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Trans-scaphoid Perilunate Fracture Dislocation

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Trans-scaphoid perilunate fracture dislocations, which account for more than half of total cases of perilunate injuries, are common in young patients and occur as a result of high-energy injuries, and improper management can impair wrist alignment and function. Understanding the related wrist anatomy and pathomechanics may help surgeons evaluate and diagnose patients. Early operation to reduce and fix the injuries should be considered to achieve optimal clinical and radiological outcomes. In this review article, we present an overview of wrist pathoanatomy, the pathomechanics of trans-scaphoid perilunate fracture dislocations, operative treatment options including an arthroscopic procedure, and reported clinical and radiological outcomes.

Keywords: Wrist Injuries, Trans-scaphoid perilunate fracture dislocation, Regional anatomy, Orthopedic surgery, Arthroscopic surgery

INTRODUCTION

The wrist joint is capable of various movements, that are made possible by the eight carpal bones and surrounding complex ligament structures [1]. Perilunate dislocation (PLD) and perilunate fracture dislocation (PLFD) are severe injuries that seriously disrupt carpal alignment [2,3]. PLDs comprise 7% of all carpal injuries [4], and are mainly caused by high-energy trauma in younger patients [5].

Early treatment of these injuries is necessary to prevent devastating complications such as chronic carpal instability and eventual posttraumatic arthritis [6,7]. As more than half of perilunate injuries are of the trans-scaphoid variety [8], this article will focus more on trans-scaphoid PLFD (TSPLFD) among the wide spectrum of perilunate injuries. Untreated TSPLFD leads to poor functional and radiographic results [9-11]. Early treatment is important, but diagnosis is missed or delayed in 25% of patients [11,12]. Therefore, appropriate initial evaluation, management, and understanding of TSPLFDs are essential.

ANATOMY

1. Carpal bones

The bony carpus consists of proximal and distal rows and is divided into three columns according to their biomechanical function in the longitudinal plane [13].

The proximal row consists of the scaphoid, lunate, and triquetrum; is more mobile; and enables wrist motion. The distal row consists of the trapezium, trapezoid, capitate, and hamate; is more rigid; and adapts to the motions of the metacarpal bases. The pisiform does not play a significant role in carpal instability. The three biomechanically organized columns include the following: the radioscaphoid column consisting of the scaphoid, trapezium, and trapezoid; the lunate column consisting of the lunate and capitate; and the ulnotriquetral (UT) column consisting of the triquetrum and hamate.

The radiocarpal joint is formed by the biconcave articular surface of the radius and the convex articular surfaces of the scaphoid and lunate. The midcarpal joint is formed by the scaphotrapezio-trapezoidal, scaphocapitate, lunocapitate, and triquetral-hamate articulations (Fig. 1) [14]. During wrist flexion, approximately half of the flexion occurs in the midcarpal joint and the other half occurs at the radiocarpal joint. This distribution shows an interesting change in the extension. During wrist extension from neutral to 60°, more movement occurs in the radiocarpal joint. However, at extreme extension, the extension of the proximal row is reduced and more extension occurs at the midcarpal joint [15,16].

2. Carpal ligaments

The wrist ligaments can be categorized by generic divisions (intrinsic or extrinsic) and location (palmar or dorsal, radiocarpal or midcarpal) [1,17,18]. The intrinsic ligaments provide intercarpal stability. The extrinsic ligaments that link the forearm bone to the carpus are further subdivided into three groups; palmar radiocarpal, palmar ulnocarpal, and dorsal radiocarpal (DRC) (Figs. 2, 3).

Extrinsic carpal ligaments

Since there is no dorsal ligament between the carpal bone and ulna, the extrinsic carpal ligament system consists of two palmar ligaments and one dorsal ligament. The palmar extrinsic ligaments are more important in wrist stabilization as they are thicker and stronger than the dorsal extrinsic wrist ligaments. The palmar capsuloligamentous structures provide 61% of the restraint to dorsal translation of the carpus and 48% of

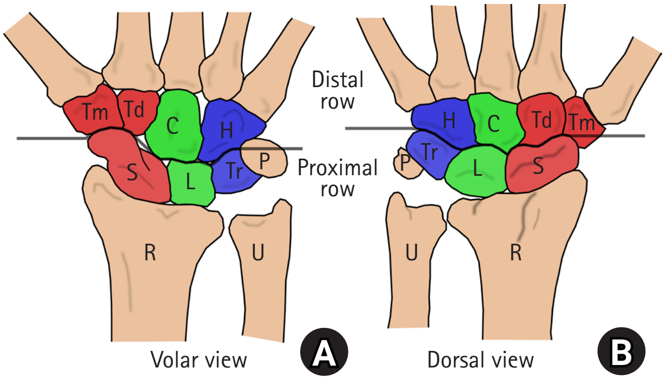

Fig. 1. Diagram of eight carpal bones and the three carpal columns (red, radioscaphoid column; green, lunate column; blue, ulnotriquetral column). (A) Volar view and (B) dorsal view. C, capitate; H, hamate; L, lunate; P, pisiform; R, radius; S, scaphoid; Td, trapezoid; Tm, trapezium; Tr, triquetrum; U, ulna.

