INTRODUCTION

The proximal interphalangeal (PIP) joints of the fingers are extremely important for gripping things with hands, more specifically, what is called the 'power grip'. Being a hinge joint, the articular surface of the joint and the soft tissue do not permit any lateral movement. Its uniaxial nature allows only a good range of movement in one plane, relying on the more proximal metacarpophalangeal joint for a more varied range of motion such as adduction and abduction. The PIP joint is normally kept in alignment by a soft tissue envelope consisting of joint capsule, the volar plate, collateral ligaments and the central slip. These structures form a tight-fitting 'box' with a very narrow joint space ***(Can, 2007).***

The proximal interphalangeal (PIP) joint injuries are considered one of the most common injuries of the hand due to its rigid nature. The severity of such injuries can vary from a minor sprain to a complex intra-articular fracture ***(Can, 2007).***

PIP injuries are classified according to the fracture morphology and stability, and the involved portion of the articular surface. In addition, the amount of the articular surface involvement can be used to determine post-reduction joint stability. Consequently, the fractures of the proximal phalanx are classified into three types: Type (1) is a stable fracture without displacement, Type (2) is a unicondylar unstable fracture and Type (3) is a bicondylar or comminuted fracture ***(Kamnerdnakta et al., 2018).*** In addition, fractures could occur at the base of the middle phalanx involving either the volar lip, dorsal lip of the middle phalanx or pilon fracture ***(Blazar and Steinberg, 2000).*** However, the most common type of PIP joint injury is the volar lip fracture at the base of middle phalanx with PIP joint dorsal dislocation which is typically caused by the hyperextension or axial loading at fingertip during joint flexion ***(Hasting and Carroll, 1988).***

The injury of this highly valuable joint presents a significant surgical challenge. There is a relative difficulty in achieving both anatomical reduction and stable fixation enough to restore its function and facilitate early mobilization ***(Deitch et al., 1999).***

Thus, the main goals of any treatment plan for fracture-dislocation injuries of PIP should focus on maintaining concentric reduction of the subluxated or dislocated joint, restoring stability, facilitating early range of motion (ROM) exercises. Thus anatomic reduction of the articular surface must be performed whenever it is feasible. Good surgical outcomes could be achieved with good alignment and concentric reduction, even with imperfections of the articular surface. However, the studies showed that imperfections to the joint articular surface are not correlated with clinically relevant post traumatic arthrosis of the PIP joint and will not affect functional outcomes ***(Kiefhaber and Stern, 1998).***

The different modalities of PIP joint repair include dynamic traction method ***(Hirth et al., 2013),*** closed reduction and percutaneous K-wire fixation ***(Rex, 2015),*** open reduction and internal fixation ***(Giugale, 2017),*** volar plate arthroplasty ***(Lee, 2008),*** inter-positional arthroplasty with silicone ***(Adkinson and Chung, 2014),*** arthrodesis ***(Jacoby and Gaspar, 2016)*** and hemi-hamate arthroplasty ***(Korambayil and Francis, 2011).***

The postoperative complications for PIP joint injury may occur due to the complex anatomy of the joint, even after an appropriate treatment. The most common complications are joint stiffness and flexion contracture. Other complications include re-dislocation, posttraumatic arthritis, chronic swelling or even permanent functional loss. Unfortunately, underestimation of the severity of the injury by patients, health care providers can delay treatment and increase incidence of complications ***(Kamnerdnakta et al., 2018).***

There is no consensus about the best treatment modality for PIP joint injuries. Some studies indicated that post-treatment outcomes may return to a full range of motion (ROM) ***(Bindra and Colantoni, 2015),*** other studies indicated that the outcomes might be significantly improved with early intervention within the first four weeks of injury regardless of the treatment modality used ***(Khouri et al., 2013).***

Early diagnosis and restoration through concentric reduction must be done to facilitate early motion exercises, if feasible, for every injury to further diminish complications ***(Hogan and Nunley, 2006).***

AIM OF THE WORK

This study aims to compare the different surgical modalities of repair of intra-articular fractures of PIP joint.

