Axial Dislocations or Fracture-Dislocations

10

10.1 Introduction

The first radiological description of a true axial dislocation of the wrist is attributed to Oberst in 1901 (cited by Shin [1]) and in the same year to Eigenbrodt [2]. The former described a case of axial-ulnar dislocation, while the latter, a case of severe crush injury to the hand that was associated with dislocation of the hamate.

The term "axial-loading dislocation" was first used by Cooney et al. [3] to emphasize that in these cases the wrist is disorganized in a direction almost parallel to the long axis of the forearm. Other terms used to describe this injury are: "carpal arch disruption" [4], "capitohamate diastasis" [5], "longitudinal disruption" [6], "crush injury of the carpus" [7], and "columnar dislocation" [8].

When the wrist is subjected to compressive high energy force in dorsopalmar direction, the resulting derangement is frequently not random, but predetermined, with the wrist being divided into two or more columns. At the same time, the metacarpals usually follow the displacement of the corresponding carpal bones causing an intermetacarpal derangement. While the transverse carpal arch widens, the transverse ligament of the wrist is either ruptured or detached from its attachments [9, 10].

Garcia-Elias et al. [8] defined axial fracture-dislocation as the longitudinal carpal and intermetacarpal derangement of the wrist, which is associated with rupture or avulsion of the flexor retinaculum. Chim et al. [11] defined axial carpal dislocation as the global disruption of the proximal (carpal) and distal (metacarpal) transverse arches of the hand with the carpus split and longitudinally displaced.

10.2 Incidence

Axial dislocations of the wrist are relatively rare injuries as, since the first radiological report in 1901 until today, approximately 72 cases have been published in the literature [12], the majority of which are case reports [11–17]. The increasing number of industrial accidents and the increased recognition of wrist injuries, will certainly result in more frequent diagnosis of such injuries.

The largest series that has been published until now, comes from Mayo Clinic with 16 cases, that is 1.4 % of all patients with fracture-dislocation of the carpus (1,140 patients) [18]. Until then, the maximum number of patients reported in a series was 4 patients [4, 6, 19]. However, in developing countries where security measures are loose and industrial accidents more frequent, this percentage increases to 2.08 % [7].

10.3 Mechanism of Injury

Most axial dislocations are industrial injuries. A crushing, explosive, or rotational mechanism usually brought upon by machinery such as a

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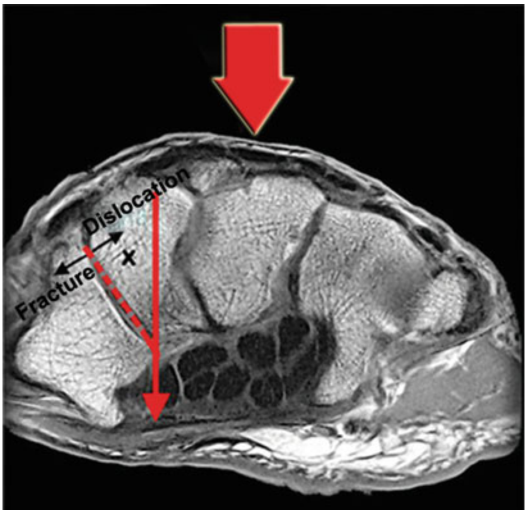

Fig. 10.1 The X angle is the angle formed between the applied force and the joint surface plane of the distal row bones. A smaller angle increases the possibility of a dislocation, while a larger angle increases the possibility of a fracture. With permission from [50]

roller or a molding press [1, 9, 20] is considered responsible for such injuries. In some cases, a direct strike by a blunt object (e.g., piston) [21] may also be implicated. The force exerted on the wrist usually has a dorsopalmar direction and the resulting injury following the application of compressive force, depends upon:

1. The angle formed by the applied force and the plane of joint surfaces of the distal carpal row. The smaller the angle, the higher the chances for a dislocation to occur, whereas the bigger the angle is, the greater becomes the possibility of a fracture at the sagittal plane [1, 10] (Fig. 10.1).
2. The magnitude, the speed, and the point of force application.
3. The relative strength of bones and ligaments.