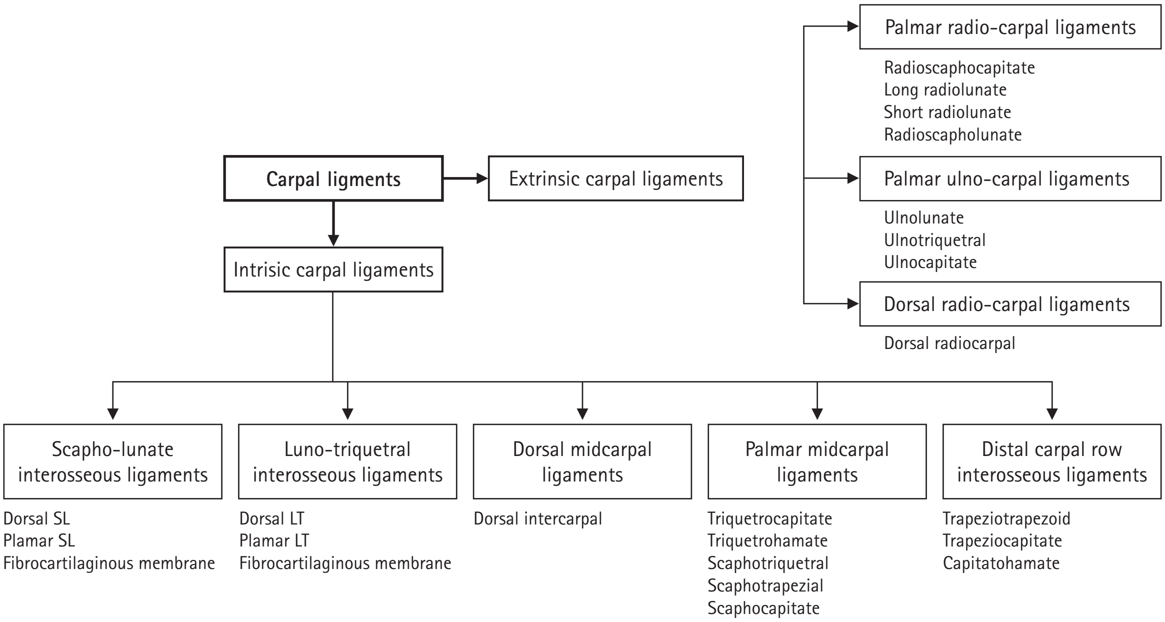

Fig. 2. The most well-characterized carpal ligaments with consensus. SL, scapholunate; LT, lunotriquetral.

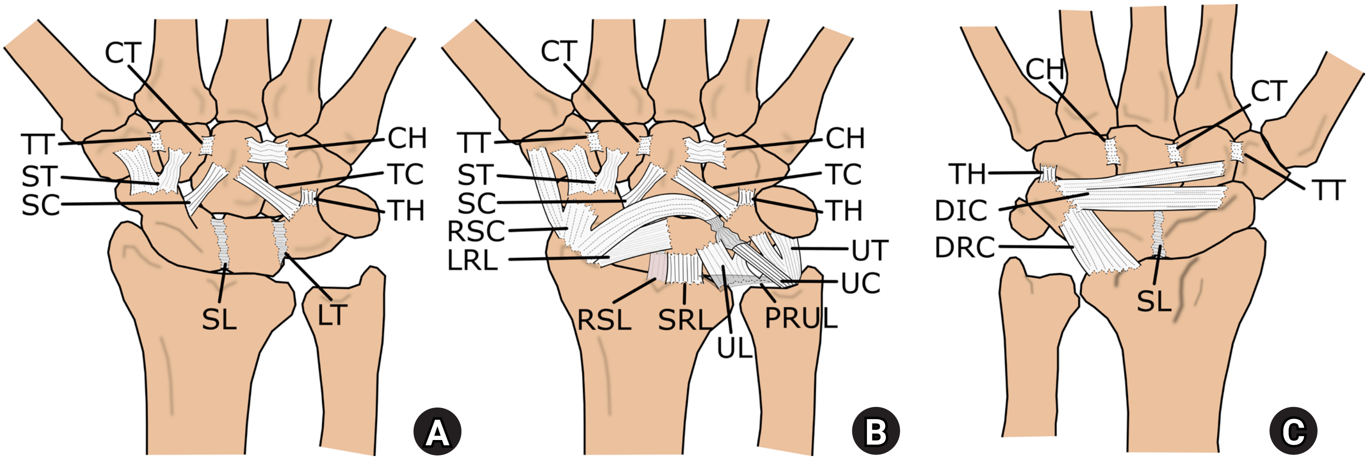

Fig. 3. Carpal ligament schematic. (A) The palmar intrinsic carpal ligaments from a palmar perspective. (B) The palmar carpal ligaments from a palmar perspective. (C) The dorsal carpal ligaments from a dorsal perspective. Ligaments: CH, capitohamate; CT, capitotrapezoid; DIC, dorsal intercarpal; DRC, dorsal radiocarpal; LRL, long radiolunate; LT, lunotriquetral; PRUL, proximal palmar radioulnar ligament; RSC, radioscaphocapitate; RSL, radioscapholunate; SC, scaphocapitate; SL, scapholunate; SRL, short radiolunate; ST, scaphotrapezium; TC, triquetrocapitate; TH, triquetrohamate; TT, trapeziotrapezoid; UC, ulnocapitate; UL, ulnolunate; UT, ulnotriquetrum.

the restraint to palmar translation [19].

① Palmar radiocarpal ligaments

The palmar radiocarpal ligaments including the radioscaphocapitate (RSC, also known as radiocapitate), long radiolunate (LRL, also known as radiolunotriquetral, radiotriquetral, and lunotriquetral [LT]), radioscapholunate (also known as the ligament of Testut and Kuenz), and short radiolunate (also known as radiolunate) are arranged on the distal volar radial rim from radial to ulnar [20].

The RSC is the most radial and runs obliquely across the volar waist of the scaphoid to insert on the proximal cortex of the distal pole of the scaphoid, capitate, and interdigitate with fibers of the ulnocapitate (UC) ligament [1]. The interdigitation is also known as the arcuate ligament, palmar distal V ligament [21]. It is the primary restraint to ulnar translocation of the carpus [5] and serves to constrain radiocarpal pronation and acts as a fulcrum for scaphoid flexion [5,22].

The LRL is immediately ulnar to the RSC ligament. This ligament is a true capsular ligament separated from the RSC ligament [1]. The LRL constrains ulnar and distal translation of the lunate as it attaches to the palmar radial aspect lunate cortex [23].

