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REVIEW ARTICLES OF TOPICS

Perilunate injuries

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Abstract Perilunate dislocations and fracture dislocations are most often a result of high-energy trauma, exerting an axial load with hyperextension and ulnar deviation of the wrist, along with intercarpal supination. Early treatment of perilunate injuries is necessary to optimize the clinical outcome. Although closed management has been the more commonly reported treatment for perilunate injuries, the current consensus is that anatomic restoration of carpal alignment has better results. The combined dorsal-volar approach offers the advantages of both approaches and is the preferred choice for the authors since it allows assessment of all the injured structures. The surgical techniques to restore carpal alignment and repair the scapholunate interosseous ligament are discussed. Current literature regarding treatment and prognosis is also included.

Keywords Perilunate · Wrist · Fracture · Dislocation · Treatment

Introduction

Perilunate dislocations are relatively rare injuries involving approximately only 7% of all injuries of the carpus [12]. They most often result from high-energy trauma, including motor vehicle accidents, falls from a height, or contact sporting activities, and thus are often associated with other significant trauma. Correct diagnosis and treatment of these injuries is imperative in order to restore wrist motion and function. Early treatment of perilunate injuries is necessary to prevent the devastating complications of chronic carpal instability and traumatic arthritis associated from missed or inappropriately treated injuries [8–10].

Patients with unreduced injuries may present very late (up to years) after the injury. Although some of these cases may have good hand function with minimal pain, patients usually present with pain, carpal tunnel syndrome, or flexor tendon ruptures because of attritional tendon injuries due to wear on dislocated carpal bones [8].

Clarification of the mechanism of perilunate dislocations was provided by a cadaveric study in 1980 by Mayfield et al. [13]. They showed that the application of an axial load causing a hyperextension and ulnar deviation of the wrist, along with intercarpal supination, reproduced a spectrum of injury termed "progressive perilunate instability," which varied according to the severity of the load applied. Four stages of perilunate injuries were described as the carpus is disrupted around the lunate. The pattern of sequential failure begins radially and is transmitted either through the body of the scaphoid (producing a trans-scaphoid fracture) or through the scapholunate (SL) interval (producing an SL dissociation). The force then propagates to the ulnar and dorsal aspects of the wrist. In stage I, there is disruption of the scapholunate and radioscaphocapitate ligaments. In stage II, the force disrupts the lunocapitate association. In stage III, there is failure of the lunotriquetrial interosseous and ulnotriquetrial ligaments, where the entire carpus essentially separates from the lunate. Finally, stage IV involves palmar lunate dislocation into the carpal tunnel. Mayfield demonstrated that slower application of load produced fractures (radial styloid, scaphoid, and/or capitate) prior to the lunate dislocation, termed "greater arc injuries."

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Conversely, a more rapidly applied force produced purely ligamentous disruptions, termed "lesser arc injuries."

The typical presentation of an acute perilunate dislocation includes pain and swelling about the wrist. Deformity may be more subtle than expected. The carpus is usually displaced dorsally. In a lunate dislocation, the lunate can come to lie within the carpal tunnel; therefore, thorough neurovascular assessment of the upper extremity is important. PA, lateral, and oblique radiographs are the key to the diagnosis. The PA view will show disruption of the normal carpal arcs, i.e., breaks in Gilula's arcs (Fig. 1). Gilula's arcs are formed by the proximal and distal articular surfaces of the proximal row and the proximal cortical margins of capitate and hamate [16]. The lateral radiograph will reveal loss of co-linearity between the capitate, lunate, and the radius (Fig. 2). Traction radiographs may be indicated to further assess the injury pattern.

Once the diagnosis of a perilunate dislocation is made, treatment consists of immediate closed manipulation to achieve reduction and immobilization. Reduction is usually undertaken with the patient under intravenous sedation. The arm is first suspended in longitudinal traction. With the wrist extended and maintaining traction, the surgeon's thumb is placed volarly against the lunate and is used to apply a dorsally directed force to push the lunate back into its fossa. Simultaneously, the wrist is progressively brought into flexion maintaining the dorsally directed force against the lunate [6]. Failure to achieve a reduction via closed means often indicates interposed volar capsule and necessitates an open procedure.