There are however in the literature isolated cases of combined injuries of axial disruption and perilunate wrist injuries, for which a compressive and simultaneously dorsal hyperextension mechanism is implicated [22, 23].

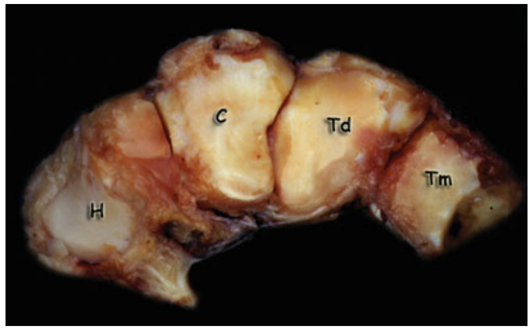

Fig. 10.2 The distal carpal row bones are positioned like stones in an arch (distal joint surfaces of the distal carpal row as seen from the side of the metacarpals). With permission from [50]

10.4 Biomechanics

In the transverse plane the carpal bones of the distal carpal row align in a semicircular, palmarly concave arch. The highly intrinsic stability presented by the distal carpal row is due not only to the interosseous ligaments (see Anatomy section), but also to its peculiar anatomy in which the bones fit together like stones in an arch where the capitate bone is the keystone (Fig. 10.2). Although it is subjected to a small rotational motion among the distal carpal row bones [24, 25], the distal row along with the 2nd and 3rd MC are regarded as the fixed unit of the hand.

The main stabilizing elements in the transverse coherence of the distal carpal row bones, are the interosseous ligaments and particularly the capitohamate ligament, which fails at an average of 252 N [8]. Conversely, the ultimate strength of each one of the remaining distal row interosseous ligaments ranges from 110 to 145 N. (Fig. 10.3). Since the capitohamate ligament has the highest ultimate strength, one would expect that axial disruptions would more often concern the radial side of the wrist. In the literature, however, axial disruptions of the ulnar side of the distal carpal row (between capitate-hamate) are not rare at all. On the contrary, out

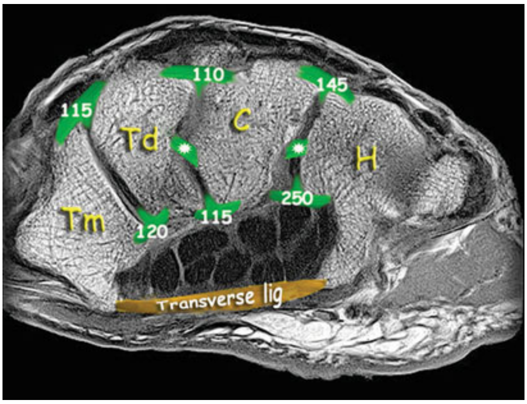

Fig. 10.3 The strength (N) of the palmar and dorsal distal carpal row ligaments (approximate values) (*Tm* Trapezium, *Td* Trapezoid, *C* Capitate, *H* Hamate). The asterisks indicate the deep part of the capitohamate and trapezoid-capitate ligaments. With permission from [50]

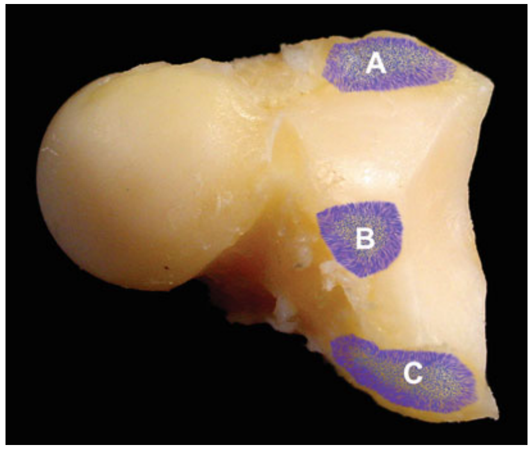

Fig. 10.4 The areas of adhesion of the capitohamate ligament at the surface of the capitate facing the hamate. **a** Dorsal part. **b** Deep part. **c** Palmar part. With permission from [50]

of the 40 cases mentioned before 1989, the 23 involved the ulnar side of the wrist [19, 26].