Chapter 1

ANATOMY

The human hand is housing plenty of specialized structures including bones, joints, nerves, muscles and tendons. These structures are working in harmony producing the precise motor biomechanics and unique fine hand movements. The hand functions can be possibly affected by a wide range of conditions which either congenital or acquired. Nevertheless, a significant stiffness and loss of function can result from even minor traumatic injuries. Thus, proper knowledge of anatomy is needed for management of all hand conditions ***(Kjima and Viegas, 2009).***

Overview of the Functional Anatomy of the Hand

The hand architecture is formed of supporting skeletal framework and restraining ligaments. This makes the hand capable of performing various functions, and fine intricate movements in different and multiple planes. This specific construction imposes specific range of joint motions and also limitations on hand function ***(Chang et al., 2012).***

Hand Elements

The hand skeletal framework can be divided into four elements. The first element is the fixed unit of the hand which consists of the second and the third metacarpal bones with the bones of the distal carpal row. The second element is the thumb and its metacarpal bone which has a wide range of motion at its carpometacarpal joint [CMJ]. The positioning and activity of the thumb is specifically and strongly influenced by the action of the intrinsic and the extrinsic muscles. The third element includes the index finger which has independent action within the range of motion that its joints and ligaments allow. Index digital independence is also allowed by the intrinsic and extrinsic muscles. The fourth element is formed of the third, fourth, and fifth fingers with the fourth and fifth metacarpals. This unit works as a stabilizing vise to help grasping objects for manipulation by thumb and index. It can also work in concert with other hand units in a powerful grasp ***(Chang et al., 2012).*** Figure (1) shows the functional elements of the hand.

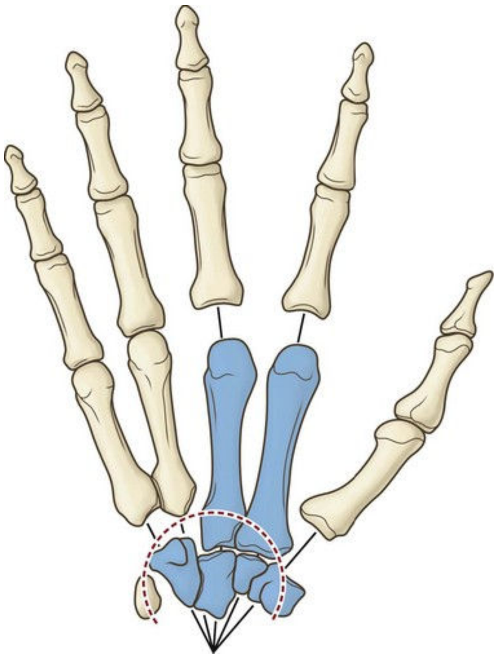

Figure (1): The functional elements of the hand ***(McCarthy, 1990).***

Bony Framework of the Hand

The bony framework of the hand consists of three groups of bones; eight carpals, five metacarpals (I to V), and fourteen phalanges ***(Landsmeer, 1976).*** Figure (2) shows the bony skeleton of the hand.

The Carpal Bones

They are small bones arranged in two rows; a proximal row and a distal row. Each consists of four bones. The proximal row of carpal bones -arranged from lateral to medial- consists of scaphoid, lunate, triquetrum, and pisiform. The distal row of carpal bones -arranged from lateral to medial- consists of trapezium, trapezoid, capitate, and hamate ***(Cohen, 1997).*** The carpal bones have numerous articular surfaces. All of them articulate with each other. The carpal bones in the distal row articulate with the metacarpals of the digits, while the proximal surfaces of the proximal row articulate with the radius and the ulna to form the wrist joint ***(Nakamura et al., 2001).***

All movements of the metacarpal bones on the carpal bones are limited except the metacarpal of the thumb which has a wide range of movement ***(Nakamura et al., 2001).***

