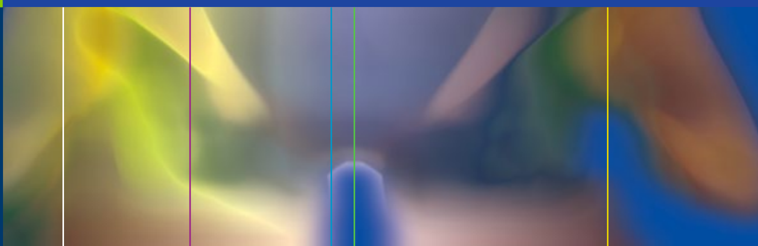
Julie E. Adams
Editor



PIP Joint Fracture Dislocations

A Clinical Casebook

Springer

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Preface

Proximal interphalangeal (PIP) joint injuries are common and often unrecognized or unappreciated by the patient or physician. It is important to be able to distinguish between stable, unstable, and tenuous lesions and to understand and appreciate the various options and principles of treatment.

This clinical casebook is a practical handbook that addresses PIP joint injuries and explores principles of treatment. Some of the more common clinical scenarios that may be encountered are described. The book provides a framework for the practicing hand therapist, physician, or surgeon to understand these injuries and choose between treatment options and therapy regimens in order to lead to optimal outcomes. Attention to a stepwise surgical and rehabilitation program is provided.

Chapter topics were chosen to cover the most common and useful areas of pathology and treatment that the surgeon, physician, or therapist may encounter. Chapters are framed in terms of practical principles and case examples to enhance understanding and provide useful guidance to the clinician. Each chapter is designed to highlight clinical pearls and pitfalls and to help the clinician avoid complications and improve outcomes. Expert authors were hand-selected by the editor; these experts were specifically chosen for their expertise and experience in surgery and rehabilitation and their ability to write clear and concise value-packed chapters.

It is my hope that *PIP Fracture Dislocations: A Clinical Casebook* becomes a frequently referenced guide for practicing clinicians and residents, fellows, or students who are interested in a practical appreciation of the issues associated with PIP joint injuries. To that end, I would like to thank the expert authors who have generously contributed to this volume and shared their experience and expertise and who have made my job as editor easy and fun and the fantastic work of Patrick Carr (Springer Developmental Editor) and Kristopher Spring (Springer Publishing Editor) in keeping the work on track and bringing it to fruition. I would also like to thank my husband Scott and our daughter Sarah for their patience and unwavering support.

Austin, MN, USA Julie E. Adams, M.D.

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Chapter 1
Dorsal Fracture Dislocations: Biomechanics and Management Principles

Brandon S. Smetana and Reid W. Draeger

Abstract Dorsal proximal interphalangeal (PIP) joint fracture dislocations represent difficult injuries to manage and are frequently missed on initial evaluation. During dorsal fracture dislocations of the PIP joint, the volar plate is either disrupted or remains attached to the volar fragments of the middle phalangeal base; thus resistance to dorsal subluxation hinges on the integrity of the bony volar articular buttress of the middle phalanx. Appropriate treatment depends on recognition of dorsal instability, if present, on lateral radiographs and maintenance of reduction throughout the healing process. Anatomic reduction of the articular surface remains less important than maintenance of stability and prevention of dorsal subluxation. As such, the most commonly utilized classification scheme divides these injuries according to the amount of volar middle phalangeal base involved in the fracture dislocation in order to guide treatment. Stable injuries involve less than 30 % of the volar middle phalangeal base and are treated with nonoperative means, typically by buddy taping or with dorsal block splinting. Unstable injuries involve more than 50 % of the volar articular base and necessitate operative intervention

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to prevent dorsal subluxation. Surgical strategies include open reduction and internal fixation, percutaneous pinning, external fixation, or arthroplasty. Tenuous injuries involve 30–50 % of the volar articular base and appropriate management is less clear.