Surgical Indications and Other Options

Although closed reduction and immobilization has historically been the definitive treatment for perilunate injuries [1], the current consensus is that anatomic restoration of the carpus is difficult to maintain via nonoperative means. As such, acute perilunate dislocations and fracture dislocations require surgical intervention. Multiple studies have shown that the complex intercarpal relationships are poorly maintained by means of closed reduction and immobilization alone [1, 2]. Comparison studies between perilunate injuries treated conservatively versus those where patients underwent open treatment have consistently shown better results in those patients that underwent operative fixation. Aspergis et al. used a scoring system based on pain, occupation, range of motion, and grip strength to compare the results of conservative versus surgical repair. In closely treated group, results were fair in 3 and poor in 5, while patients who were operated (early open reduction) had a better clinical score with 4 excellent, 9 good, and 7 fair or poor results [2]. Inadequate realignment of the carpal bones in a perilunate dislocation has been shown to be associated with chronic carpal instability, traumatic arthritis with persistent pain, scapholunate advanced collapse, and loss of motion [4, 21]. Open reduction allows for direct visualization of the injury and makes anatomic reduction more feasible. It is for these reasons that open reduction and internal fixation is our preferred method of treatment for all acute perilunate dislocations. Open perilunate injuries should be considered an orthopedic emergency, and patients require emergent trip to the operating room for irrigation and debridement, followed by repair of the injured structures. The prognosis of closed injuries seems to be better due to lower magnitude of energy involved and also preservation of soft tissue envelope [8].

Despite the overall consensus that open reduction and internal fixation is the treatment of choice for restoring carpal alignment in acute perilunate dislocations [7, 11], the ideal surgical approach is less explicit. There are three basic surgical approaches that can be used: volar, dorsal, and combined dorsal-volar approach.

The volar or palmar approach is typically used for reduction of the lunate and carpal tunnel release. Additionally,

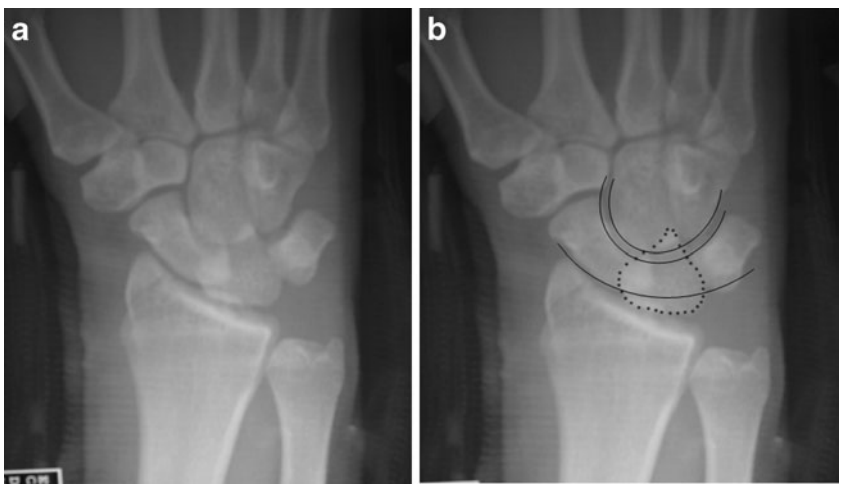

Fig. 1 **a** Posterior–anterior radiograph of a stage III trans-styloid perilunate dislocation. **b** Same radiograph outlining the abnormal triangular appearance of the lunate that has disrupted Gilula's arcs

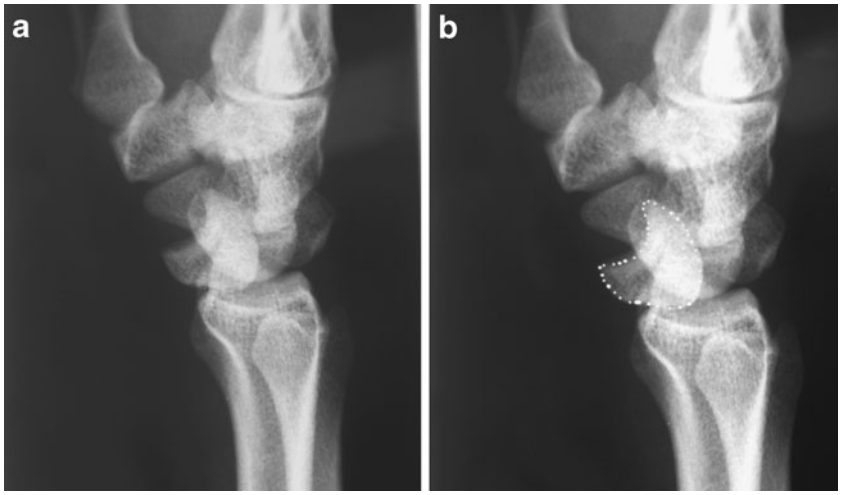

Fig. 2 **a** Lateral radiograph of a stage III perilunate dislocation (same patient as in Fig. 1. **b** Same radiograph showing the lunate (*outlined*) is still articulating with the distal radius; however, there is dislocation of luno-capitate articulation. There is loss of co-linearity between the radius, lunate, and capitate