Ritt et al. [27] found up to 12° rotation at the capitohamate joint, which is stabilized by 3 ligaments: the dorsal, the palmar, and the deep interosseous ligaments. Failure testing showed the deep ligament was strongest at 289 N, followed by the palmar at 171 N and the dorsal at 133 N. (Fig. 10.4). The authors considered the capitohamate as the strongest joint of the wrist, supporting that it is not surprising that capitohamate dissociation was evident in only 3 out of 16 cases in the series of Garcia-Elias et al. [18].

Some authors [28, 29] have supported the crucial role of the transverse carpal ligament in the coherence of the carpal arc. Although sectioning of the transverse ligament may increase the width of the carpal tunnel (distance between the ridge of the trapezium and the hook of the hamate) up to 11 % or reduce the grip strength [30, 31], the dynamic behavior of the transverse carpal arc is not altered [30, 32]. Even though the strength of the transverse carpal ligament is greater than that of any carpal ligament (withstands 343 N), it has small axial tensile stiffness (131 N/mm) and its contribution to the transverse coherence of the wrist does not exceed 7.5 % of the total strength [8]. Despite these, Shin [1] expressed the opinion that in cases of injury of the palmar interosseous ligaments of the distal carpal row, repairing the transverse carpal ligament can possibly restore to some extent the stability of the transverse arc.

10.5 Clinical Presentation

Patients with traumatic axial fracture-dislocations typically present severe soft tissue damage, ranging from marked swelling and tenderness, to partial or total denudation of the hand from soft tissues. Intrinsic muscles are often severely damaged; thenar muscles (more frequently) and hypothenar muscles (less commonly) are damaged at varying degrees [7]. Often extensor or flexor tendon ruptures coexist and neurovascular injuries are often present. Vascular injuries with rupture of the radial or ulnar artery or both, are not common. More frequent are nerve injuries, ranging from transient neuroapraxia to axonotmesis.

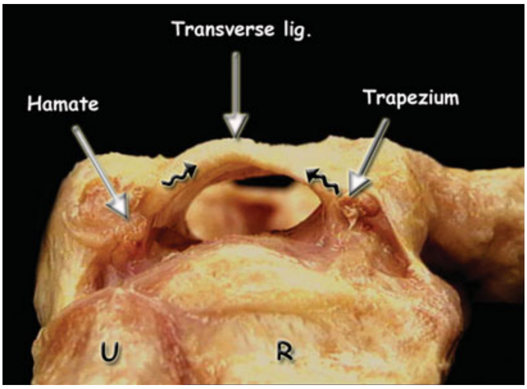

Fig. 10.5 The carpal tunnel, the transverse ligament and its attachments to the hamate and the trapezium, as seen from the proximal surface. With permission from [50]

Other frequently associated fractures are: the trapezial ridge, hook of the hamate, metacarpals, phalangeals, carpal bones or the distal radius [10, 33]. Also frequent are the dislocations of the carpometacarpal joints, while rotational deformity of the fingers is also a common clinical finding. The prevalence of acute carpal tunnel syndrome is rare, due to the traumatic decompression of the carpal tunnel that occurs with the rupture or avulsion of the transverse ligament from the hook of the hamate or the ridge of the trapezium [18] (Fig. 10.5).

Despite the rarity of reports, there certainly are cases of partial or complete rupture of distal carpal row interosseous ligaments and which manifest as chronic wrist pain due to the difficulty in diagnosing such injuries [34].

10.6 Imaging Studies

Unless there is gross disruption of the carpus, in standard radiographic views the following findings are assessed: loss of parallelism between the articular surfaces of the distal row, while diastasis or overlapping of the articular surfaces are findings suggesting subluxation or dislocation of the bones.

Breaks in Gilula's arcs are also evaluated and suggest disruption of the smooth contour of the proximal articular surfaces of the distal carpal row. It is also possible that the longitudinal axis of the affected metacarpal shafts may lack the normal parallelism to the unaffected metacarpal shafts. The lateral view reveals the direction of the dislocation and associated fractures. Traction radiographs often delineate the extent and nature of associated bony pathology [1].

Avulsion fracture of the hook of the hamate and/or the fracture of the ridge of the trapezium may be considered as indirect radiological findings indicative of the axial disruption of the wrist [33].