The radioscapholunate ligament is located just ulnar to the LRL; it consists of loosely organized collagen fibers, so it is not a true ligament in a mechanical sense. It integrates with the scapholunate (SL) ligament after piercing the palmar radiocarpal capsule and serves as a neurovascular conduit [1,24].

The most ulnarly located radiocarpal ligament is the short radiolunate ligament. It vertically inserts on the radial half of the palmar cortex of the lunate, providing a stabilizing force to prevent dorsal dislocation in hyperextension injuries [5]. Thus, the lunate has a thick sheath of ligament connection to the radius via the long and short radiolunate ligaments, which may explain why the lunate tends to remain with the radius in a complete PLD [1,25].

② Palmar ulnocarpal ligaments

The palmar ulnar ligaments include the UC, UT, and ulnolunate (UL) that link the carpus to the ulna. The UC ligament joins with RSC at the capitate to form the arcuate ligament. It is the only ulnocarpal ligament that attaches directly to the ulnar head and serves as an ulnar anchor of the carpus [1,21]. The UL and UT ligaments originate proximally from the palmar radioulnar ligament and form the anterior and ulnar aspects of the ulnocarpal joint capsule. They have no direct insertion to the ulna, and there is no clear demarcation between them [1].

③ Dorsal radiocarpal ligaments

The DRC ligament is the only one present in the DRC joint; its origin is in the distal radius with insertions onto the lunate and triquetrum [21]. The DRC ligament reinforces the dorsal region of the LT interosseous (LTIO) ligaments, contributes to the stabilization of the proximal carpal row [26]. The DRC ligament forms a lateral V configuration with the dorsal intercarpal (DIC) ligament—classically described as the dorsal V ligament—and it serves to constrain ulnocarpal supination and ulnar translation of the carpus [25,27].

Intrinsic ligaments of the carpal bone

Intrinsic carpal ligaments connect bones of the same carpal row or link the two rows together; they originate and insert within the carpus.

① Proximal interosseous ligaments

The proximal row is an intercalated segment, has no direct tendon insertions, and maximizes the ranges of motion (ROMs) of the radiocarpal and midcarpal joints. There are two proximal interosseous ligaments (the SL and LTIO ligaments), which are the primary stabilizers of the proximal row [26,28]. While these ligaments have similar general characteristics, there are certain differences. Both have volar, dorsal, and proximal components. The SL ligament has the strongest dorsal component as it resists scaphoid flexion, translation, and abduction [27,29]. On the other hand, the LT ligament has a stronger volar component as it resists translation, rotation, and distraction of the triquetrum [30]. There are a total of seven ligaments crossing over or attaching to the scaphoid or lunate. The DRC, RSC, DIC, and scaphotrapezial ligaments act as secondary stabilizers of SL joints [26]. On LT joints, the DRC, DIC, and ulnar half of the volar arcuate ligament in conjunction with the LTIO ligaments serve as secondary stabilizers [31].

② Dorsal midcarpal ligaments

The DIC ligament is the only dorsal midpalmar ligament; it originates from dorsoradial triquetrum and passes radially. The ligaments generally insert on dorsoradial ridge of the scaphoid and have varying additional insertions; it sometimes attaches to the dorsal distal aspect of the lunate, trapezium, trapezoid, or even capitate in some cases [21,32]. Along with the DRC, the DIC prevents dorsal intercalated segment instability and serves to stabilize the scaphoid and lunate [33].

③ Palmar midcarpal ligaments

On the palmar side, midcarpal ligaments course from the scaphoid and triquetrum to the distal row, and there are no direct connections between the lunate and distal row. The ligaments originating from the triquetrum are the triquetrohamate and triquetrocapitate, which contribute to forming the ulnar arm of the arcuate ligament. The ligaments originating from the scaphoid are the scaphocapitate and scaphotrapezial ligaments; they stabilize the scaphotrapeziotrapezoid (STT) joint and scaphoid and are also important secondary stabilizers of the SL articulation [26,34].

④ Distal carpal row interosseous ligaments

The bones of the distal carpal row have little intercarpal motion as a result of ligamentous and bony constraints [28,34]. Three distal interosseous ligaments connect the trapezium, trapezoid, capitate, and hamate. The ligaments are composed of both dorsal and palmar regions spanning nearly the entire length of the joint surfaces, but the head and neck of the capitate are devoid of ligamentous connections [1,34].

MECHANISM OF INJURY

PLD and PLFD are usually caused by high-energy trauma and typically result from an axial load applied to the outstretched hand (Fig. 4). Load application to the fixed pronated forearm leads to hyperextension, intercarpal supination, and ulnar deviation of the wrist [2,5,35]. The path may go through the carpal joint from the radial side to the ulnar side, through the wrist bones themselves, producing "path" fractures or ligamentous injury [35]. Mayfield et al. [2,17] showed sequential failures in cadaveric specimens and classified perilunate injuries in continuous stages. At first, the scaphoid hyperextends and either fractures or ruptures the SL interosseous ligament. As the load progresses to the ulnar side, a fracture or dislocation occurs between the lunate and capitate. The so-called "less arc injury, PLD" refers to a case where all the perilunar carpal joints are dislocated without fracture, and a case accompanied by a fracture corresponds to a "great arc injury, PLFD" [2,36]. When defining the type of PLFD, "trans-" is inserted as a prefix to the bone part where the fracture occurred, and it is import-

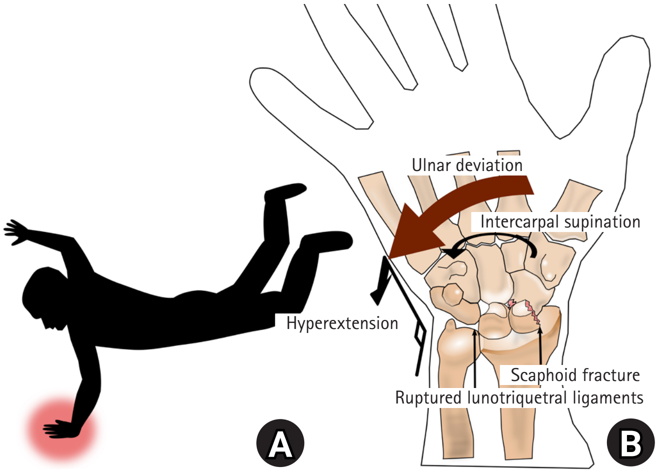

Fig. 4. Mechanism of dorsal trans-scaphoid perilunate dislocations. (A) Perilunate injury typically results from an axial load applied to outstretched hand. (B) The load applied to fixed pronated forearm leads to hyperextension, intercarpal supination, and ulnar deviation of the wrist.

ant to reduce and fix the fracture during treatment.