direct repair of the capsular rent at the space of Poirier can be done volarly. Volar approach can also be used for repair of the volar LT ligament and possibly the SL ligament as well. The dorsal approach provides exposure of the carpus for restoring alignment and repairing the scapholunate interosseous ligament (SLIL) which is thought to be the key to successful long-term results [15]. Moreover, scaphoid and other carpal bone fractures can also be addressed dorsally. The combined dorsal-volar approach offers the advantages of both and is the preferred choice for the senior author since it allows access to all the injured structures.

There are certain injury patterns that are not easily managed with just open reduction and internal fixation. Associated comminuted distal radius fractures and severe soft tissue or ligament disruption often require spanning external fixation for additional stabilization. Proximal row carpectomy and scaphoid excision with four-corner fusion are usually reserved for missed or chronic perilunate dislocations.

Authors' Surgical Techniques

The arm is prepped and draped on the hand table with the patient in the supine position. In general, we approach acute perilunate dislocations from the volar side first to facilitate reduction of the lunate, as well as decompressing the carpal tunnel. An extended carpal tunnel incision is used, commencing 2–3 cm proximal to the wrist crease in line with the ulnar border of the palmaris longus tendon. The incision is angled ulnarly across the wrist crease to avoid injury to the palmar cutaneous branch of the median nerve and ends at the distal region of the transverse carpal ligament (TCL) in the mid-palm. The transverse carpal ligament and the antebrachial fascia are incised longitudinally, thereby releasing the carpal tunnel. The flexor tendons along with the median nerve can be retracted to expose the lunate within the tunnel (Fig. 3). The lunate is then reduced using the same technique as described for closed manipulation, but in this case with direct pressure on the bone itself. At times, reduction of the lunate requires retraction of the interposed capsule. After reduction, the rent in the volar capsuloligamentous complex is repaired with a 3–0 or 4–0 suture to prevent redislocation during the remainder of the operative procedure.

Attention is turned to the dorsal side of the wrist. The approach consists of a 4–5-cm longitudinal incision in line with Lister's tubercle. The incision is carried down to the extensor retinaculum, raising skin flaps radially and ulnarly. The retinaculum is divided in line with the third dorsal compartment, and the extensor pollicis longus (EPL) tendon is retracted radially. The second and fourth compartments are then reflected off the dorsal capsule. Often, a capsular tear is encountered at this point with the dorsal radial carpal (DRC) ligament avulsed from the radius. Depending on the capsular tear, a capsulotomy is either

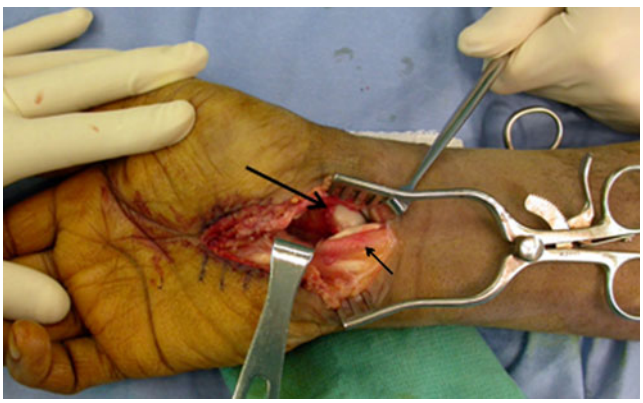

Fig. 3 Intraoperative photograph of a volar approach for a perilunate injury. The transverse carpal ligament has been divided longitudinally, and the content of the carpal canal (including the median nerve, *small arrow*) is retracted ulnarly. The lunate (*large arrow*) is seen dislocated into the canal

extended longitudinally or along the fibers of the dorsal radiocarpal and dorsal intercarpal (DIC) ligaments, as a ligament-sparing capsulotomy [3] (Figs. 4 and 5). At this point, inspection of the cartilage surfaces of the carpal bones is performed, and a direct assessment of the injury pattern is made. Small osteochondral fragments are often encountered and removed from the joint. Kirschner wires (K-wires) are placed into the scaphoid and lunate and used as joysticks to correct the intercalated segment instability pattern. This usually requires correcting scaphoid flexion and lunate extension, and closing down the scapholunate interval. In most instances, the midcarpal and lunotriquetral (LT) joints will reduce with restoration of the normal alignment of the scaphoid and lunate.

