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Original article

Fracture dislocation of the proximal interphalangeal joint

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ABSTRACT. ***Introduction:*** **the proximal interphalangeal (PIP) joint is the most commonly dislocated joint in the body and the hand. We did a review of the literature and report herein our experience treating this condition at the ABC Medical Center from 1991 to 2007.** ***Material and methods:*** **systematic review of the literature. Retrospective and descriptive study.** ***Results:*** **a total of 13 patients were included between 1991 and 2007. Three of them were managed with ORIF with Kirschner nails, 3 with OR and Kirschner nails blocking extension, 2 with plasty with volar plate interposition, and one with CRIF with a Kirschner nail. Mean follow-up was 4.8 months in 8 patients, the ranges of motion were recorded. The following factors were negatively correlated with the range of motion: age, time elapsed between the injury and the treatment, the combined approaches, and the pins blocking extension. Those treated with interposition arthroplasty had a better range of motion.** ***Conclusion:*** **the fracture dislocation of the PIP joint is a rare pathology with multiple treatments and variable outcomes that usually result in the limitation of flexion and extension.**

Key words: fracture dislocation, treatment, interphalangeal joint.

RESUMEN. ***Introducción:*** **La articulación más comúnmente luxada en el cuerpo humano y en la mano es la interfalángica proximal (IFP) por lo que se hizo una revisión de la literatura y se reporta la experiencia en el tratamiento de esta patología en el centro médico ABC entre 1991 y 2007.** ***Material y métodos:*** **Revisión sistemática de la literatura. Estudio retrospectivo y descriptivo.** ***Resultados:*** **Entre 1991 y 2007, 13 pacientes son los que se incluyeron, tres fueron manejados mediante RAFI con clavos Kirshner, tres mediante RA y colocación de clavos Kirshner de bloqueo de extensión, 2 con plastía por interposición de placa volar y uno con RCFI con clavo de Kirshner. Ocho tuvieron un seguimiento promedio de 4.8 meses, registrando los arcos de movimiento. Los factores que se correlacionaron negativamente con el arco de movimiento fueron: la edad, el tiempo entre la lesión y el tratamiento, los abordajes combinados y los clavos de bloqueo de extensión. Los tratados con artroplastía por interposición tuvieron mejor arco de movilidad.** ***Conclusión:*** **La fractura-luxación de la articulación IFP es una patología rara con múltiples tratamientos y con resultados variables que generalmente provocan una limitación de la flexo-extensión.**

Palabras clave: articulación interfalángica proximal, fractura-luxación, tratamiento.

Introduction

The most commonly dislocated joint in the human body, and therefore in the hand, is the proximal interphalangeal (PIP) joint.[1-3] The severity of the injury is usually underestimated, which results in inappropriate treatment and long term morbidity. The spectrum of the pathology ranges from a simple sports injury treated on site by the patient himself all the way to irreducible fracture dislocations.[1,4,5] The direction of the dislocation is usually dorsal, but lateral or volar dislocations may also occur.[3,4-6] There are also reports of simultaneous dislocations of the PIP and distal interphalangeal (DIP) joints.[7,8]

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Eaton has classified the PIP dislocations according to specific patterns of the ligament and bone injuries. Types I to IIIA represent injuries that are stable after being reduced. Type III injuries involve a fracture; however IIIB injuries involve a fracture or impaction of more than 40% of the articular surface, turning it unstable. The volar plate and the collateral ligaments are not attached to the middle phalanx, so closed reduction becomes almost impossible.[1]

The PIP tends to become stiff after trauma or immobilization due to pain, instability, and capsular and ligament fibrosis. Immobilization for more than 3 weeks may result in permanent loss of mobility, so early mobilization is essential; to this end, the surgeon must determine when the joint is stable enough.[9]

The purpose of surgical treatment is to reduce the middle phalanx and restore the broken articular surface. Surgical options include skeletal traction, static or dynamic external fixation, dynamic traction with passive movement, dynamic traction with active movement, volar plate interposition arthroplasty, closed reduction with intraarticular fixation with Kirschner nails, and open reduction and internal fixation with or without bone grafting.[11-25] Regardless of the treatment used, the reported complications include limitation of extension, limitation of flexion, instability with recurrent dislocation, residual pain and functional disability.[26]