Keywords Dorsal proximal interphalangeal joint fracture dislocation • Biomechanics • Classification • Treatment • Management principles

Introduction

Finger fractures are common with an annual incidence of 67.9 per 100,000 persons per year with dislocations occurring with an annual incidence of 11.2 per 1000 persons per year [1]. The proximal interphalangeal (PIP) joint sits in an unprotected position and carries a long moment arm, placing it at increased risk of injury compared to surrounding structures [2]. It is additionally susceptible to injury given the high degree of articular congruity between the proximal and middle phalanges [3]. Some injuries to the PIP joint only affect ligamentous structures or are associated with small avulsion fractures of the base of the middle phalanx at the insertion of the palmar plate, while others are associated with larger fractures of the base of the middle phalanx [2]. PIP joint fractures often go unrecognized as “sprains” or “jams” leading to delayed diagnosis. Failure to recognize and treat injuries may result in subsequent stiffness, pain, swelling, angulation, and radiographic changes associated with early arthritis [2]. When dislocations occur in conjunction with fractures, they often are significantly comminuted, can be difficult to treat, and may result in a painful and stiff joint [4]. Although much is written regarding the appropriate management of closed dorsal PIP fracture dislocations, there is wide variation regarding the choice of treatment for these injuries [1, 2, 5]. This chapter reviews the biomechanics of the PIP joint in relation to PIP fracture dislocations and the treatment principles behind the approach to their management.

Biomechanics

Anatomy

The PIP joint is composed of a bicondylar convex proximal phalangeal head with a central groove and a biconcave middle phalangeal articular surface with a central ridge to match the proximal phalanx [6]. The dorsal-volar length of the radial condyles is larger on the index and middle fingers; however the ulnar condyles are larger on the ring and small fingers resulting in the convergence of the fingers toward the volar scaphoid tubercle during flexion [6]. The PIP joint is mostly a simple hinge joint with the majority of motion occurring in the volar/dorsal plane [1, 4], although most refer to it as a “sloppy hinge” due to small amount of rotational and angular motion [1, 7, 8]. The range of motion of the PIP joint averages from 10° of hyperextension to 110° of flexion for a total arc of motion of 100–120° about a static center of rotation [7, 9, 10]. This long arc of motion at the PIP joint contributes to approximately 85 % of finger flexion during grasp [9]. This large range of motion necessitates limited bony constraint with the middle phalangeal articular surface covering approximately 110° of the overall 210° arc of the proximal phalangeal articular surface [10]. The axis of PIP joint rotation is a single static point, which lies on lateral radiographs at an equidistant point from the dorsal, palmar, and distal articular surface of the proximal phalanx [4]. Anatomically, this is found in between the origin of the dorsal and palmar bundles of the proper lateral collateral ligament [4].

Stability of the PIP Joint

Stability of the PIP joint is provided both by the bony architecture of the proximal phalanx head and middle phalangeal base articular surfaces in addition to its soft tissue envelope. Bony constraint is provided by the cup-shaped articular surface of the middle phalangeal base on the cylindrical distal articular surface of the head of

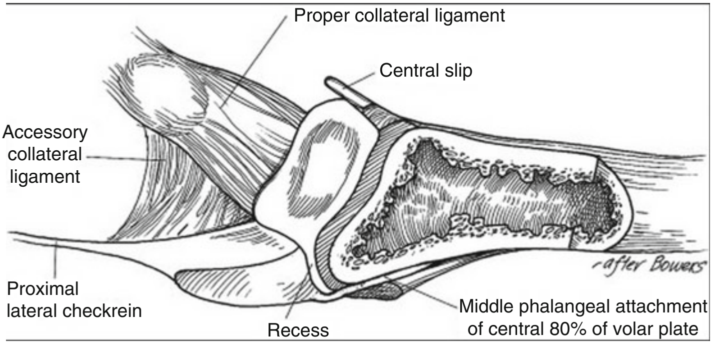

Fig. 1.1 Soft tissue stabilizers of the PIP joint: the "box" configuration. Soft tissue constraint to the PIP joint is afforded by a boxlike configuration composed of four distinct structures surrounding the joint: dorsally the central slip, palmarly the volar plate, and both radially and ulnarly the proper and accessory collateral ligaments (From Williams IV CS. Proximal Interphalangeal Joint Fracture Dislocations: Stable and Unstable. Hand Clinics. 2012; 28:409–416 p.410. Originally published In Bowers WH. The anatomy of the interphalangeal joints. In: Bowers WH, editor. The interphalangeal joints. New York: Churchill Livingstone; 1987. p. 11; with permission)

the proximal phalanx. This bony stability is further enhanced by the central groove separating the radial and ulnar condyles of the proximal phalanx and the corresponding central ridge of the articular surface of the middle phalangeal base.