It is known that the relationship between the loading direction and carpal bone position affects the type of PLD and PLFD. Rapid and slow force applications induce “lessor arc injury” and “greater arc injury,” respectively [2]. When scaphoid hyperextension occurs, a scaphoid waist fracture occurs due to impingement by the dorsal radial rip. If scaphoid dorsal subluxation occurs prior to impingement, a scaphoid proximal pole fracture occurs [36]. In the early stage of TSPLFD, the proximal part of the scaphoid is typically maintained in the proximal row with the lunate, but distal fracture fragments dislocate dorsally with the capitate [37]. However, in the late stage, palmar enucleation of the lunate with the proximal pole of the scaphoid or isolated palmar enucleation of the proximal scaphoid or lunate can be noted [35]. The median nerve can be stretched by the relative protruded palmar rim of the lunate, directly impinged by a displaced carpal bone, or indirectly compressed by soft tissue swelling [5,35].

CLINICAL PRESENTATION AND EVALUATION.

As it is an injury caused by high-energy trauma, 10% of PLD and PLFD are open injuries, 26% of patients have associated polytrauma, and 11% have concomitant ipsilateral upper extremity injuries [11]. A careful examination of the ipsilateral forearm and elbow should be performed. In the acute period, there is obvious pain and swelling over the hand and wrist, and gross deformity of the wrist can be noted [5,28]. Evidence of median nerve injury is common. Acute carpal tunnel syndrome is observed in about 25% of patients [11,28,38,39]. The dorsal TSPLFD represents 96% of the dorsal PLFDs and 61% of all perilunate injuries [11]. Volar TSPLFD is rare and will not be discussed further in this paper.

Orthogonal plain radiographs of the wrist are usually enough to make a diagnosis. A traction view can also be helpful when findings are subtle. The key to diagnosis is recognizing the dislocated head of the capitate to the lunate [5,11,35,38]. Although the four-stage classification by Mayfield et al. [2] according to pathomechanics was previously described, the classification by Herzberg et al. [11,35] is more useful when classifying according to initial radiographs (Table 1, Fig. 5).

In posteroanterior radiographs, the continuity of the “arcs of Gilula” should be closely checked [40]. The first arc outlines the major convexities of the proximal articular surfaces of the scaphoid, lunate, and triquetrum. The second arc conforms to the distal concave surface of these same carpal bones. The third arc contours the proximal cortical surface of the capitate and hamate. By scrutinizing these arcs, the trauma path can be deduced (Fig. 6). The classification according to Herzberg et al.

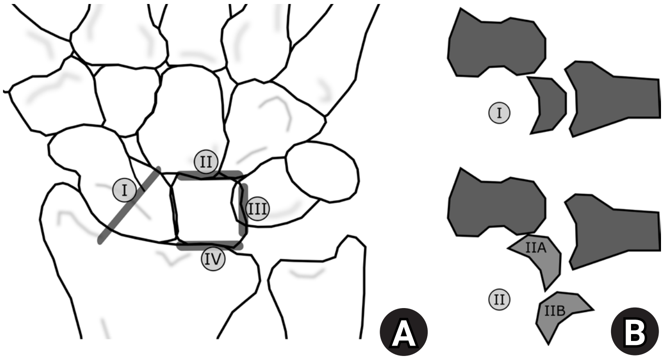

Fig. 5. (A) Stages of trans-scaphoid perilunate dislocations according to Mayfield et al. [2]. Stage I involves trans-scaphoid fracture. Stage II shows interruption of the lunocapitate connection. In stage III, the capitate and triquetrum peel away from the lunate. In stage IV, the lunate dislocates from radius fossa. (B) Stages of trans-scaphoid perilunate dislocations according to Herzberg et al. [11]. In stage I, the capitate dislocates dorsally, but the lunate remains in the lunate fossa. Stage II means dislocation of the lunate and is divided into stages IIA and IIB based on 90° of lunate rotation.

Table 1. Stages of trans-scaphoid perilunate dislocations according to Mayfield et al. [2] and Herzberg et al. [11]

Classification	Description
Mayfield	
Stage I	The force transfers directly through the scaphoid, resulting in a trans-scaphoid fracture
Stage II	The force propagates ulnarly and interrupts the lunocapitate connection
Stage III	The lunotriquetral connection is violated, and the distal carpus separates from the lunate
Stage IV	The lunate freely rotates downward into the carpal tunnel
Herzberg	
Stage I	The capitate dislocates in a dorsal direction; the lunate remains under the radius
Stage II	Volar dislocation of the lunate
Stage IIA	The lunate dislocates with a rotation of less than 90°
Stage IIB	The lunate dislocates with a rotation of more than 90°

Fig. 6. Radiograph of the wrist showing the three "Gilula's arcs." The first arc (1) outlines the major convexities of the proximal articular surfaces of the scaphoid, lunate, and triquetrum. The second arc (2) conforms to the distal concave surface of these same carpal bones. The third arc (3) contours the proximal cortical surface of the capitate and hamate.