When in doubt, CT scans or trispiral tomography may possibly assist in the clarification of the injury.

10.7 Classification

In the classification of carpal instabilities, axial disruption of the distal carpal row belongs to the dissociative type of instabilities (CID). The spectrum of axial carpal instability ranges from acute, gross traumatic fracture dislocation with severe soft tissue trauma to chronic, dynamic instability between the axial components of the carpus [1]. In chronic cases, if the carpal derangement is evident on plane radiographs, then the case is considered as "static axial instability", while if the derangement can be diagnosed only under certain loading conditions, the term "dynamic axial instability" is used [10].

Although axial disruption of the wrist, in the majority of cases, is presented with an obvious clinical and radiological picture, in the literature at least one case of dynamic axial dissociation has been reported, due to isolated rupture of the capitohamate interosseous ligament [34]. The patient remained undiagnosed for several months complaining of ulnar wrist pain, as all examination methods were normal. The diagnosis was finally established arthroscopically (through the midcarpal ulnar portal), where a complete loss of integrity of the capitohamate interosseous ligaments was observed. The patient was treated successfully with a capitohamate fusion.

A similar case from the personal archive, involved a patient with radial wrist pain who remained undiagnosed for 6 months. It was found to be a case of dissociative instability (CID), concerning the distal carpal row and particularly the trapezium-trapezoid joint, the interosseous ligaments of which were ruptured. Clinically, a clunking associated with the appearance of a sulcus to the radial side of the wrist, during active radial deviation, was noticed (Fig. 10.6a–g).

As incomplete cases of axial dissociation of the wrist following the application of compressive forces can be considered, the avulsion of the transverse ligament from its attachments (hook of the hamate and ridge of the trapezium) as an isolated injury [35] or in combination with fracture at the body of the trapezium in the frontal plane [36] or dislocation of the hamate combined with fracture of the palmar ridge of the trapezium [37].

After reviewing the literature and adding 16 new cases, Garcia-Elias et al. [18] classified axial dissociations of the wrist into three types, according to the direction of instability:

10.7.1 Axial-Ulnar Dislocations

The carpus splits into two columns in which the radial column is stable with respect to the radius whereas the ulnar column displaces proximally and ulnarly. The fourth and fifth metacarpals are displaced along with the ulnar column. Depending on the path of injury, these injuries are adequately described by using the term "trans" to indicate fracture and the prefix "peri" to express dislocation.

The most common axial-ulnar dislocation involves the pisiform and the hamate, identified as a peri-hamate, peri-pisiform axial-ulnar dislocation [4, 16, 19, 20, 38]. Less common types of axial-ulnar dislocations that have been reported, are: the trans-hamate axial-ulnar dislocation [15], the trans-hamate peri-pisiform [16, 19], the peri-hamate dislocation with fracture of the hook of the hamate [14], the peri-hamate, peri-pisiform, trans-triquetrum with fracture of the hook of the hamate [21], the peri-hamate trans-triquetrum fracture dislocation [13, 19, 39], and the peri-hamate, peri-triquetrum axial-ulnar dislocation [6, 10, 26]. The most common types of axial ulnar dislocation injuries and their terminology are shown in Fig. 10.7a–d.

10.7.2 Axial-Radial Dislocations

In this type the ulnar column of the wrist maintains its relation to the radius, while the radial column is displaced proximally and radially. The first or also the second metacarpal follows the displaced radial column of the wrist. The most common type of axial-radial dislocation is the peri-trapezium dislocation, followed by the peri-trapezium, peri-trapezoid, and the trans-trapezium axial dislocations (Figs. 10.8a–c, 10.9a–e). Spreading of the applied force to the proximal carpal row could injure the ligamentous support of the scaphoid, leading to a complex scaphoid dislocation [40–43].

10.7.3 Combined Axial Radial-Ulnar Dislocations

In this rare type of injuries, only the central column of the wrist maintains its relation to the radius, whereas both the radial and ulnar columns are dissociated and proximally displaced (Fig. 10.10). Only few such cases have been reported in the literature [4, 16, 18, 44–47] while the case presented by Irwin [22] was considered as a variant of the combined axial radial-ulnar disruption. In two cases from the personal records, as well as the case presented by Dobyns and Linscheid [45], the carpus separated into two columns with the central part also being dissociated (Figs. 10.11a–c, 10.12a–e). These cases possibly constitute a separate type of injuries.