Soft tissue stability is afforded by a "box" configuration about the hinge joint (Fig. 1.1) [1, 10]. The sides of the box are formed by the radial and ulnar proper and accessory collateral ligaments, the floor by the palmar plate, and the ceiling by the central slip [1]. The palmar plate provides constraint to both hyperextension and dorsal translation of the middle phalanx on the proximal phalanx with intact bony anatomy [10]. It arises from the distal margin of the A2 pulley and inserts at the lateral volar aspect of the middle phalanx [10]. It is composed of thick checkrein portions laterally and a thinner portion centrally [6, 10].

The proper collateral ligaments originate near the center of rotation of the PIP joint at the central aspect of the head of the proximal phalanx and course distally and volarly to insert on the volar proximal aspect of the middle phalangeal base [1, 10]. They act as secondary stabilizers to dorsal translation in addition to providing radial and ulnar stability, especially with the PIP joint in slight flexion [1, 11].

The accessory collateral ligaments are generally less substantial upon anatomical dissection than typically represented on pictorial depictions [1]. They originate from a more distal and volar aspect of the proximal phalanx than the origin of the proper collateral ligaments and course along a more volar trajectory inserting on the volar plate near its insertion [1, 10, 11]. The accessory collateral ligaments help to provide radial and ulnar stability to the PIP joint when in extension.

Injury to the PIP Joint and Instability

Disruption of any one of the soft tissue stabilizers will not typically result in dislocation, as it typically takes injury to at least two of the structures to result in dislocation [1]. With complete disruption of the collateral ligaments and volar plate seen with dislocations, reconstruction is typically not necessary as neocollateral ligaments form and provide adequate stability to the PIP joint [12]. Lutz et al. examined this anatomical ligamentous disruption in a cadaver model during pure dislocation events. In 10° of flexion, reduction of the palmar plate to its insertion occurred, as did reduction of the collateral ligaments to their site of avulsion off of their proximal phalangeal origin [11].

Fractures can commonly occur with dislocation secondary to the transmission of a longitudinally applied force vector and a large angular moment across the joint [2]. Due to variations in force transmission, three different patterns based on the joint position at the time of injury and the injury's force vector are reported (Fig. 1.2): volar lip fractures associated with dorsal fracture dislocations, dorsal lip fractures associated with volar fracture dislocations, and pilon fractures associated with longitudinal load [2]. Hyperextension at the PIP joint leads to either palmar plate disruption near its insertion or volar avulsion injuries of the palmar lip of the middle phalanx, whereas load and shear injuries lead to more profound fractures and comminution [2].