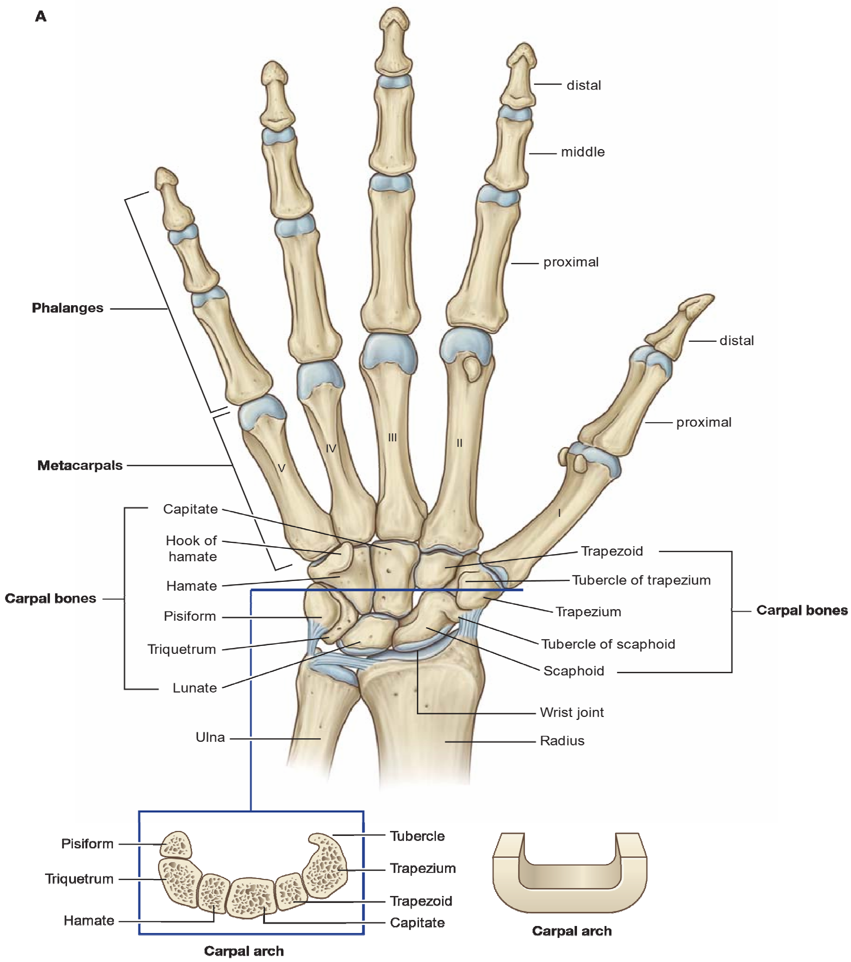

Figure (2): Hand and wrist joint bones ***(Gray et al., 1980).***

Metacarpals

Each of the five metacarpal bones is related to one digit, the first metacarpal is related to the thumb, the second to fifth metacarpals are related to the index, middle, ring, and little fingers, respectively. Each metacarpal bone consists of base, shaft, and head ***(Doyle and Botte, 2003).***

All of the the bases of the metacarpals articulate proximally with the carpal bones ***(Doyle and Botte, 2003).*** The carpal bones and metacarpals of the index, middle, ring, and little fingers (metacarpals II to V) tend to function as a unit and form much of the bony framework of the palm. The metacarpal bone of the thumb functions independently has increased flexibility at the carpometacarpal joint to provide opposition of the thumb to the fingers ***(Leversedge, 2008).***

The heads of the metacarpal bones articulate distally with the proximal phalanges of the digits. The heads form the knuckles on the dorsal surface of the hand when the fingers are flexed. In addition, the bases of the metacarpal bones of the fingers articulate with each other except for the first metacarpal ***(Doyle and Botte, 2003).***

Phalanges

The phalanges are the bones of the digits, the thumb has two phalanges; a proximal and distal phalanx, while the rest of the digits have three phalanges; proximal, middle, and distal phalanges. Each phalanx has a base, a shaft and a head. The base of each proximal phalanx articulates with the head of the related metacarpal bone forming the metacarpophalangeal joint [MPJ]. The head of each distal phalanx is non-articular, and it is flattened into a crescent-shaped palmar tuberosity lying under the palmar pad at the end of the digit ***(Doyle and Botte, 2003).***

Hand Joints

The hand is formed of multiple joints with different biomechanics working in harmony allowing the precise hand function. Hand joints include -from proximal to distal- the wrist, the inter-carpal joints, the carpometacarpal joints, the metacarpophalangeal joints, and the interphalangeal joint.