Literature review by Garcia–Elias et al. [18] revealed 40 cases of axial dissociation of the wrist with adequate information about radiologic

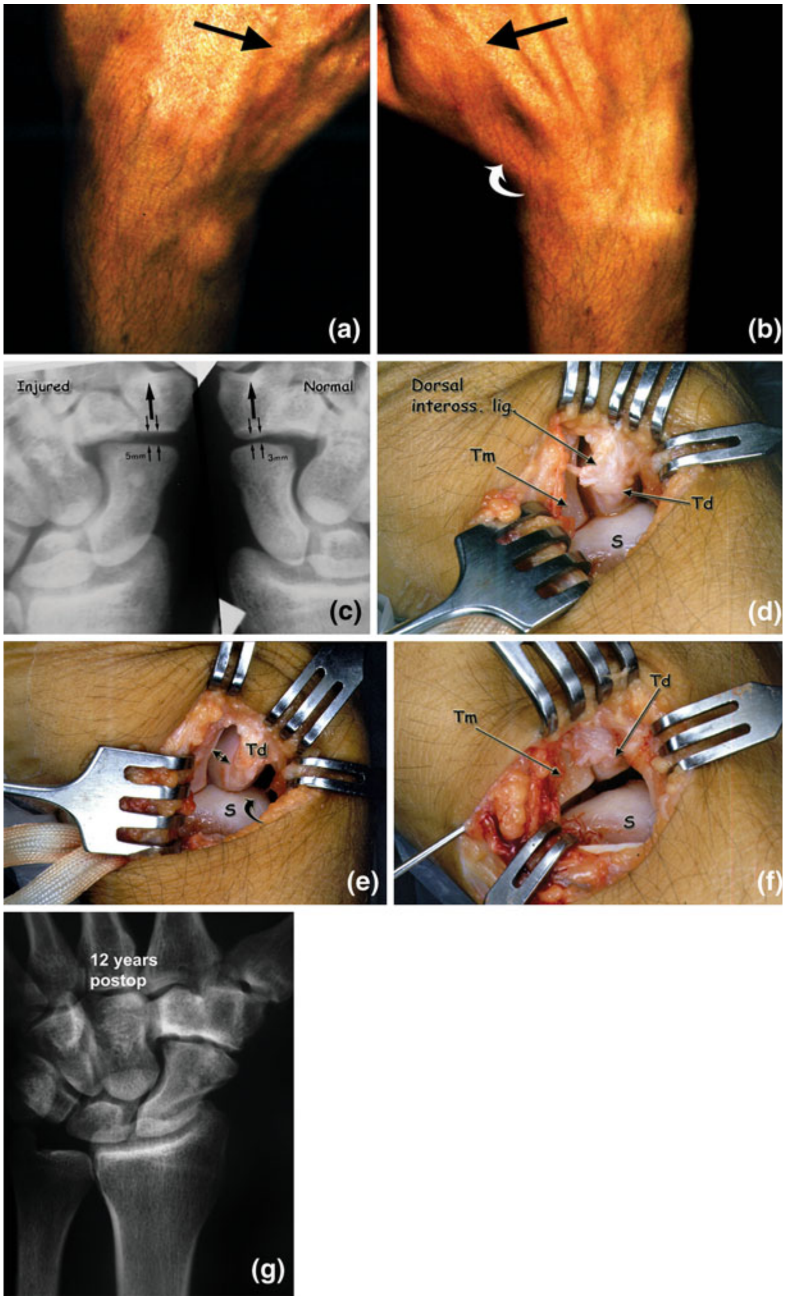

Fig. 10.6 A 25-year old male, fell from height. He presented with radial wrist pain, which did not respond to the conservative treatment administered, while radiological imaging was negative. Six months later he was still undiagnosed with anatomic snuffbox sensitivity, while during active radial deviation he presented with sudden palmar collapse of the radial half, accompanied by a clicking sound and the appearance of a sulcus in that area. The wrist in ulnar deviation (**a**) and in radial deviation with the sulcus being evident (**b**). In comparative, under traction X-rays of the injured wrist a step between the trapezium and trapezoid was observed (**c**). With the wrist in neutral position, the subluxation of the trapezoid and rupture of the dorsal interosseous ligament were evident (**d**). With the wrist in radial deviation the subluxation was exacerbated, whereas the distal pole of