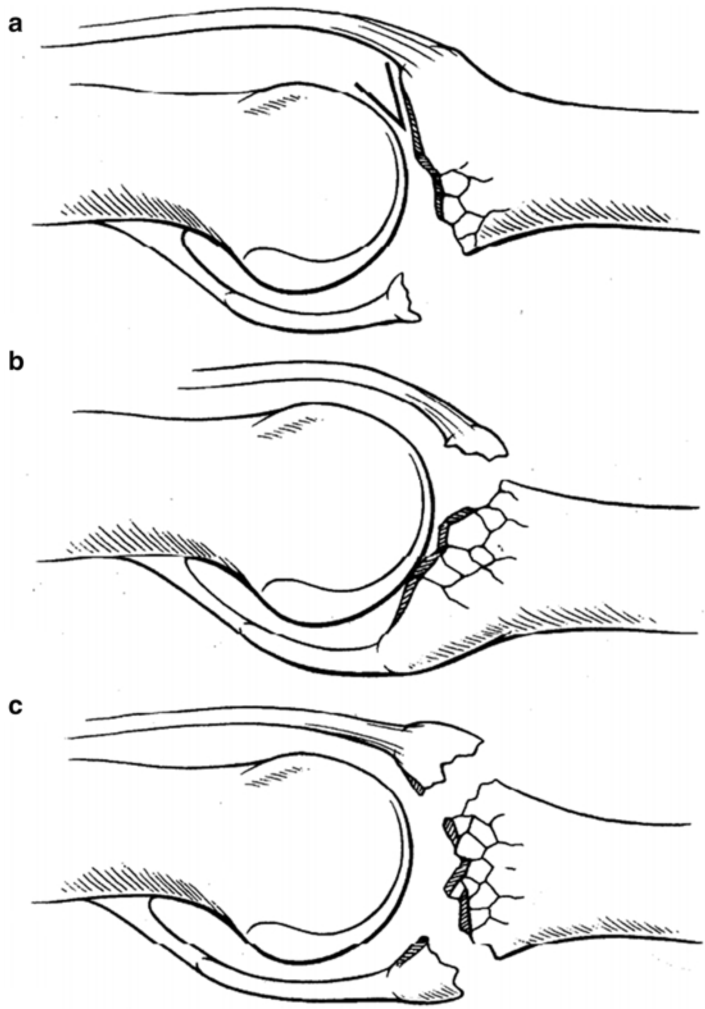

Fig. 1.2 PIP joint fracture dislocation: patterns of injury. (**a**) Palmar lip fracture and dorsal subluxation can arise from either an avulsion (hyperextension)- or an impaction shear (axial load in flexion)-type mechanism. The pattern depicted in this figure represents an impaction shear injury. (**b**) Dorsal lip fracture with palmar subluxation can additionally arise in a similar fashion through avulsion (hyperflexion)- or impaction shear (axial load in relative hyperextension)-type mechanisms. (**c**) Pilon fractures as depicted in this image occur from axial load

When Eaton first classified these injuries, he made reference to a “critical corner” encompassing the palmar plate and lateral collateral ligament attachments to the volar base of the middle phalanx, which, when disrupted, led to instability [2, 13]. He later noted that when greater than 40 % of the palmar articular surface of the middle phalanx was involved that instability resulted secondary to loss of the stabilizing effects of the palmar plate and collateral ligaments [2]. When less is involved, the remaining fibers of the collateral ligament attached to the main middle phalangeal fragment provide adequate palmar stability to prevent dorsal subluxation during extension and subsequent hinging during flexion [2]. Hastings and Carroll further support the biomechanical importance of the volar lip of the middle phalangeal base in preventing dorsal subluxation. They state that when the volar lip fragment becomes of significant size, the normal semicircular shape of the middle phalangeal base is lost leaving behind a small oblique dorsal remnant. This remnant is susceptible to the forces of the central slip in allowing dorsal subluxation about the proximal phalanx [4]. The flexor digitorum superficialis inserting on the middle phalanx additionally creates a rotational moment, exacerbating this apex dorsal deformity, and increases the tendency of the middle phalanx to hinge on the volar articular remnant during flexion [4].

This dorsal subluxation of the middle phalanx necessitates disruption of the continuity of palmar restraints including the volar plate, collateral ligaments, and the palmar bony buttress [14, 15]. The volar plate is invariably disrupted in dorsal dislocations [11], and thus, the primary determinants of stability of PIP joint dorsal fracture dislocations are the degree of volar lip involvement and the subsequent amount of remaining proper collateral ligament fibers attached to the major middle phalangeal fragment [1]. Recent biomechanical evaluation of dorsal fracture dislocations demonstrated uniform stability with involvement of only 20 % of the volar lip and instability with involvement of 60–80 % involvement. 40 % articular

Fig. 1.2 (continued) in extension with disruption of both the dorsal and volar cortical margins (From Kiefhaber TR, Stern PJ. Clinical Perspective: Fracture Dislocations of the Proximal Interphalangeal Joint. Journal of Hand Surgery 1998. 23(A):368–379 p.369. Originally published by Kiefhaber TR. Phalangeal dislocations/periarticular trauma. In: Peimer CA ed. Surgery of the hand and upper extremity. Vol 1. New York: McGraw-Hill, 2996:963; with permission) involvement had variable amount of instability noted on their evaluation and appeared to be the threshold for stability, although they did not examine 50 % articular involvement [16].

Work by Eaton, Hastings, Carroll, Kiefhaber, and Stern has provided evidence of the importance of the volar lip size in determining stability of the fracture dislocation and provides the basis for PIP joint fracture dislocation management.

Management Principles

Principles of management rest on creating a concentric reduction of the middle and proximal phalanges while avoiding dorsal subluxation of the middle phalanx during terminal extension and subsequent hinging of the middle phalanx during flexion [2, 4]. Poor results have been reported with persistent subluxation [2, 4, 17]. Evidence suggests that the prevention of “hinging” of the PIP articulation is of paramount importance for optimizing PIP fracture dislocation outcomes.