Anatomy and biomechanics

The PIP structure is closely related to its function. It is much more than a simple hinge. The PIP is located exactly between the finger tip and the metacarpophalangeal joint, which turns it into the functional and anatomical base of the finger. It is estimated that the PIP joint provides 85% of the finger movement upon grasping an object, while the DIP joint contributes with 15%. The former is evident given that the arthrodesis of the DIP joint is much better tolerated than arthrodesis of the PIP joint.[27]

The articular surface of the proximal phalanx is bicondylar. The condyles are separated by a groove. On either side of the head of the proximal phalanx there are crests and clefts from where the collateral ligaments originate. Underneath them there are flat surfaces that are also attachments of the collateral ligaments, besides providing them with a sliding surface during flexion and extension. The hyaline cartilage covers 210° of the head of the proximal phalanx.[1,11]

The articular surface of the middle phalanx is biconcave and has an intercondylar crest. It has a 110° hyaline cartilage arch that at times extends all the way to the volar surface of the phalanx base. The base of the middle phalanx has widened margins and its volar aspect is wider than its dorsal aspect. On either side of the base there are two crests where part of the collateral ligaments attach. In the dorsal margin there is another widened area that corresponds to the attachment of the central band of the extensor apparatus. The proximal articular surface of the middle phalanx is almost completely congruent with the proximal phalanx surface. This congruence provides stability to the PIP joint, particularly when it is subjected to an axial load *(Figure 1)*.[11]

The PIP joint has a 120° flexion-extension motion arch which makes it the most mobile one of the fingers. It also has a certain rotation motion that, in the case of the index finger, has 9° of supination according to Minamikawa.[28] Collateral ligament contracture due to prolonged or inappropriate immobilization limits this range of motion.

The main ligament structures of the PIP joint are the volar plate and the proper and accessory collateral ligaments. There is no true articular capsule. The proper collateral ligaments are 2-3 mm thick and originate in the concavities of the proximal phalanx lateral surface; their trajectory is volar with respect to the flexion axis and they attach to one tubercle of the lateral and volar aspect of the middle phalanx on its two volar thirds. The accessory collateral ligaments have a volar origin with respect to the proper collateral ligaments and extend like a fan to attach themselves to the volar plate and the flexor tendon sheath. These ligaments are stressed during extension and maintain the volar plate in close contact with the joint.

The volar plate is a fibrocartilaginous structure forming the floor of the joint. Its dorsal aspect is covered by synovium and its volar aspect forms the floor of the flexor sheath. It is thicker distally (0.5 – 2.5 mm), where the middle phalanx has a low bone density; the volar plate collagen fibers are transversally oriented so this constitutes the failure site under hyperextension and longitudinal tension. Laterally,

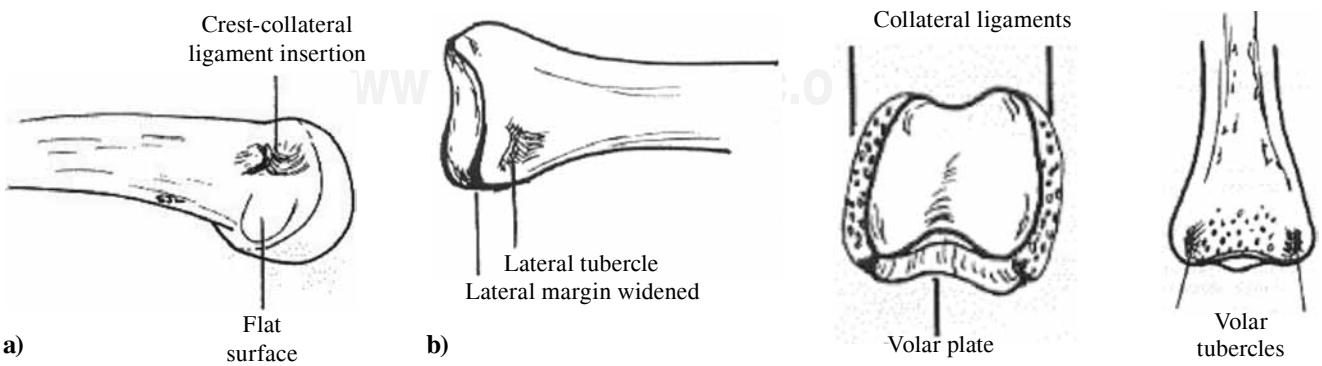

Figure 1. Bone anatomy.

the volar plate receives inputs from the collateral ligaments and represents the thinnest central portion. The central attachment of the volar plate in the middle phalanx is distal to the proximal margin thus creating a true articular recess.