the scaphoid "sunk" ulnovolarly (**e**). The patient was successfully treated with fusion of the trapezium–trapezoid bones (**f**); final radiographic appearance after 12 years (**g**). (*Tm* Trapezium, *Td* Trapezoid, *S* Scaphoid). With permission from [50]

features. The same author added 16 new cases, and if we include the 13 cases presented by Pai and Wei [16], the 4 cases presented by Primiano and Reef [4] and the 2 of 3 cases presented by Norbeck et al. [6], the total of 75 cases allow us to estimate the distribution of these injuries. Thirty six of these cases were of AU type, 33 cases were of AR type and 6 cases were of combined AR-AU type. According to the above, the frequency of dissociation of the radial and ulnar columns of the wrist is approximately the same, while the combined AR-AU type is the most unusual.

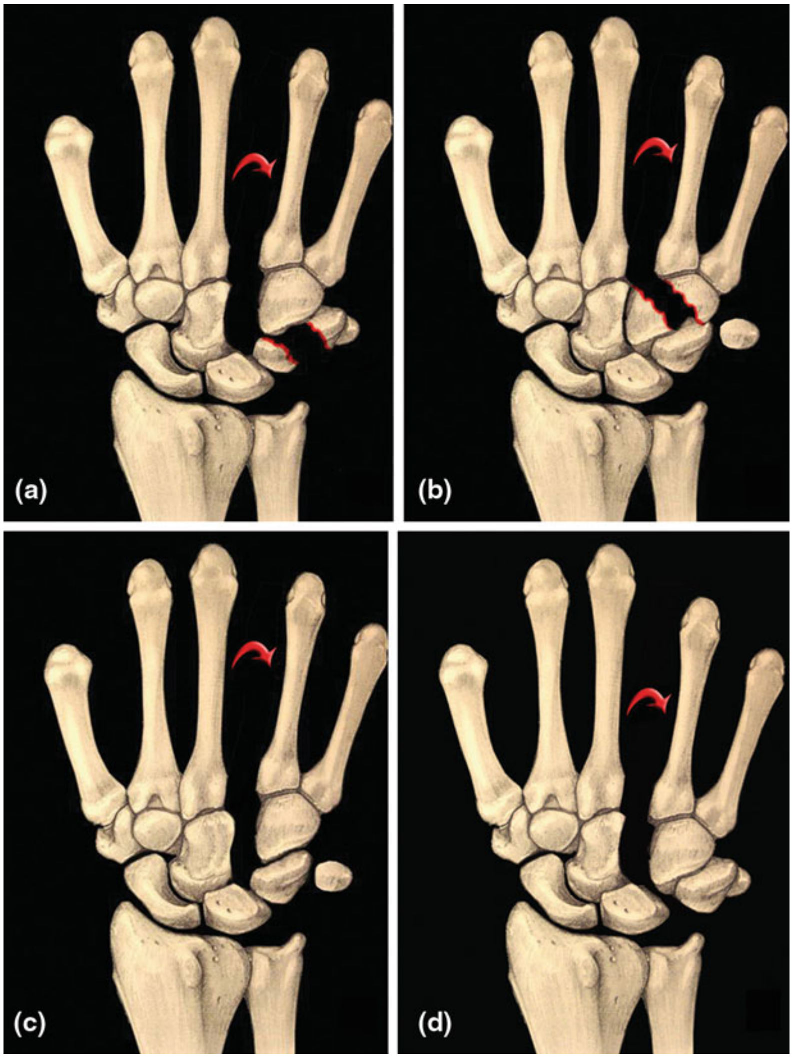

Fig. 10.7 Axial-ulnar dislocations: Peri-hamate, Trans-triquetral (**a**); Trans-hamate, Peri-pisiform (**b**); Peri-hamate, Peri-pisiform (**c**); Peri-hamate, Peri-triquetral (**d**). With permission from [50]