The wrist joint is a synovial joint between the distal end of the radius and the articular disc overlying the distal end of the ulna, and the scaphoid, lunate, and triquetrum. The articular surfaces of the carpals form together an oval shape with a convex contour, which articulates with the corresponding concave surface of the radius and articular disc. The wrist joint allows movement around two axes. Thus, the hand can be abducted, adducted, flexed, and extended at the wrist joint. Nevertheless, the capsule of the wrist joint is reinforced with multiple ligaments ***(Kjima and Viegas, 2009).***

The inter-carpal joints are synovial joints between the carpal bones sharing a common articular cavity. The capsule of such joints is reinforced by numerous ligaments. Although movement at the inter-carpal joints is limited, they do contribute to the positioning of the hand in abduction, adduction, flexion and particularly extension ***(Cohen, 1997).***

The carpometacarpal joints are located between the metacarpal for each finger and the related distal row of carpal bones. The carpometacarpal joint of the thumb is located between the first metacarpal and the trapezium. It is a saddle joint allows a wide range of mobility to the thumb that is not a feature of the rest of the digits. The movements at this first carpometacarpal joint are flexion, extension, abduction, adduction, rotation, and circumduction ***(Kuczynski, 1974).***

The metacarpophalangeal joint located between the distal heads of the metacarpals and the proximal phalanges of the fingers are condylar joints allowing flexion, extension, abduction, adduction, circumduction, and limited rotation. Thus the second to fifth MCPs are much less mobile than the first MCP allowing only limited gliding movements ***(Kuczynski, 1974).*** The capsule of each MCP is reinforced by the palmar ligament and by medial and lateral collateral ligaments ***(Wise, 1975).***

The interphalangeal joints of the hand are hinge joints that allow mainly flexion and extension. They are reinforced by medial and lateral collateral ligaments and volar plate ***(Kuczynski, 1968).***

Muscles of the Hand

The muscles of the hand are divided into intrinsic and extrinsic groups. The intrinsic muscles are located within the hand itself, whereas the extrinsic muscles are located proximally in the forearm and insert to the hand skeleton by long tendons ***(Sahin and Seelig, 2001).*** The extrinsic muscles include the long flexors and extensors, while the intrinsic muscles include thenar, hypothenar, lumbricals and interossei muscles ***(Standring et al., 2006).***