Anatomic reduction of the articular surface is less important for these injuries, as long as concentricity is achieved at the PIP joint. Few investigators and leading clinicians in the field are proponents of joint surface reduction as a main goal of PIP fracture dislocation treatment [2]. There has been increasing evidence that satisfactory outcomes can be obtained without obtaining anatomic articular reduction if joint subluxation is avoided and early motion is instituted [2, 14, 18–20].

Early motion has emerged as a key component of successful management of PIP fracture dislocations and parallels the early work of Salter on the positive impact of continuous passive motion on the cartilage healing process [2, 4, 5, 21]. Although stressed in most reviews, there is a paucity of high-level evidence supporting these claims [1, 2, 4, 5]. A few series claim good outcomes with slightly delayed mobilization (with as much as 3–4 weeks of immobilization) [5], yet some report the contrary with poor outcomes found with a similar period of immobilization [1]. However, with many treatment modalities permitting and demonstrating good results with early active motion, the general consensus rests on instituting motion as early as possible provided that stability is not sacrificed.

Table 1.1 Kiefhaber and Stern's stability-based classification of PIP joint dorsal fracture dislocations

Stable	Tenuous	Unstable
<30 % articular surface involvement	30–50 % articular surface involvement	>50 % articular surface involvement
And	And	Or
Does *not* require >30° of flexion to maintain congruous reduction	Does *not* require >30° of flexion to maintain congruous reduction	Requires >30° of flexion to maintain congruous reduction

Based on the size of the volar lip fragment expressed in percentage of the articular surface and clinical and radiographic stability of the fracture dislocation pattern in terms of amount of flexion required to maintain congruous reduction

Classification

Based on these principles, classifications were developed in hopes of guiding treatment. Eaton first classified PIP fracture dislocations according to degree of injury from a simple hyperextension injury, followed by simple dislocation, to dislocation associated with fracture [13]. He noted the importance of the bony volar aspect of the middle phalanx with instability seen with disruption exceeding 40 % [13]. In a large retrospective series examining injuries to the MCP and PIP joint, Hastings and Carroll additionally stress the importance of the middle phalanx palmar buttress in affording stability to the joint [4]. They found that management of these injuries should center on restoring this buttress and preventing dorsal subluxation [4], which has been confirmed by multiple other investigators [2]. Further investigation has yielded similar findings regarding the importance of the volar lip of the middle phalanx in providing PIP joint stability in the setting of PIP fracture dislocations. It is generally accepted that fractures involving more than 30–40 % of the volar articular base are at risk of dorsal instability [2, 4, 16].

Kiefhaber and Stern noted that not only was the fragment size important in predicting instability, but also examination of dynamic stability was essential in treating these injuries [2]. They proposed a stability-based classification of PIP joint dorsal fracture dislocations based both on fracture size in addition to clinical and radiographic examination of stability. This classification is widely used to guide

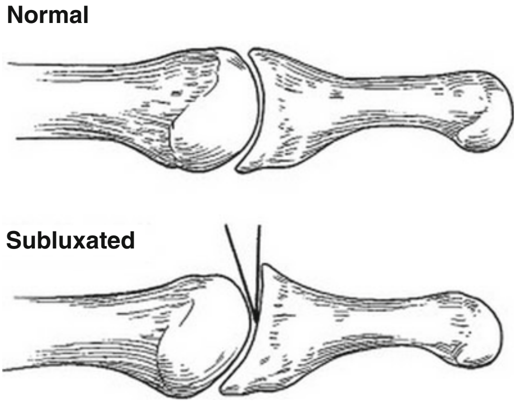

Fig. 1.3 The V-sign: evidence of dorsal subluxation of the middle phalanx. As first described by Light, the V-sign, as seen on a true lateral radiograph of the PIP joint, is an indicator of an otherwise subtle radiographic finding of dorsal subluxation of the middle phalanx on the proximal phalanx after volar injury (From Williams IV CS. Proximal Interphalangeal Joint Fracture Dislocations: Stable and Unstable. Hand Clinics. 2012; 28:409–416 p.410. Originally published by Blazar PE, Steinberg DR. Fractures of the proximal interphalangeal joint. JAAOS. 2000; 8(6): 383–390; with permission)