The clarification of dissociated metacarpals is necessary to be included in terminology because the path of injury, proximal to the base of the metacarpals, is not always on the same side with the metacarpals dissociation. Häcki et al. [12] reported a case with dissociation between the third and fourth metacarpals while proximally the injury progressed radially with fractures of the capitate and trapezium and dislocation of the trapezoid. A similar case was reported by Horton et al. [41] in which the dissociation between the third and fourth metacarpals was associated with disruption between capitate and hamate and proximally with scapholunate dissociation leading to a complex dislocation of the scaphoid [42]. Garcia-Elias [10] stated that this injury fulfills the criteria of an axial-radial dislocation.

A particular type of injuries are the cases reported, where the axial disruption of the wrist is associated with dislocation of the lunocapitate joint, as these cases constitute a variant between axial and perilunate dislocation [17, 23, 41, 48].

10.8 Differential Diagnosis

Differential diagnosis of axial dislocations must be made from perilunate and isolated dislocations of the carpal bones [10]. Concerning perilunate injuries the differential diagnosis is

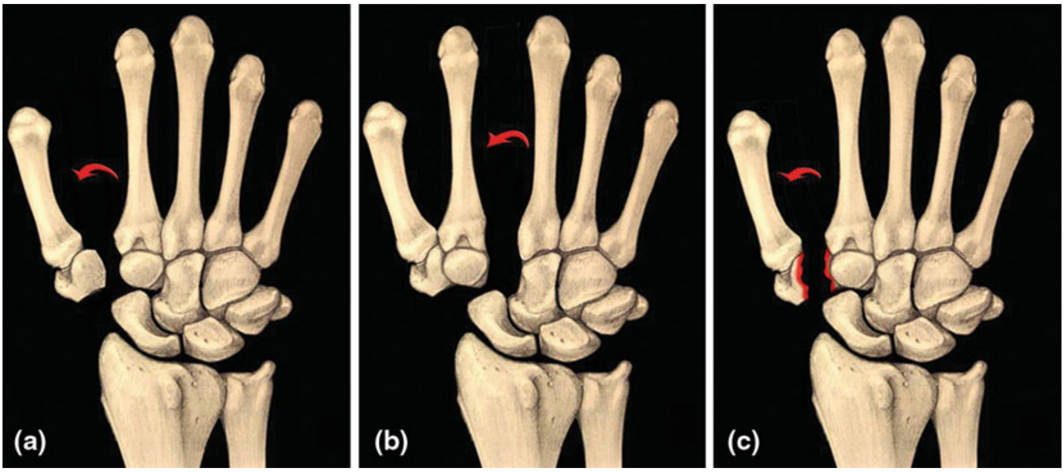

Fig. 10.8 Axial-radial dislocations: Peri-trapezium (**a**), Peri-trapezium, Peri-trapezoid (**b**), Trans-trapezium (**c**). With permission from [50]

associated with: (a) *the mechanism of injury*, where axial dislocations arise following the application of direct crushing force, while the perilunate dislocations are the result of indirect force (hyperextension, axial rotation and lateral deviation of the wrist); (b) *the path of injury*, where in axial dislocations follows a longitudinal pattern of disruption, whereas in perilunate dislocations the injury presents a progressive perilunar pattern of instability; (c) The *acute carpal tunnel syndrome* is common in perilunate injuries, while axial disruption implies a traumatic decompression that occurs with discontinuity of the flexor retinaculum. The nerve dysfunction in axial dislocations is related to the direct blow or to the associated soft-tissue swelling; and (d) *Soft tissue damage,* which is common in axial dislocations, but rare in perilunate dislocations.

Regarding isolated dislocations of carpal bones, when a localized force is concentrated over a single bone, a localized dislocation or fracture-dislocation may be caused which however is not truly an axial disruption, as there is no global carpal and metacarpal disruption and the flexor retinaculum does not appear disrupted.