Prior to scapholunate ligament repair, percutaneous intercarpal pinning is done to maintain the carpal relationship. Usually, three K-wires (0.045 or 0.062 in.) are inserted from radial side of the wrist just distal to the radial styloid. Two are used to stabilized the scaphoid to the lunate; the other pin is used to secure the distal scaphoid to the capitate to help prevent scaphoid flexion. The lunotriquetral joint is pinned from the ulnar side of the wrist, starting at a point dorsal to the pisiform and aiming slightly proximal. Carpal alignment and K-wire positions are confirmed with intraoperative fluoroscopy. Attention is turned to the SLIL. This ligament is usually avulsed off bone, either the scaphoid or the lunate, and not ruptured at its mid-substance. The bony bed is prepared by removing any interposed soft tissue and creating a bleeding surface. One or two suture anchors are placed into the bed and used to repair the dorsal portion of the ligament. Any osteochondral fragment that may still be attached to the ligament is preserved and incorporated into the repair for better suture retention and healing potential.

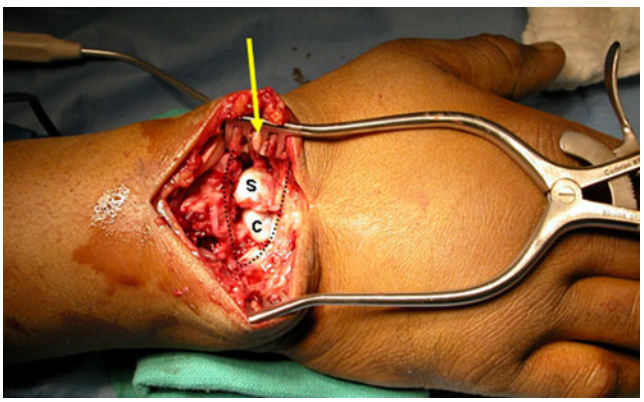

Fig. 4 Intraoperative photograph of a dorsal approach for a perilunate injury. The dorsal radiocarpal (*DRC*) ligament is disrupted from the radius and is extended into a "v-flap" capsulotomy (outlined by *black dots*). The capsule (*yellow arrow*) is retracted behind the self-retaining retractor. The proximal poles of the scaphoid (*S*) and capitate are well seen because the lunate (not seen) is still in the dislocated position volarly

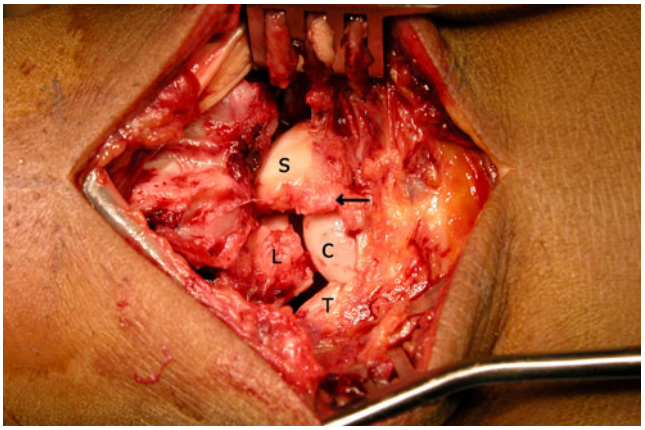

Fig. 5 A close-up photograph of the same patient as in Fig. 4. The lunate (*L*) has been reduced, but there is still a dorsal intercalated segment instability pattern of the carpus. The dorsal part of the SLIL (*arrow*) has avulsed from the lunate and remains attached to the scaphoid (*S*). *C* capitate, *T* triquetrum

The capsulotomy incision is re-approximated with braided non-absorbable 3–0 or 4–0 sutures in an interrupted fashion. If the DRC ligament had avulsed from the distal radius, it is repaired with suture anchor(s) placed along the dorsal lip of the radius. This is followed by retinacular repair, leaving the EPL in the subcutaneous layer. The skin is closed with nylon sutures. The K-wires can be left out of the skin or buried underneath the skin. A sugar-tong splint is placed with the wrist and forearm in the neutral position.