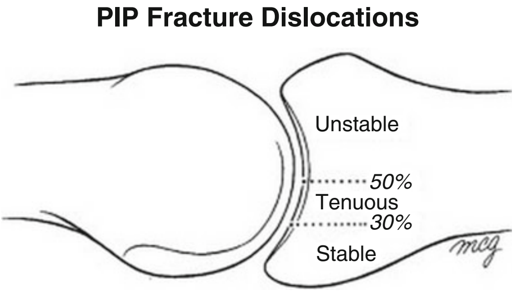

Fig. 1.4 Kiefhaber and Stern's stability-based classification of PIP joint dorsal fracture dislocations: a schematic representation. Within this classification, resultant stability of the PIP joint after dorsal fracture dislocation is classified based on the percentage of joint surface involvement and integrity of the volar articular buttress (From Williams IV CS. Proximal Interphalangeal Joint Fracture Dislocations: Stable and Unstable. Hand Clinics. 2012; 28:409–416 p.410. Originally published by Kiefhaber TR. Phalangeal dislocations/periarticular trauma. In: Peimer CA ed. Surgery of the hand and upper extreity. Vol 1. New York: McGraw-Hill, 2996:963; with permission)

treatment (Table 1.1) [2]. The finger is examined under digital block for clinical signs of subluxation during extension, followed by true lateral radiographic examination in full extension. If subluxation is noted in extension, clinical and radiographic examination with progressive flexion is performed [2]. Many authors additionally stress the importance of recognizing subtle subluxation at the PIP joint on a lateral radiograph by the formation of a "V-sign" first described by Light, between the dorsal distal aspect of the proximal phalanx and the dorsally subluxated articular surface of the middle phalanx (Fig. 1.3) [1, 2, 4, 5, 10]. Based on the clinical and radiographic findings, one may classify PIP fracture dislocations as stable, tenuous, or unstable; a stepwise treatment algorithm is suggested based upon this classification (Fig. 1.4, Table 1.1) [2].

Stable Injuries

Stable injuries about the PIP joint associated with dorsal fracture dislocations represent a range of injuries, from pure hyperextension injuries with small volar avulsion fractures, to fracture dislocations involving less than 30 % of the volar articular base without evidence of joint subluxation at less than 30° of flexion on clinical and true radiographic examination [2]. It is important to examine hyperextension injuries for the presence of persistent hyperextension due to disruption of the palmar plate, as these injuries are prone to developing a swan neck deformity. Additionally, when stable volar fractures are present, the degree of flexion necessary to obtain concentric reduction is important, as this will guide initial degree of permitted extension during early motion rehabilitation protocol. In the setting of hyperextensibility or with subluxation seen near terminal extension, treatment with extension block splinting [22], figure-of-eight bracing, short-arm casting with dorsal extension block, or a double AlumaFoam splint according to Strong's method [23] can be utilized to allow for full flexion but prevent hyperextension, while the palmar stabilizing structures heal [2]. Similarly, a transarticular K-wire extending from the distal aspect of the proximal phalangeal articular surface, serving as a PIP extension block, may be utilized while allowing early motion and avoiding problems with noncompliance with splint wear [1, 2, 4].

If the injury does not result in any clinical hyperextension or subluxation with terminal extension, then simple buddy taping is usually sufficient to allow institution of early, unrestricted motion [2]. Early motion is critical in the management of these injuries, and prolonged immobilization in lieu of dorsal block splinting or buddy taping is not advised due to problems with stiffness and development of flexion contractures [2].

Tenuous Injuries

Tenuous injuries consist of those involving 30–50 % of the volar articular surface of the PIP joint, which also demonstrate concentric reduction with less than 30° of flexion [2]. In this scenario, close observation is critical, as joint reduction and stability must be maintained until fracture union and soft tissue stability are achieved. Typically, dorsal block splinting as described above is performed for fractures fitting this description with gradual increase in extension over a course of 6–8 weeks with close clinical and radiographic examination for evidence of subluxation with a low threshold to transition to operative intervention [2]. However, limited data exists promoting either nonoperative or operative intervention of these injuries falling into this category. If at any point greater than 30° of flexion is necessary to provide stable reduction, the injury should be reclassifed as "unstable" and surgical intervention should be entertained [2]. Tenuous injuries requiring >30° of flexion to maintain concentric reduction are thought to be associated with a greater tendency to subluxate with nonoperative treatment protocols. Additionally, greater stiffness, pain, and flexion contracture development may be associated with prolonged immobilization at >30° of flexion.

Unstable Injuries

Unstable injuries are those with fractures involving greater than 50 % of the articular surface or those in which greater than 30° of PIP flexion is required to maintain joint congruity. In these scenarios,