This allows the volar plate to bend during flexion.

The central part of its proximal portion is thin. Its lateral borders are formed by the «checkrein» ligaments, which are ligament structures originating in the periosteum of the proximal phalanx, from the distal margin of the second annular pulley (A2) to the proximal border of the first cruciform pulley (C1), which is a continuation of such ligaments.[29]

The central band of the extensor apparatus attaches to a tubercle of the middle phalanx dorsal margin. The lateral bands of the extensor apparatus cross the PIP joint, where they are stabilized by the transverse retinacular ligament which prevents their dorsal dislocation. The flexor digitorum superficialis attaches in the lateral and volar margins of the middle phalanx, distal to the volar plate, after having split forming Camper's chiasm. The flexor digitorum profundus crosses the DIP joint at its central and volar portion remaining inside its sheath.[11] The volar plate separates the flexor tendons from the flexion axis thus increasing its lever arm 25%.[29]

The volar plate is the main stabilizer in extension, while the proper and accessory collateral ligaments resist the movements on the coronal plane.[30] The flexor and extensor tendons are secondary stabilizers of the PIP joint upon supporting the axial articular load. The «checkrein» ligaments resist hyperextension and guide the bending of the volar plate during flexion allowing an appropriate arch of motion to occur with articular stability. The continuation of the «checkrein» ligaments with the proximal aspect of the C1 pulley suggests a dynamic mechanism of the volar plate tension exerted by the flexor tendons *(Figure 2).*[29]

Overall, the volar plate and the collateral ligaments form a box-shaped structure that provides stability and motion occupying a limited volume. For a PIP joint dislocation to occur, this structure has to break in two planes, that is, at least one collateral ligament and the volar plate must be torn.[1,30,31]

Mechanism of injury and classification

The mechanism of injury of the dorsal PIP joint dislocation is hyperextension with some degree of axial load. In most cases an injury in the distal aspect of the ligament complex occurs, which has been confirmed by Bowers in clinical and cadaver studies.[32] On rare occasions the volar plate breaks close to its proximal attachment, which makes it stand between the proximal and middle phalanges thus preventing closed reduction. The presence of a greater axial load component during the injury increases the chance of fracture of the middle phalanx lower border.[1,29] The dorsal displacement of the middle phalanx produces specific injuries to the ligament system, which have led to the classification of dorsal PIP joint dislocations proposed by Eaton.[1,11] Type I is a hyperextension injury with avulsion of the volar plate, longitudinal tear of collateral ligament and a joint that remains in contact. Type II is a dorsal dislocation with avulsion of the volar plate and a cross-sectional and complete tear of collateral ligaments. The base of the middle phalanx rests on the condyles of the proximal phalanx without articular contact. Type IIIA is a stable fracture dislocation with the fracture involving less than 40% of the articular surface and with the dorsal portion of the collateral ligament remaining attached to the middle phalanx. Type IIIB involves a fracture or impaction of the articular surface of more than 40%. The volar plate and the collateral ligaments are not attached to the middle phalanx, so closed reduction becomes almost impossible[1] *(Figures 3-5).*

Assessment

One should question the patient as to the time course of the injury, the mechanism of injury, whether previous reduction attempts were made, and the initial direction of the deformity.

Upon inspection one should note the deformity, swelling and skin injuries. Stability should be actively and passively assessed. If necessary, this should be done under a regional block.[33] While assessing active stability, the patient should be asked to move the finger through its entire range of motion. If the PIP joint does not dislocate again, this means that