[11,35] is assessed in the lateral radiographs view. The lateral view demonstrates the relationships of the capitate, lunate, and radius, which shows linear collinearity in the normal wrist. The lunate remains in the lunate fossa in the radius in stage I, whereas in stage II, palmar subluxation or dislocation of the lunate can be observed, resulting in "a spilled cup sign." In dorsal TSPLFD stage I, the proximal pole of the scaphoid typically remains attached to the lunate by an intact SL interosseous ligament [11,35]. In case of TSPLFD stage II with concurrent SL ligament disruption, anterior dislocation of the lunate with or without the proximal pole of scaphoid is possible. Although the SL ligaments are usually intact, TSPLFD has a wide variety of variants, so it is important to be mindful of the possibility of accompanying SL ligament injury when evaluating patients [11].

Magnetic resonance imaging of intercarpal ligamentous injury and occult fractures or bone contusion is possible. High-resolution computed tomography is very helpful in assessing the positions of fracture fragments and the degree of comminution, as well as in identifying occult fracture or associated chip fractures [20,41].

TREATMENT

After evaluation and imaging, the initial treatment of these injuries is closed reduction to reduce pain, swelling, and pressure on the median nerve. This is performed in the emergency department using the technique described by Jones [42]. The wrist must be immobilized with a splint to maintain reduction, and postreduction films should be obtained to confirm the status. Sometimes closed reduction is not possible, such as when the dorsal capsule is entrapped between the capitate and lunate or impaled by the distal fragment of the scaphoid [43].

While closed reduction and immobilization is the initial treatment of choice, it cannot reliably maintain carpal alignment [4,11,35,39,44]. In TSPLFD, anatomical reduction can be achieved by closed manipulation only in 67% of cases, and more than half of patients reportedly lose the anatomic position during the first 6 weeks of treatment despite adequate immobilization [39]. So, early surgical management is mandatory after closed reduction. Herzberg et al. [11] reported that perilunate injuries treated 6 weeks after injury showed significantly worse clinical outcomes. Budoff [45] suggested that surgery should be performed within the first week after injury. Two months after injury, surgical reduction may not be possible, and a salvage procedure should be considered after 4 months.

Many studies reported improved outcomes in patients who underwent open reduction and internal fixation (ORIF) compared to those treated with closed methods [4,28,35,45-47]. Many different open approaches to TSPLFD have been described, but there is still some debate regarding the surgical exposure [28,38,48,49].

The dorsal approach, which is the preferred open approach of the authors, allows for adequate visualization and accurate reduction of the carpus. The SL and LT ligaments can be directly repaired during reduction, and it is possible to evaluate stability of the SL and LT interval. With this approach, the volar ligamentous and capsular structures are indirectly reduced, which is sufficient for healing [11,35,45,50,51]. However, the volar approach is recommended when the lunate is dislocated in the volar direction and carpal tunnel release is required. The volar approach also enables direct repair of the volar aspect of the LT ligament and RSC [4,5,52]. The combined dorsal–volar approach offers the advantages of both and allows the surgeon complete visualization and dual access to all structures requiring repair [44,53,54]. However, some surgeons avoid volar incision as much as possible due to concerns of swelling, difficulties in wound closure, and slower recovery [11,45,51].

Although open surgery provides clear visualization of each injured component, it is obvious that open surgery introduces additional trauma to the already injured wrist. Surgical trauma can damage the blood supply to the scaphoid and torn ligaments [11,18,49,53,55]. With a conventional open procedure, there is greater exposure, more capsular and soft tissue scarring will occur, and postoperative fibrosis and stiffness will increase.

From this point of view, many surgeons recently described arthroscopic surgical techniques for TSPLFD [18,55-60] and the arthroscopic approach is preferred by the senior author [60]. Though technically challenging, arthroscopic reduction and internal fixation are possible and reliable for TSPLFD. Promising short-term results have been reported including improved postoperative ROM with less stiffness and short rehabilitation periods [18,55,59,60].

If LT joint reduction is hard to be achieved, single radiolunate Kirschner wire (K-wire) can be helpful. It reduces ulnar translation of carpus by fixing the keystone bone of carpus to radius [61]. When arthroscopy is unavailable or failed to achieve anatomical reduction, open approach should be used. A combination of arthroscopy and a dorsal mini-open approach can be used, either. The dorsal mini-incision can be made with enlarging the 3–4 portal with a horizontal skin incision. By using mini-V-shaped capsular incision, the DIC ligament can be preserved [18]. In author's opinion, arthroscopic technique is hard to be used in case of volar dislocation, scaphocapitate syndrome, severely comminuted carpal fracture, completely dislocation of lunate, and delayed cases. In such cases, it is better to implement an open approach.

SURGICAL TECHNIQUES

1. Anatomical reduction and fixation using dorsal approach (Fig. 7)

- With the patient in the supine position, the arm was prepped and draped on a hand table. A pneumatic tourniquet and Esmarch bandage were used to exsanguinate the arm.
- A 5-cm longitudinal incision was created on the dorsal aspect of the wrist in line with Lister's tubercle. The incision was extended down to the extensor retinaculum.
- The retinaculum was divided in line with the third dorsal