Postoperatively, finger motion is started immediately. The wrist, forearm, and elbow are immobilized for 3–4 weeks by casting. The patient is then converted to a Muenster cast to allow elbow motion in the flexion-extension plane but no forearm rotation. Immobilization and intercarpal K-wires are discontinued at 10 weeks, and therapy is started on the wrist and elbow.

Tips and Tricks

Difficulty Restoring Carpal Alignment At times, restoring the normal relationships of the carpal bones seems impossible even with the joysticks. Part of the problem may be that the initial joysticks may not be in the optimal positions. The trick is to partially reduce the SL interval, then place a second set of joysticks in better positions to complete the reduction. At other times, loss of capsular and ligamentous attachment to the distal radius renders the carpus highly unstable. In these cases, where the scaphoid and lunate will not assume the normal alignment on the distal radius simultaneously (despite joysticking), it is worthwhile to provisionally secure the radiolunate articulation with a K-wire from the radial metaphyseal (Fig. 6). This maneuver will eliminate "one moving part" of the carpus and

Fig. 6 Intraoperative fluoroscopy showing K-wire positions used. In this case, a radiolunate K-wire was used to stabilize the lunate to the radius, and the rest of the carpus was then reduced to the lunate. Also shown is fixation of a trans-styloid fragment which may be part of the injury pattern

will facilitate reduction of the remainder to the carpal bones to the now stable lunate. The radiolunate pin can be removed at the end of the case or left in place to provide additional stability. However, the increased risk of pin loosening, chondrolysis, and broken hardware should be taken into consideration with radiocarpal pinning.

Irreparable Scapholunate Interosseous Ligament Although the key step to a good outcome may be reestablishing a stable SL interval, many times the SLIL is torn in such a way that it cannot be repaired securely. When encountered with this situation, we denude the cartilage from the SL articulation (similar to that described by Rosenwasser et al. [19]) to try to promote some stability by chondrodesis. This maneuver is performed prior to the intercarpal pinning step (Fig. 7). We still advocate trying to tack down the remnant SLIL as best as possible, but it is also augmented with a dorsal capsulodesis. A 3–5-mm wide capsular flap is fashioned, leaving it attached distally to the distal pole of the scaphoid. Its proximal end is then sutured to the dorsum of the lunate with suture anchors. Alternatively, the SL interval can be closed down with the reduction and association of the scaphoid and lunate procedure [19]. Bioabsorbable pins or screws can also be used to stabilize across the SL interval; however, they are less stiff than their stainless-steel pin counterparts. Despite such, relatively high loads are required to destabilize the bio-pin fixation [18].

Trans-scaphoid Perilunate Dislocation In stage IV trans-scaphoid injury patterns, the proximal pole of the scaphoid is dislocated with the lunate into the carpal tunnel. Reduction may require enlarging the rent in the volar capsule. The scaphoid fracture is assessed and reduced through the dorsal capsulotomy. After which, a headless screws is placed, usually from proximal to distal, through the central axis of the bone. Not infrequently, we have found that the SLIL is attenuated despite the scaphoid fracture. In such cases, the SL interval is pinned in addition to the scaphoid fixation. The midcarpal (scaphocapitate) and LT pinning is performed as previously described.

Pitfalls and How to Avoid Them

Delayed Diagnosis The major pitfall in treating perilunate carpal injuries is delayed or missed diagnosis. The patient may have multiple (even life-threatening) injuries which preclude adequate workup and imaging of extremity