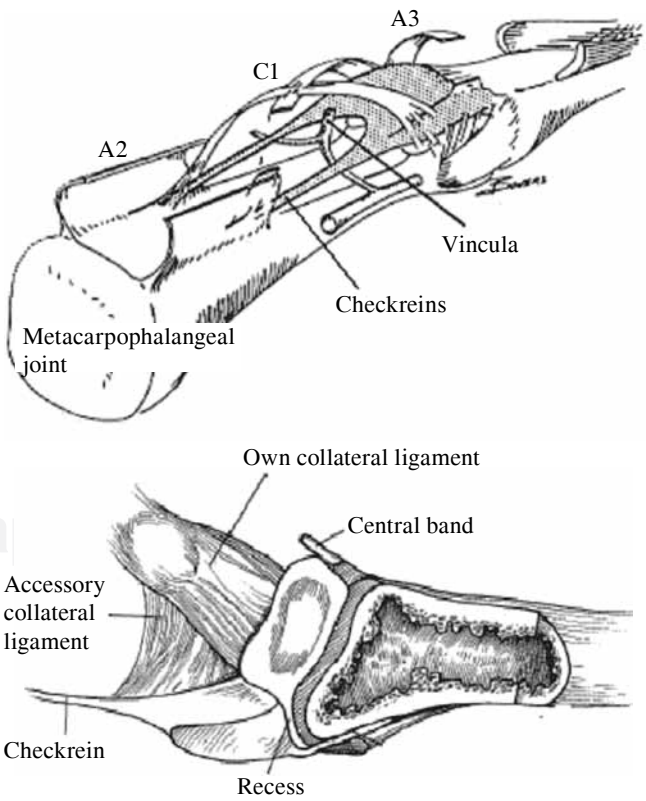

Figure 2. Ligament anatomy.

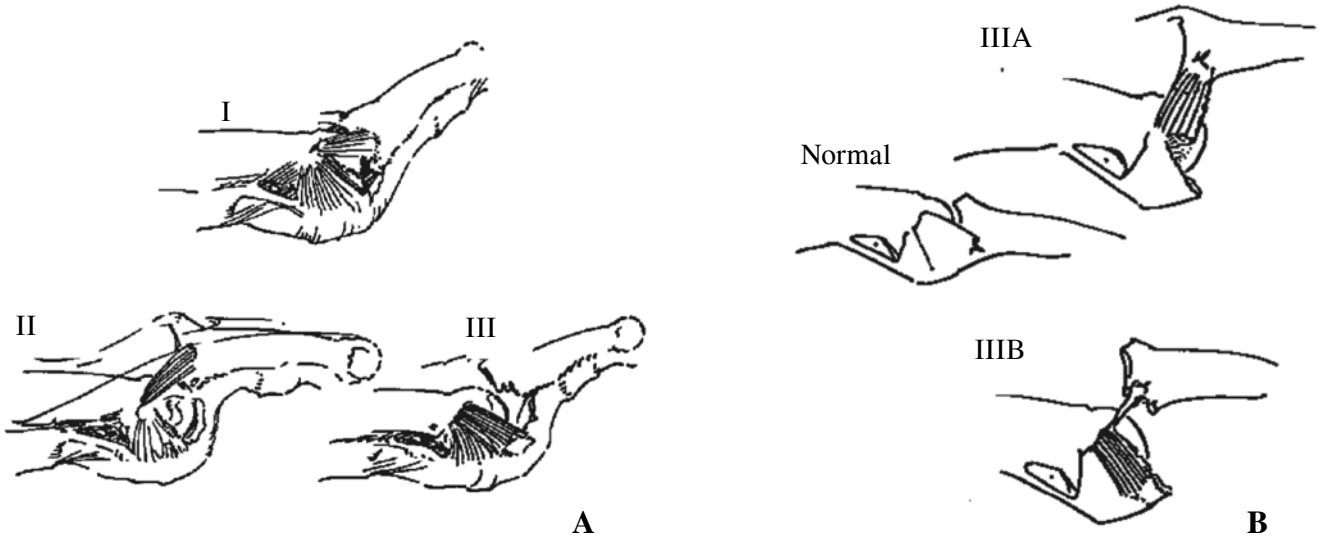

Figure 3 A. Eaton classification, **3B**: PIP joint fracture dislocations according to Eaton.

Figure 4. Eaton IIIA.

Figure 5. Eaton IIIB.

there is stability despite the ligament tear. In the opposite case there is a substantial reduction of the ligament complex. In assessing passive stability, lateral motions are done to test each collateral ligament and a shearing stress is applied in the anteroposterior plane to test the volar support.[10]

Radiologically, two orthogonal views are required; it is essential that one of them be a true lateral view. Fluoroscopy is useful to assess post-reduction stability.

Treatment

Type I and II dislocations are usually reducible and are treated by means of closed reduction under nerve block followed by a splint or nail to block extension.

