique pattern and insert into the dorsolateral aspect of volar plate, deep to and contiguous with transverse retinacular ligament. The role of ACL is to suspend and stabilize volar plate and also serve to complete the joint capsule and act as a base for synovial lining. Because of its orientation these fibers taut on extension and relax on flexion.

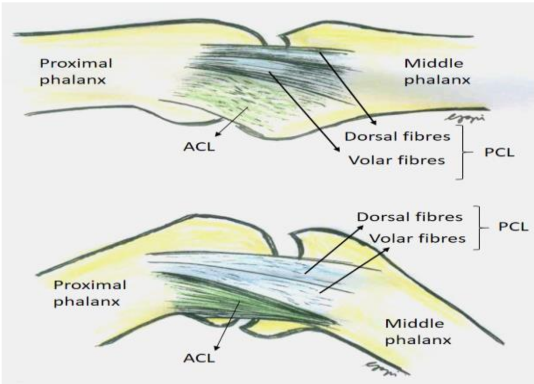


Fig 8. Showing orientation of collateral ligaments on PIP joint extension and flexion.

## Collateral Ligament Biomechanics and Its Clinical Importance:

The collateral ligaments serve as the primary stabilizers of varus and valgus stress. Leibovic and Bowers[7] demonstrated that the PCL is the primary stabilizer of the PIPJ in whole range of flexion, whereas the ACL and volar plate confer stability only from 0 – 15 degrees of flexion.

Chen et al[8] used 3D reconstruction of CT scans to study the change in length of ACL and PCL during flexion and extension. The dorsal portion of radial and ulnar PCL lengthens in flexion by upto 2mm at 90 flexion. This is believed to be due to passing of ligament over the condylar tubercles of proximal phalanx head. The volar portion of the PCL lengthens in extension in contrast to dorsal portion and shortens by 2.6 mm moving from extension to full flexion. This provide stability to joint in complete range of motion. ACL shortens by 3mm as finger goes from full extension to full flexion.

Minamikawa et al[9]in their serial studies have explained the importance of various structure around the PIPJ in maintaining lateral stability. Based on their cadaver study of PIPJ collateral ligament they observed:

1. With intact collateral ligaments there is 5 degrees of abduction and 9 degrees of supination throughout the entire arc of motion on lateral stress.
2. In case of complete transaction of collateral ligaments, the remaining ACL, volar plate, lateral band, and central slip can prevent lateral angulation under load.
3. As long as half of the PCL is intact the sectioning of all other stabilizers will not destabilize the PIPJ. The clinical importance is that while dealing with PIPJ contracture, during arthrolysis complete excision of ACL and palmar half of PCL will enhance ROM without destabilizing the joint.
4. **Lateral stress test**: Done in extension and 30 degree of PIPJ flexion. 10 degrees of lateral angulation in extension and 20 degrees in 30 degrees of flexion will indicated complete rupture of PCL. Beyond this degree of lateral angulation indicate injury to other stabilizers along with PCL.

The lateral stress can cause damage to the collateral ligaments and the injury could be in its mid-substance, at its proximal and distal attachment with or without a bony avulsion (Rhee et al)[11]. The disruption may also progress to the ACL and the attachment of volar plate at the middle phalanx.

Bowers[12] and colleagues developed the following grading system for classification of collateral ligament injuries:

**Grade 1**: Clinically 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 examination depicts a stable active arc of motion (AOM) and less than 20 degree of deviation with a firm end point on the lateral stress test.
**Grade 3:** Total collateral ligament disruption and volar plate rupture.
Clinical examination shows greater than 20 degree of joint laxity on lateral stress test with no firm end point.

By virtue of high intrinsic stability partial injuries would heal and don't require surgical repair. Furthermore, the collateral ligament may spontaneously heal itself over time and does not always require surgical correction.
Eaton and colleagues[11] also 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. Thus, open ligament repair should be reserved for only grade 3 collateral ligament injuries that require restoration of the volar plate integrity.

## Volar Plate Anatomy

The volar plate is a stout fibrous structure that spans the volar aspect of PIPJ. In other words it is basically thickening of volar joint capsule that contains predominantly of type 1 collagen. The volar plate forms gliding surface for overlying flexor tendons. Proximally, the attachment is broader which includes the membranous portion centrally made up of disorganized connective tissue and checkrein ligament laterally, forming a small opening in the midline permitting the nutrient artery to joint and flexor tendon (*fig.9*). Distally, it is more stout and fibrocartilaginous achieving the property of resistance to hyperextension. Proximally the checkrein ligament is attached to periosteum over the length and also to the flexor sheath at A3 pulley (*fig.7*) and distally it inserts directly into the bone. Bony adhesions of volar plate or contraction of checkrein ligaments can result in diminished range of motion and flexion contracture. In order to prevent this contractures the immobilization of fingers should be in PIPJ extension.