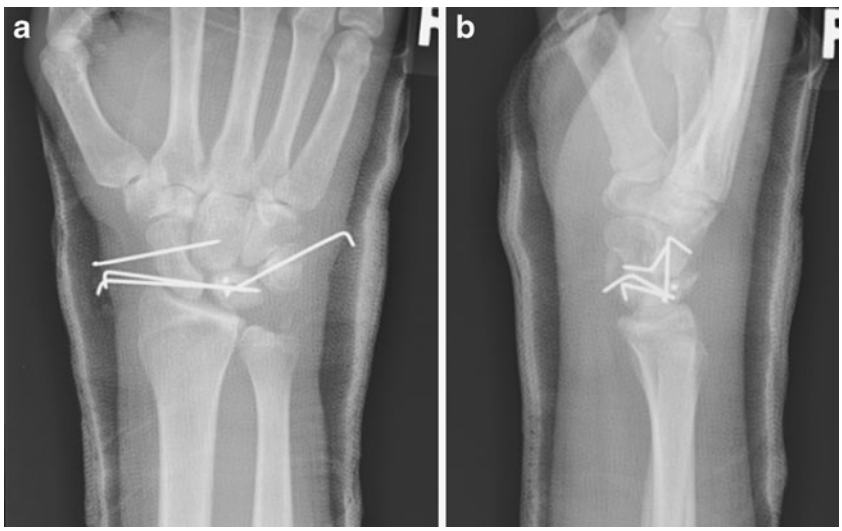

Fig. 7 **a** Posterior–anterior and (**b**) lateral radiographs of the typical pattern of intercarpal pinning for a perilunate dislocation. In this particular case, two suture anchors were used to repair the SLIL to the lunate

injuries. Other times, the dislocation is missed because the radiographs are misread by inexperienced observers. The key to avoid this problem is adequate radiographs (PA, lateral, and oblique views) and recognition of the loss of normal arcs of the carpal bones. Unless the patient is young (less than 30 years old), it is our belief that missed perilunate dislocation greater than 4 weeks requires a salvage procedure, due to our personal experience of poor outcome with reconstruction in these cases.

Pin Track Infection and Septic Arthritis Percutaneous pins left outside the skin are susceptible to infection because they are kept for 10 weeks and are covered by casting material. We have had a few instances where the infection has led to septic arthritis and osteomyelitis. We are now more cognizant of burying K-wires under the skin in patients where we suspect that reliability to follow-up is of question. Leaving pins outside the skin can avoid an additional trip to the operating room for wire removal but requires closer follow-ups.

Discussion

As our knowledge of the mechanism and pathophysiology of acute perilunate dislocations has expanded, our treatment algorithm for these injuries has progressed. The traditional belief that these injuries can be definitively managed via closed methods alone has virtually been abandoned. Currently, virtually all perilunate injuries are treated with some form of operative fixation. Aspergis et al. [2] compared the result of closed treatment versus operative repair in patients with perilunate dislocations and illustrated that all patients treated closed had poor results, while those treated open with a combined dorsal-volar approach reported good-to-excellent results. Though operative repair is the gold standard of treatment of perilunate dislocations, the complex nature of these injuries is such that patient outcomes are variable even with operative fixation. Herzberg et al. [8] showed in their large multicenter study of 166 perilunate dislocations and fracture dislocations that despite satisfactory clinical outcomes, 56% of patients that were treated surgically had radiographic evidence of arthritis. The best results were seen in patients treated early, and a delay in diagnosis was shown to have an adverse effect on the outcome. In a similar study, Hildebrand et al. [10] used multiple validated outcome instruments to assess the results in a cohort of 22 patients who underwent operative fixation of a perilunate injury with a combined dorsal-volar approach at 1-year follow-up. They found that most patients reported decreased grip strength and motion, and had radiographic evidence of arthritis and early carpal collapse. Despite this, three out of four patients were able to return to full duties in their previous occupations.

Percutaneous and arthroscopic techniques have been reported for the treatment of perilunate injuries [17]. Fracture reduction, guide wire placement, and identification of gross ligamentous injuries are done under the fluoroscopy guidance. Arthroscopy is used to diagnose occult injuries and confirm satisfactory reduction [20]. Although such technique might decrease the extent of soft tissue dissection compared to open surgery, there is not enough evidence to show the superiority of the outcome over open operative management [8].

Based on a follow-up of 13 years by Forli et al., signs of posttraumatic arthritis increase progressively, but clinically, they are well tolerated [5]. However, extensive osteochondral defects have been recognized as precursors to joint deterioration, which might impair hand function. Thus, accurate articular restoration seems to be an essential step in all cases. For athletes, it might take up to a year to return to sports, and they should be advised to engage in strengthening programs [14].

In conclusion, perilunate dislocations and fracture dislocations are complex wrist injuries that severely disrupt normal carpal anatomy and wrist biomechanics. Early and appropriate diagnosis of these injuries is imperative to ensure the most optimal outcome. Initial closed reduction of the perilunate dislocation, followed by operative fixation using a combined dorsal-volar approach, provides the best chance for anatomic alignment and decreased risk of arthritis, but patients will not likely regain normal wrist motion or grip strength.

Conflict of Interest The authors declare that they have no conflict of interest with the subject of this report.

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