In the case of dislocations with a fracture, one must distinguish between the stable (IIIA) and the unstable (IIIB) variety. Most types IIIA are reducible and are treated like types I and II. Type IIIB injuries are unstable, occasionally irreducible, and warrant surgical treatment.[1,11]

The purpose of surgical treatment is to reduce the middle phalanx and restore the broken articular surface. The surgical options include skeletal traction, static or dynamic external fixation, dynamic traction with passive motion, dynamic traction with active motion, volar plate interposition arthroplasty, closed reduction with intraarticular fixation with Kirschner nails, and open reduction and internal fixation with or without a bone graft.[11]

Newington et al. reported a series of 10 patients with type IIIB fracture dislocations treated with open reduction and intraarticular fixation with Kirschner nails, with a 16-year follow-up. Seven patients reported no pain and none had severe pain. There was one contracture in a mean of 8° of flexion with an 85° range of motion. No patients had relevant degenerative changes. The authors concluded that this is a reliable method to treat these injuries and that it produces good long-term outcomes.[12]

Open reduction and internal fixation is only possible when the fragments are large enough to allow for a secure fixation. Weiss reported good outcomes in 12 patients treated with cerclage. Eleven of the 12 patients did not show any degenerative changes during a mean follow-up of 2.1-years. The mean range of motion was 89° with an extension lag of 8°. There were no infections or failure of the osteosynthesis material and there was no need to remove the material due to irritation. This method requires less devitalization of the bone fragments and causes less soft tissue damage.[13]

Williams reports a 100% healing rate in 12 patients with fracture dislocations involving more than 50% of the articular surface treated with autologous hamate bone graft and fixed with interfragment screws. In the technique he describes, the proximal articular surface of the middle phalanx is replaced with a graft taken from the dorsal and distal

portion of the hamate bone. The mean range of motion was 86°. Eleven of the 12 patients reported being very pleased with the result.[14]

Green used interfragment screws with a palmar approach through the volar plate. The two patients treated with this technique had complete healing at the one-year follow-up, with ranges of motion of 0-105° and 5-95°, respectively. He suggests that the screws provide a more stable fixation than the Kirschner nails, and that a greater range of motion is obtained as the collateral ligaments are not incised.[25] Hamilton et al. mention that open reduction and internal fixation (ORIF) should be used only when the fracture fragments are large enough. This treatment allows for early mobility; however, 8 of the 9 patients had a flexion contracture with a mean of 14°.[34] To achieve a stable fixation even in comminuted cases, Chew and Cheah used a plate that served as a shelf with good results in one patient.[35]

ORIF may be associated with complications like loss of motion, infection, chronic instability and degenerative arthritis.[11] External fixation with reduction by means of distraction and ligamentotaxis has the biologic advantages of preserving the blood supply to small articular fragments and allowing for early mobilization, when compared with ORIF.

Multiple forms of dynamic or static external fixation have been described.[18-22,36] Among them, the one reported by Suzuki has become the most popular one.[15] De Smet conducted a study of 8 patients with DIP joint fracture dislocation treated with the Suzuki method. The extension deficit was 9.9°, total flexion was 91°, reduction was maintained and no patient reported osteoarthritis during a 16.5-month follow-up.[16] Deshmuck modified the Suzuki system to prevent rubbing between the nail and the bone thus avoiding osteolysis. In his 13-patient series he achieved 85° of motion and 92% strength, compared with the contralateral finger, and no cases had osteolysis or osteomyelitis.[17] Badia et al. in turn, modified the system to prevent the use of rubber bands, proposing that this would make it more reproducible. They reported good outcomes in 6 patients.[37]

The volar plate interposition arthroplasty was described by Eaton and Malerich, and consists of advancing the volar plate to the defect created by the fracture fixing it to the dorsum of the middle phalanx with a pull-out suture.[23] Dionisian reported 17 patients treated with volar plate interposition arthroplasty, with an 11.5-year follow-up; a mean range of motion of 85°was obtained at less than 4 weeks after surgery. Patients in whom arthroplasty was delayed for more than 4 weeks had a range of motion of 61°. Two patients had decrease of the articular space.[24]

Regardless of treatment, all authors coincide in the importance of early mobilization to promote the nutrition of the injured tissues and cartilage repair, and to avoid fibrosis and joint stiffness.[38]

Complications include recurrence, flexion contracture, limited range of motion, DIP joint stiffness and arthrosis.[26] The angular deformity may occur in cases of volar plate interposition arthroplasty, and infection is a complication of external fixators.[11] Boutoniere deformity is a complication described by Fernández in the dislocations and various PIP joint traumas.[39]

Case series

Thirteen patients (8 males, 5 females) with a diagnosis of PIP joint fracture dislocation were included; they were treated at Centro Médico ABC between 1991 and 2007. Most of the injuries involved the right hand (76.9%) and the ring finger was the most affected one. Ten of the fracture dislocations (76.9%) were IIIB.