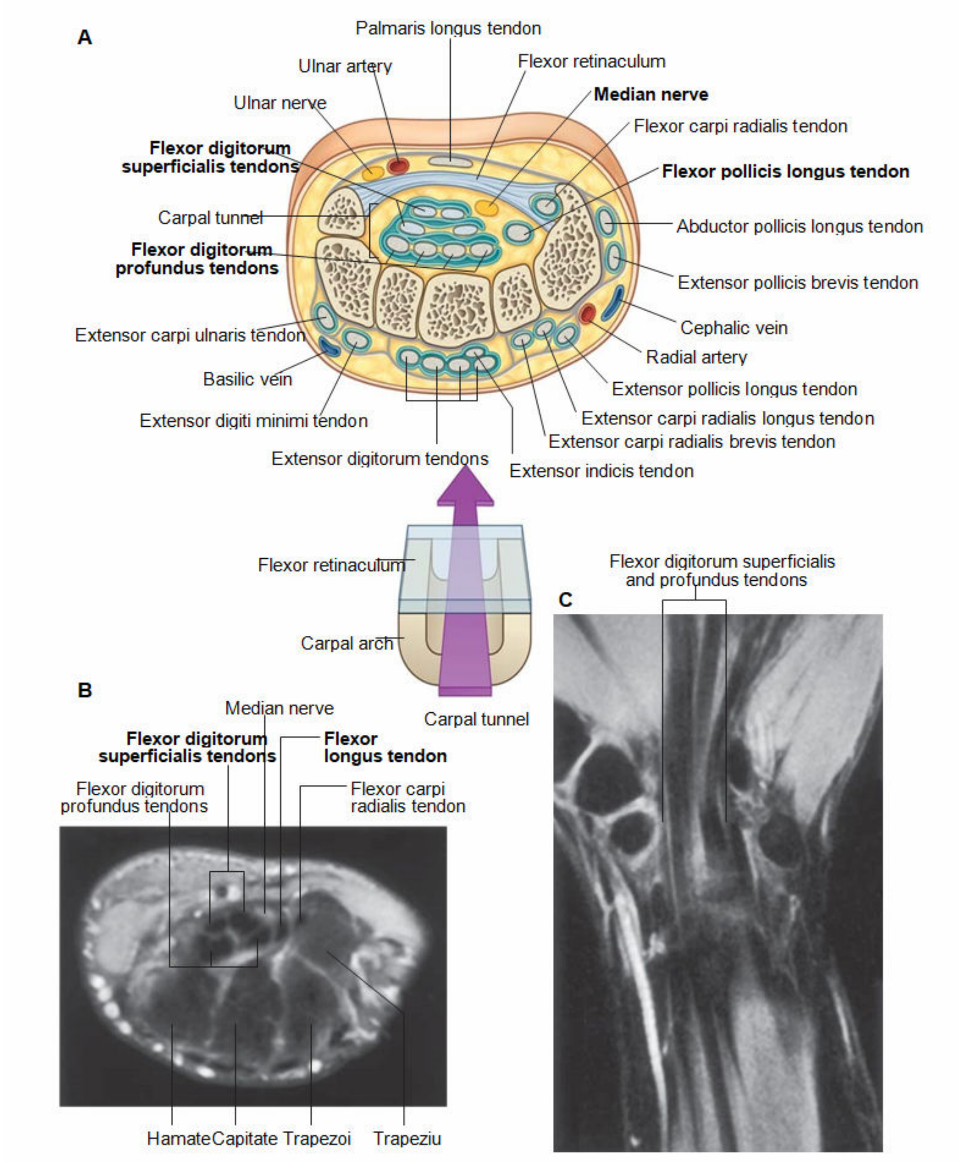

Figure (3): Carpal tunnel. A. Structure and relations. B. Magnetic resonance image of a normal wrist in the axial plane. C. Magnetic resonance image of a normal wrist in the coronal plane ***(Gray et al., 1980).***