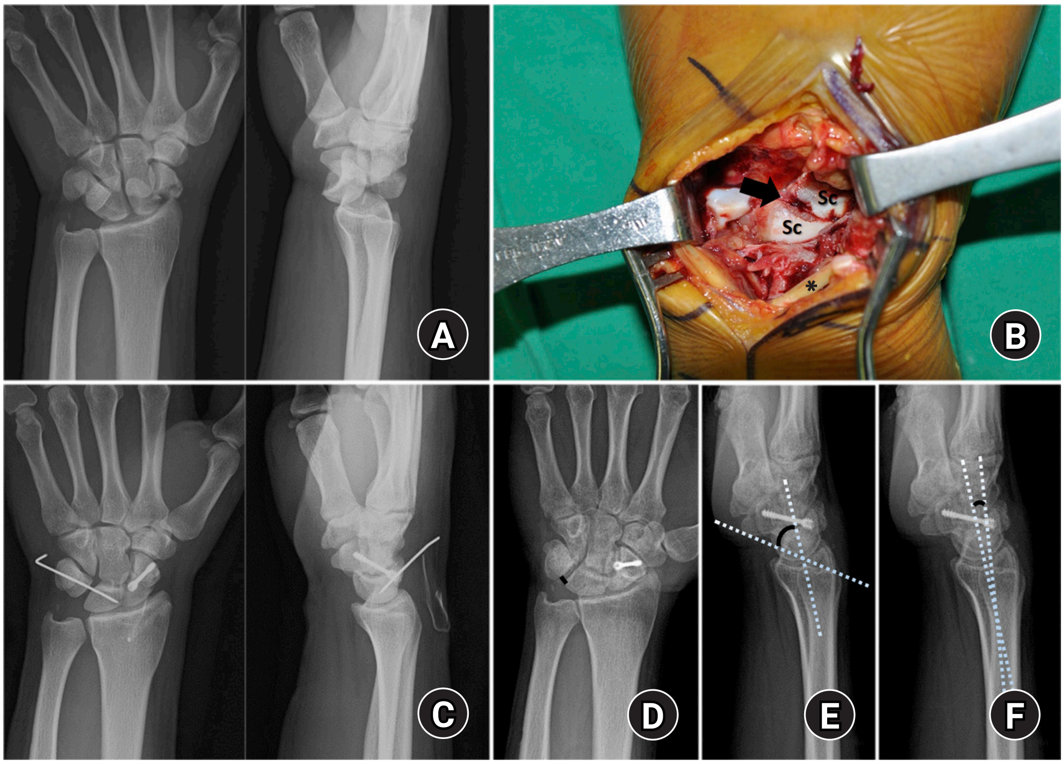

Fig. 7. Open reduction and fixation for trans-scaphoid perilunate fracture dislocation (PLFD). (A) Posteroanterior and lateral views of the preoperative radiographs of a 46-year-old man showing a dorsal trans-scaphoid PLFD of the left wrist. (B) Approaching on the dorsal aspect of the wrist, the extensor pollicis longus tendon (asterisk) is retracted radially, and the scaphoid (Sc) fracture is shown with a displacement (arrow). Sc, scaphoid. (C) The postoperative radiographs show proper fixation and normal carpal alignment. (D-F) The radiological measurements after 2 years postoperatively identify 2.0 mm of lunotriquetral distance (D), 56.0° of scapholunate angle (E), and 4.6° of radiolunate angle (F). Reprinted from Oh et al. [60] with the permission of Elsevier.

compartment, and the extensor pollicis longus tendon was identified distally and retracted radially.

- The second and fourth compartments were then reflected off the dorsal capsule. A capsulotomy was created and extended longitudinally.
- Bone or cartilage fragments were removed from the joint, which was irrigated to remove any hematoma or other debris.
- The scaphoid fracture was reduced using percutaneous joystick K-wires, and the guidewire for headless screw fixation was introduced along the long axis of the scaphoid.
- After reaming, a headless compression screw (either an HCS 3.0 [Synthes, West Chester, PA, USA] or a Herbert mini screw [Zimmer, Warsaw, IN, USA] system) was inserted over the guidewire. The authors prefer cannulated headless screws over K-wires for scaphoid fracture fixations.
- The LT joint was reduced and percutaneously pinned from the ulnar side of the wrist.
- Capsulotomy incision was closed with interrupted absorbable 2-0 or 3-0 sutures.
- The retinaculum was repaired, leaving the extensor pollicis longus free distally but still within its compartment proximally. The skin was then closed with nylon sutures.

2. Arthroscopic-assisted reduction and fixation (Fig. 8)

- The patient's arm was suspended in an Arc Wrist Tower (Acumed, Hillsboro, OR, USA) with 5 to 8 kg of traction after