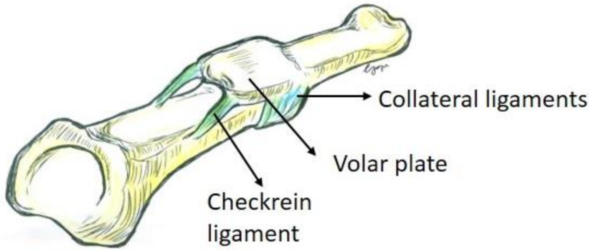


Fig 9. Anatomy of the volar plate and checkrein ligaments.

The function of volar plate is primarily to resist hyperextension at the proximal interphalangeal joint. Loaded cadaveric experiments by Bowers and colleague[12] have shown the radial digits to be more resistant to hyperextension compared to ulnar digits suggesting difference in the strength of volar ligamentous complex between fingers. Further, various studies have described that thickness of volar plate differs between fingers with the fifth finger having the thinnest central and lateral thickness compared to other digits. This has got clinical implication in PIP joint injuries where radial digits are more prone to fracture-dislocation whereas ulnar digits have more dislocations.

Recent studies have shown that the insertion of volar plate into middle phalanx is not uniform and is found to have a recess at the insertion site. With flexion, the volar plate slides proximally followed by its elevation by A3 pulley[4] through its attachment to checkrein ligaments (*fig.10)*. This allows the middle phalanx to roll into recess without impinging, allowing the volar plate to fall away from joint during flexion arc of motion. This recess creates fold like protrusion of volar plate like meniscus in the knee joint which acts a cushion between two articular surfaces. Proximally membranous portion of volar plate fold onto itself during flexion (*fig.10*).

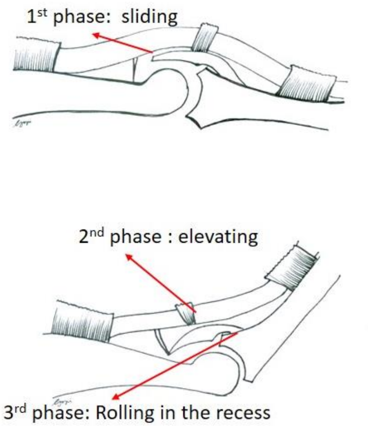


Fig 10. Showing 3 phases of volar plate motion there by allowing the middle phalanx to roll into recess without impinging.

Despite the abundance of knowledge we have regarding the anatomy of PIP our understanding of anatomy and biomechanical properties shall continue to evolve. As, better understanding of anatomy permits one to understand the injuries better and to deliver a more effective treatment. Also, knowing anatomical details better would allow surgeons to design better prosthesis for PIP joint which would fill the void in the management of the PIP joint pathologies.

## References

1. Sami H. Tuffaha, W.P. Andrew Lee, Treatment of Proximal Interphalangeal Joint contracture, Hand Clin 34 (2018) 229–235.

2. Nicholas M. Caggiano, Carl M. Harper, Tamara D. Rozental, Management of Proximal Interphalangeal Joint Fracture Dislocations, Hand Clin 34 (2018) 149–165.

3. James Jung, Brandon Haghverdian, Ranjan Gupta, Proximal Interphalangeal Joint Fusion Indications and Techniques, Hand Clin 34 (2018) 177–184.

4. Nathan P. Douglass, Amy L. Ladd, Therapy Concepts for the Proximal Interphalangeal Joint. Hand Clin 34 (2018) 289–299.

5. Eric Quan Pang, Jeffrey Yao, Anatomy and Biomechanics of the Finger Proximal Interphalangeal Joint. Hand Clin 34 (2018) 121–126.

6. Allison DM. Anatomy of the collateral ligaments ofthe proximal interphalangeal joint. J Hand Surg2005; 30(5):1026–31.

7. Leibovic S, Bowers W. Anatomy of the proximal interphalangeal joint. Hand Clin 1994; 10(2):169–78.

8. Chen J, Tan J, Zhang AX. In vivo length changes of the proximal interphalangeal joint proper and accessory collateral ligaments during flexion. J Hand Surg 2015; 40(6):1130–7.

9. Minamikawa I, Horii E, Amadio VC, Cooney WP, LinscheidRL,An KN. Stability and constraint of the proximal interphalangealjoint.J Hand Surg Am. 1993; 18(2):198e204.

10. Eaton RG, Sunde D, Pang D, et al. Evaluation of “neocollateral” ligament formation by magnetic resonance imaging after total excision of the proximal interphalangeal collateral ligaments. J Hand Surgery 1998;23(2):322–7.

11. Rhee RY, Reading G, Wray RC. A biomechanical study of the collateral ligaments of the proximal interphalangeal joint. J Hand Surgery 1992;17(1): 157–63.

12. Bowers W, Wolf J, Nehil J, et al. The proximal interphalangeal joint volar plate. I. An anatomical and biomechanical study. J Hand Surg Am 1980;5(1): 79–88.