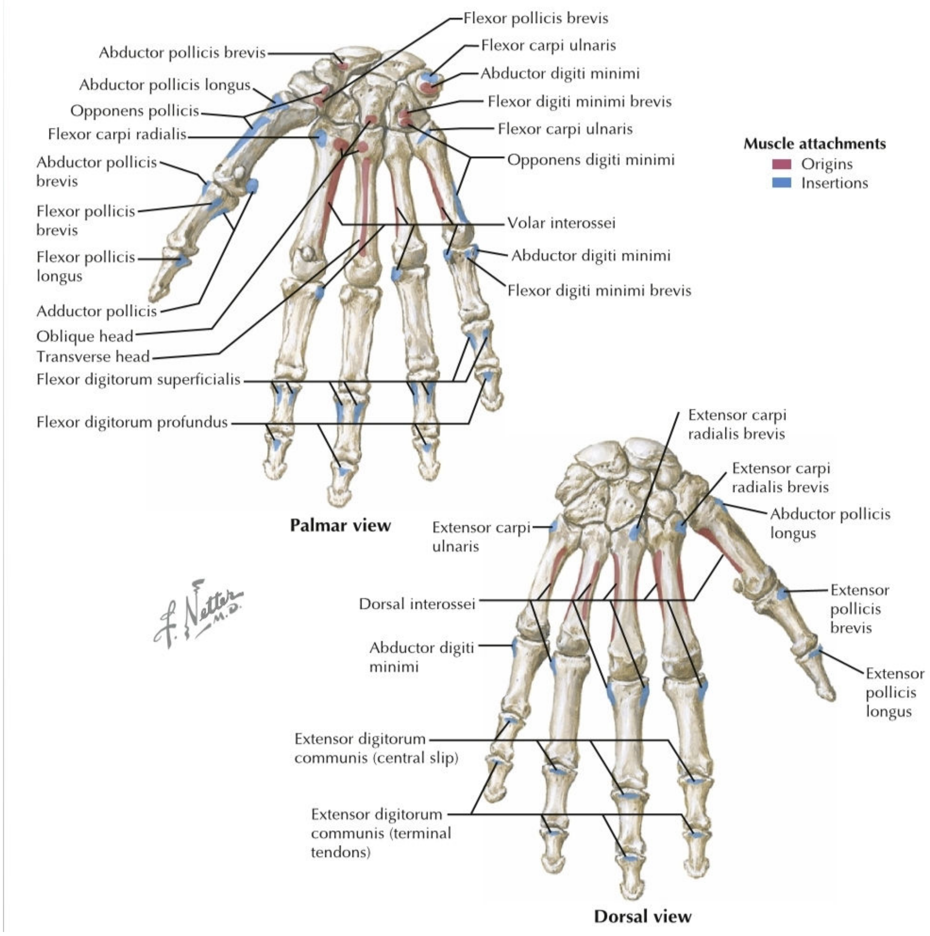

Figure (4): Attachments of intrinsic and exterensic muscles in the hand ***(Gray et al., 1980).***

Arteries and veins

The blood supply to the hand is via the ulnar and radial arteries. The ulnar artery enters the hand via Guyon's canal between the pisiform and the hook of the hamate. It continues as the superficial palmar arch, which gives rise to the common palmar digital arteries, which later bifurcate at the web spaces to form the proper palmar digital arteries. On the other hand, the deep palmar arch is a continuation of the radial artery, which gives arise to the palmar metacarpal arteries and form anastomoses with the common palmar digital arteries (Fig. 5). Blood supply to the dorsum of the hand typically originates from the posterior and anterior interosseous arteries, that later arise from the ulnar artery and are not major sources of blood supply to the hand. The superficial and deep palmar arches are accompanied by corresponding venous arches. The dorsal digital veins unite to form a dorsal venous network in the superficial fascia of the hand, which drains proximally into the lateral cephalic vein and medial basilic vein ***(Landsmeer, 1976).***

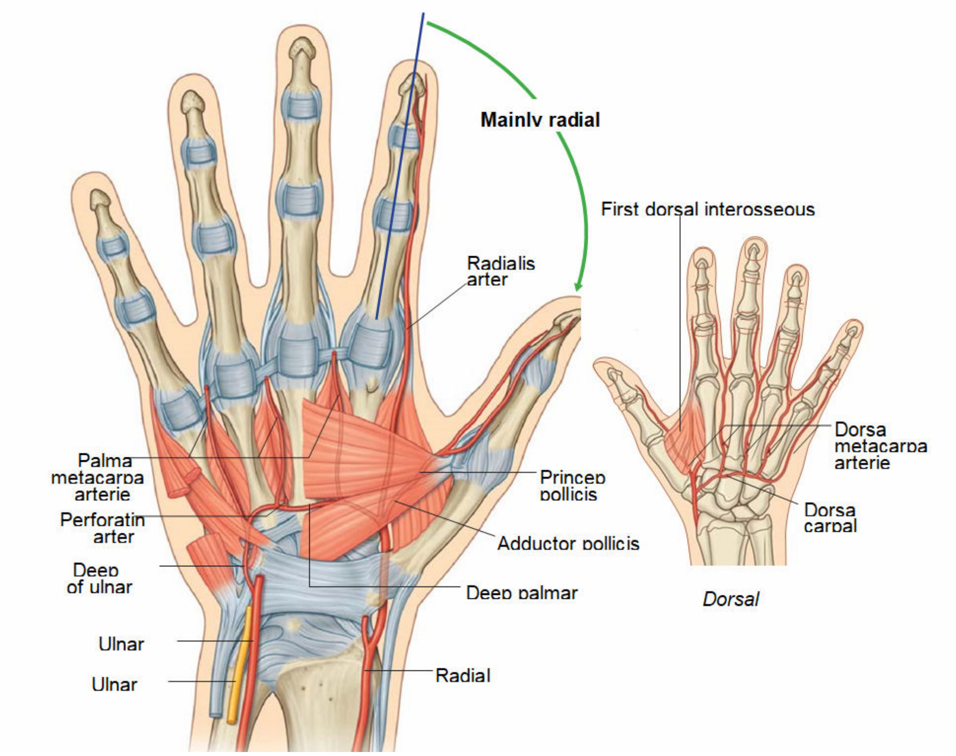

Figure (5): Deep palmar arch ***(Gray et al., 1980).***