Among 9 available patients, 3 were managed with open reduction with Kirschner nails (33.3%) *(Figure 6)*, 3 with open reduction and placement of Kirschner nails to block extension (33.3%) *(Figure 7)*, 2 with plasty by means of volar plate interposition (22.2%), and one with closed reduction and internal fixation with a Kirschner nail (11.1%) *(Figure 8)*.

Table 1 shows the descriptive statistics of the quantitative variable results (available for 7 patients). One may see the great variability that exists in virtually all population variables, particularly in the time elapsed between the injury and its management and follow-up.

It was found that the older the age and the longer the time elapsed before treatment, there was less flexion and more limitation of extension, without a statistically significant

Figure 6. ORIF.

Figure 7. Extension-blocking nails.

correlation. Patients with a palmar approach had the greatest mean range of motion, with 85° (100°-15°), followed by the case treated with closed reduction, with 80° (90°-10°). The patient treated with the dorsal approach had the smallest range of motion of 55° (67.5°-12.5°) *(Chart 1)*.

Patients treated with volar plate interposition arthroplasty had the greatest mean range of motion of 90° (110°-20°) and those treated with extensor blocking nails had the smallest of 63.4° (75°-11.6°) *(Chart 2)*.

Patients with type IIIB fracture dislocations had a greater mobility, 78° (94°-16°) than IIIA patients, who had 66.6° (81.6°-15°) *(Chart 3)*.

Figure 8. CRIF.

Table 1. Descriptive statistics.

	Minimum	Maximum	Mean
Age	24	62	46.42
Time between injury and management (days)	3	120	42.71
Follow-up period (months)	1	14	4.85
Flexion °	45	110	89.37
Limitation of extension °	5	30	15.62

A patient treated with volar plate interposition arthroplasty had persistent pain and had to be reoperated to resect a dorsal neuroma.

Finally, gender and the mechanism of injury were not related with joint mobility.

Discussion and conclusion

The demographic variables of this study were similar to those reported in other papers. This means that males were predominant (61.5%), the ring finger was the most commonly affected (69.2%) and falls, together with sports injuries, were the most frequent mechanisms of injury (46.2%).[1,11,40,41]

As expected, we found that the older the age, the lesser the total flexion and the greater the extension limitation, but this was not statistically significant. Likewise, the time