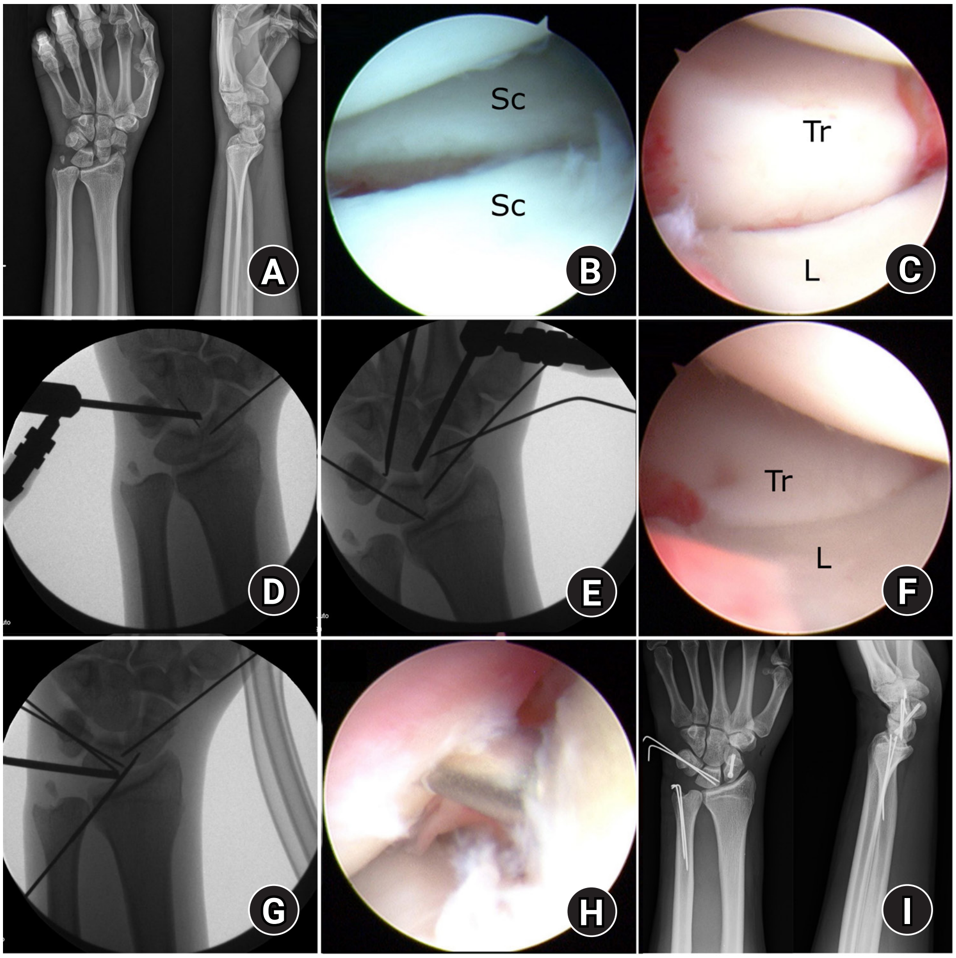

Fig. 8. Arthroscopic-assisted reduction and fixation for a trans-scaphoid perilunate fracture dislocation (PLFD). (A) Posteroanterior (PA) and lateral views of the preoperative radiographs of a 21-year-old male showing a dorsal trans-scaphoid PLFD of the left wrist. (B, C) An arthroscopic photo viewed from the ulnar midcarpal portal, showing a scaphoid fracture and instability of the lunotriquetral joint. (D) The scaphoid fracture was reduced with manipulation of the distal fragment using an 18-gauge needle. Then a Kirschner wire was inserted from the scaphoid tubercle and passed through the fracture site for temporary fixation. (E) The lunotriquetral joint was reduced using a probe and percutaneously pinned from the ulnar side of the wrist. (F) The lunotriquetral joint was well reduced after pinning. (G, H) The optimal starting point for screw fixation of the scaphoid is targeted using the arthroscope and fluoroscope. (I) The postoperative PA and lateral views showing proper fixation and normal carpal alignment. L, lunate; Sc, scaphoid; Tr, triquetrum.

placing the index, middle, and ring fingers in finger traps.

- A 3–4 portal, 6 radial (6R) portal, and midcarpal ulnar portal were sequentially created, and a 1.9-mm video arthroscope was introduced through each portal.
- While using the midcarpal ulnar portal as the viewing portal, an STT portal or midcarpal radial portal (depending on the scaphoid fracture level) was created under direct vision as the working portal to facilitate the approach (Fig. 8B, 8C).
- If present, bone or cartilage fragments and frayed edges of torn intrinsic or extrinsic ligaments that interrupted reduction were thoroughly debrided or removed to facilitate reduction of the scaphoid fracture or LT joint.
- After releasing longitudinal traction, the scaphoid fracture was reduced with manipulation of the distal fragment using a probe, 18-gauge (G) needle, or percutaneous joystick K-wire under guidance from arthroscopic and fluoroscopic images.
- A K-wire was subsequently inserted from the scaphoid tubercle and passed through the fracture site for temporary fixation (Fig. 8D).
- After the arthroscopy switched into the STT or midcarpal radial portal, the LT joint was reduced using the same method and percutaneously pinned from the ulnar side of the wrist, starting at a point dorsal to the pisiform and aiming in a slight proximal direction (Fig 8E, 8F).
- The arthroscope was introduced into the 6R portal to insert a guidewire for headless screw fixation of the scaphoid fracture.
- The guidewire was percutaneously inserted through a 15-G needle, proximal and ulnar to the 3–4 portal, to target the ideal starting point at the most proximal tip of the scaphoid pole, immediately adjacent to the insertion of the SL interosseous ligament along the long axis of the scaphoid (Fig. 8G, 8H).
- After removal of the provisional K-wire, a 5-mm transverse incision was made at the point of the prepositioned guidewire.
- A sharp, straight hemostat was used to spread the soft tissue and pierce the dorsal capsule.
- After reaming, a headless compression screw (either a Synthes HCS 3.0 or Acutrak mini screw system [Acumed]) was inserted over the guidewire to fix the scaphoid fracture.

REHABILITATION

A sugar-tong splint was placed postoperatively, with the wrist and forearm in the neutral position. All patients were encouraged to initiate immediate digital exercises to reduce swelling. At the first postoperative visit at 2 weeks, a well-molded short arm cast that held the wrist in a functional position was fashioned and worn for 6 to 8 additional weeks. The short arm cast and K-wires transfixing the LT joint were removed 6 to 8 weeks postoperatively, then active-assisted wrist movement exercises were encouraged.

DISCUSSION

As closed reduction and immobilization cannot reliably maintain carpal alignment, surgical treatment is essential [39,44]. ORIF has become a gold standard, but the arthroscopic treatment is clearly the way to go [49,50]. Arthroscopic reduction expects to limit the soft tissue injury associated with a surgical procedure and may encourage good operative outcome with less stiffness [49]. By using standard portals, the operator can get more information of wrist in larger magnification in a few minutes, assessing intra-articular pathology without deep dissection or long incision. Debridement of the joint and fracture site can be immediately started.

The first cases of arthroscopic treatment for PLD were reported by Savoie and Grondel [62] in 1995. Since then there have been steady reports confirming the feasibility of this future-oriented treatment. In 2005, Park and Ahn [56] reported arthroscopically assisted reduction combined with percutaneous K-wire fixation followed by 12 weeks of immobilization in three cases of TSPLFD. In 2010, Jeon et al. [57] reported arthroscopically assisted percutaneous screw fixation and cancellous chip olecranon bone grafting followed by 4 weeks of immobilization in four cases of TSPLFD. The follow-up period of these two small series was similar at about 18 months, and all patients showed normal radiographic findings and there was no evidence of instability or arthritis.

In 2012, Kim et al. [58] reported purely arthroscopic reduction and fixation technique, in 15 TSPLFD and five PLD type IIA, followed by 10 weeks of immobilization. At a mean follow-up of 31.2 months, the mean modified Mayo wrist score was 79, and the flexion-extension motion arc and grip strength of the injured wrist averaged 79% and 78%, respectively. Two of the 15 TSPLFDs developed scaphoid nonunion that were fixated with K-wires, one of the two underwent scaphoid excision and midcarpal fusion.

In 2015, Herzberg et al. [18] reported 27 patients treated with arthroscopic assistance, but only four patients were TSPLFD. All TSPLFD patients showed normal radiographic findings in a mean of 27-month follow-up. In the authors' technique, dry arthroscopy with the adjunct of “automatic washout,” which is simultaneous automatic shaver suction of a volume of fluid equal to the whole water syringe content, was used for all patients. In this way, severe swelling and compartment syndrome caused by excessive use of irrigation fluid in TSPLFD patients with high-energy injury expect to be reduced.

In 2015, Liu et al. [55] reported 20 TSPLFD and four dorsal PLD type IIA, treated with arthroscopically assisted mini-invasive reduction and screw fixation, followed by 8 weeks of immobilization. At a mean follow-up of 14.8 months, The mean modified Mayo wrist score was 86, and the flexion-extension motion arc and grip strength of the injured wrist averaged 86% and 83%, respectively. The reported average operation time was 170 minutes. Among the 20 TSPLFD, nonunion of the scaphoid developed in only one, but the patient did not want further treatment and functioned well. In this study, the author discussed that the reason for the low nonunion is that the arthroscopic technique has less influence on the scaphoid blood supply and that the screw has better mechanical strength than K-wire. At a mean time of 4.9 months, all patients were able to return to their preinjury occupations.

In 2017, Liu et al. [59] published another similar paper. The mean operation time was shortened to 155 minutes. The authors argued that arthroscopic management is a favorable alternative in the treatment option to encourage healing with less stiffness as a key point in the paper.

In 2017, our research team reported on 11 dorsal TSPLFDs treated with arthroscopic-assisted reduction and internal fixation and nine patients with ORIF through a dorsal approach who were reviewed at an average of 2-year follow-up [60]. Though a small number of patients and a low statistical power were limitations, this was the first retrospective comparative study. With regard to comparison of the active flexion-extension arc, modified Mayo wrist score, and disabilities of arm, shoulder, and hand (DASH) score, the arthroscopic procedure seems to have an advantage over the open procedure. In the arthroscopic group, the mean grip strength was 81.1% that of the contralateral side, the mean Mayo wrist score was 85.5, and there was no scaphoid nonunion. As inclusion and exclusion criteria are different from studies, the outcome can differ. We excluded complicated types of PLFDs and missed or delayed cases, which can be the reason for better clinical outcomes compared with previous studies [56-58]. We used a headless compression screw rather than K-wires, which can be another reason for better outcomes [58,63].

Wong and Ip [64] described the use of minimally invasive management with only fluoroscopic guidance. They reported about 21 cases of TSPLFD, an average of 3 years of follow-up, there was only one nonunion and another one carpal malalignment. However, this approach may oversimplify the complex nature of TSPLFD, and carpal ligament evaluation is limited. As the removal of the loose body and soft tissue interposition is impossible which results in carpal gapping, the technique should be considered in very limited indications.

There are no long-term follow-up reports about the arthroscopic managed TS-PLFD. In open techniques, the reported incidence of carpal arthritis following open surgery ranges from 18% to 22% within 3 years but increases to 50% to 100% with follow-up periods of 6 to 13 years [44,46,53,63].

In our study, carpal arthritis was noted after a mean follow-up period of 4 years in 36% and 33% of patients who underwent open and arthroscopic surgery, respectively. Kim et al. [58] reported no carpal arthritis at a mean follow-up of 31.2 months after using the arthroscopic technique. Other arthroscopic studies stated that arthritis did not occur, but the follow-up period was shorter [18,55]. The incidence of radiologic arthritis and clinical outcomes are not proportional, and longer follow-up is required to evaluate this issue [53,60].

CONCLUSIONS

TSPLFDs are rare high-energy injuries, but the diagnosis is frequently missed. A clear understanding of pathoanatomy and pathomechanics will be of great help when assessing patients with these injuries. Proper evaluation and appropriate early surgical management are important to achieve optimal outcomes. ORIF is the standard approach for this injury, but an arthroscopy is attractive future-oriented technique seams to provide better short-term outcome with less stiffness, although long-term follow-up data are needed. The screw shows better mechanical strength than K-wire, and if comminution is severe, additional K-wire can be used.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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주상골 경유 월상골 주위 골절 탈구

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월상골 주위 골절 및 탈구는 고에너지 손상으로 인하여 발생하는 것으로, 젊은 환자에서 주로 발생한다. 이중 주상골-경유 월상골 주위 탈구 및 골절은 절반 이상의 빈도를 차지하며, 수상 초기에 적절하게 치료하지 못하면 손목의 기능에 지대한 저하와 변형을 초래하게 된다. 정확한 진단을 위해서는 손목의 골과 인대에 대한 해부학적 지식과 손상 기전을 이해하는 것이 필요하다. 진단 후에는 최선의 임상적, 방사선적 결과를 도모하기 위해서 조기에 수술을 통한 해부학적 정복과 안정적 고정이 필수적이다. 본 종설에서는, 월상골 주위 골절 및 탈구, 특히 주상골-경유 월상골 주위 골절 및 탈구의 해부학적 이해와 그 진단, 치료 방법과 임상 결과에 대해 기술하고자 한다. 특히, 최근 들어 각광받고 있는 관절경을 이용한 수술 방법과 그 결과를 관혈적 수술 방법과 같이 논하고자 한다.

색인단어: 손목 손상, 주상골 경유 월상골 주위 골절 탈구, 국소 해부학, 정형외과적 수술, 관절경 수술

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