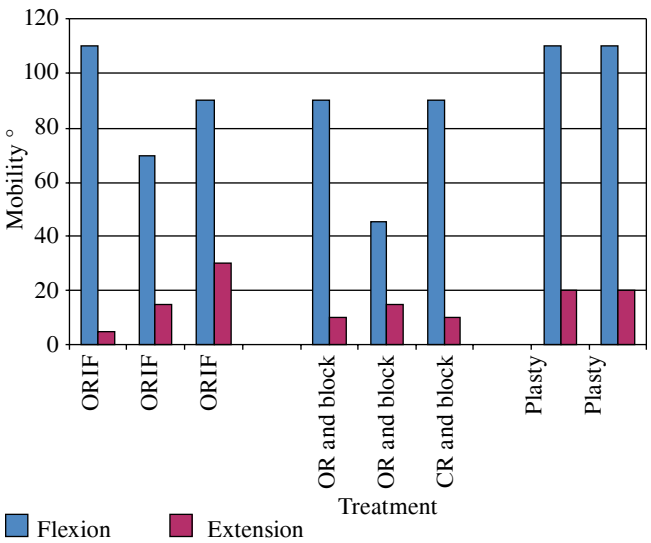

Chart 2. Treatment and Mobility

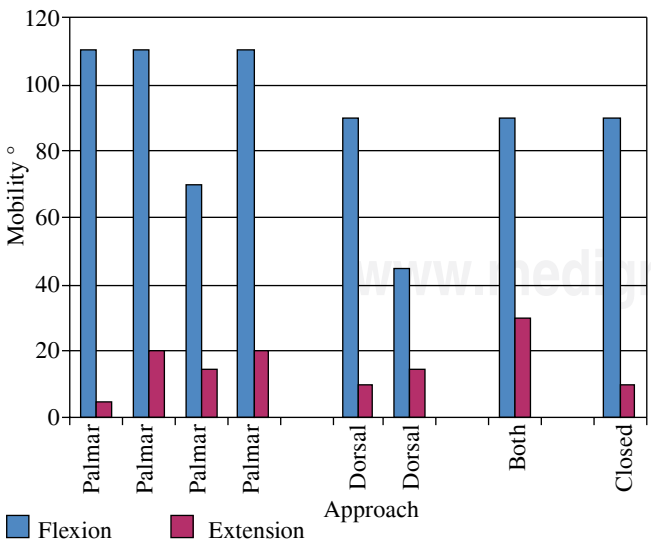

Chart 1. Approach and Mobility

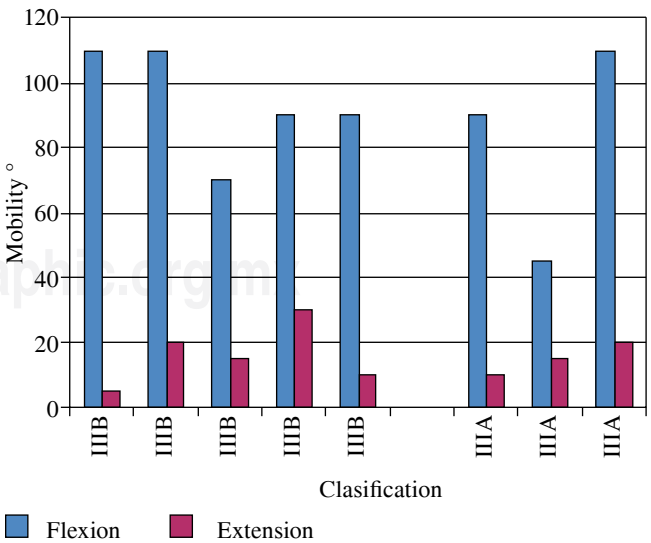

Chart 3. Classification and Mobility.

Table 2.

Authors	Treatment	Number of patients	Follow-up	Range of motion	Comments
Weiss	Wire cerclage	12	2.1 years	-9°/89°	Less fragment devitalization
Newington	ORIF with Kirschner nails	10	16 years	-8°/85°	
Williams	Autologous hamate bone graft	11	17 months	86°	100% healing
Green	Interfragment screws	2	1 year	-5°/105, 5°/95°	Only possible in large fragments
DeSmet	Suzuki fixator	8	16.5 (6-36) months	-9.9°/91°	Simple and unexpensive method
Deshmukh	Modified Suzuki fixator	13	34 (12-49) months	85°	92° force with respect to the contralateral
Malerich, Eaton	Volar plate interposition	24	10 (6-106 months) years	<6 sem: 95° > 6 sem: 78°	Rx with middle phalanx remodeling
Dyonisian	Volar plate interposition	17	11-5 (4-26) years	< 4 sem: 85° > 20 sem: 61°	4 patients with joint space narrowing

elapsed between the injury and the treatment had an untoward effect on the range of motion, but there was no statistical significance either.

The greater flexion and total range of motion found in patients treated with a palmar approach and with volar plate interposition arthroplasty may be explained by the absence of fibrosis in the extensor apparatus and the absence of palmar bone fragments that prevent flexion from occurring. Likewise, patients treated with interposition plasty undergo a palmar approach.

The greater mobility and total flexion seen in patients with Eaton IIIB injuries compared to those with IIIA injuries was not foreseen; however, the limited number of patients may account for it.

As was already discussed above, several treatments for the PIP joint fracture dislocation have been reported and they are summarized in *table 2*.

None of the patients analyzed herein were treated with cerclage, interfragment screws, hamate bone graft or external fixators.

Fracture dislocation of the proximal interphalangeal joint is a rare injury with multiple possible treatments. The personality of each fracture dislocation prevents us from providing a universal treatment; the latter should be individualized in each patient and this is reflected in the various treatments reported in the literature and used in the patients analyzed herein.

This paper presents an overview of the PIP joint fracture dislocation, as well as our experience in the treatment of this condition. Unfortunately, of the 13 patients treated for PIP joint fracture dislocation, only 8 had records that included all the data necessary for the analysis, which prevented us from obtaining statistically significant results.

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