10.9 Management

The majority of axial carpal dislocations are open injuries with significant associated soft tissue injuries. Treatment depends on whether the injury is open or closed and upon the extent of damage of the osseous structures and soft tissues. However, the role of nonoperative treatment in axial injuries of the carpus is limited. Careful evaluation of the condition of the neurovascular and musculotendinous units must be performed. Early and accurate diagnosis of the soft tissue and bony injuries is necessary, as delayed treatment from incorrect diagnosis is much less successful than early treatment. Injury to the soft-tissues may be severe enough to warrant fasciotomies of the volar and dorsal compartments of the forearm and hand if compartment syndrome is present or suspected throughout the perioperative period [1, 49]. We often need to put priorities in addressing these injuries. Failing to manage the osseous injuries adequately, could result in flattening of the palm, spread of the carpometacarpal arch, weakness and motion restriction [4, 45]. If soft tissue loss is significant and there is crushing, swelling,

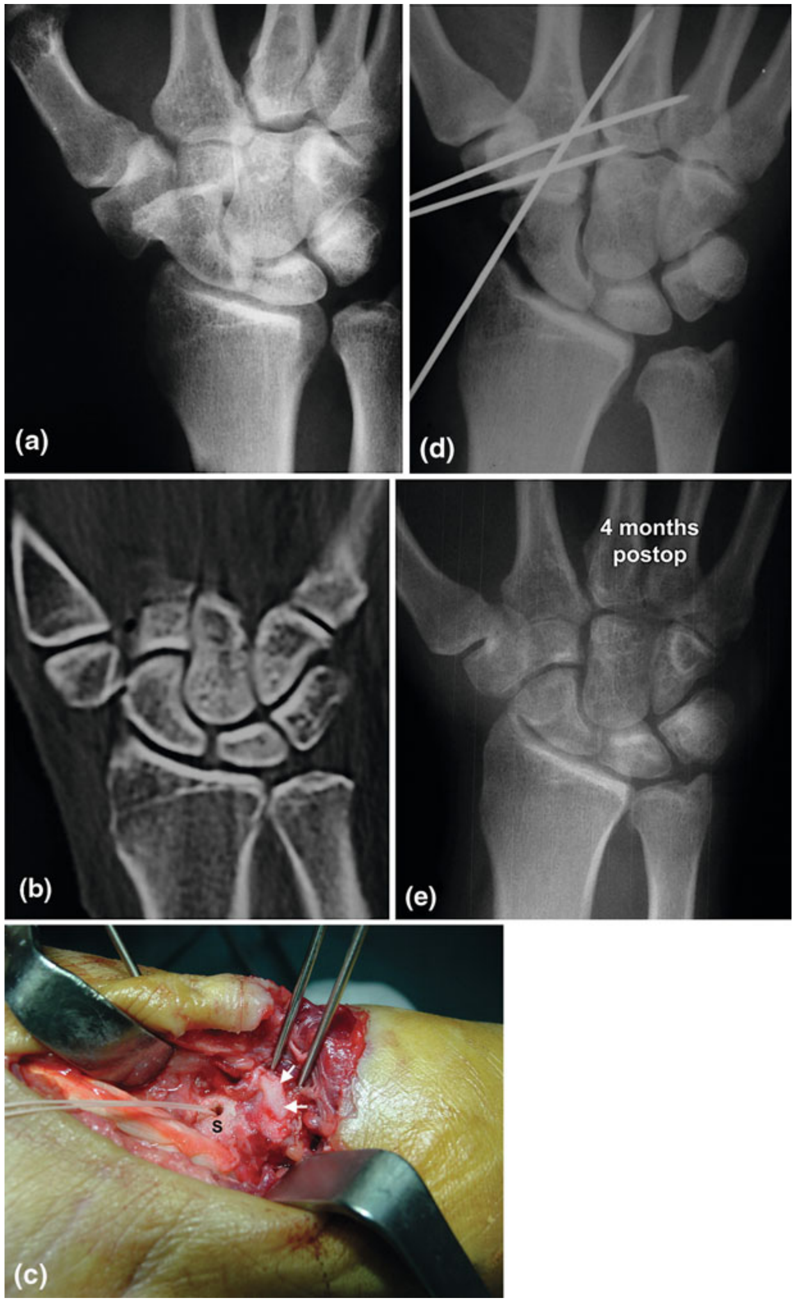

Fig. 10.9 Male, 39 years old. Motorcycle accident. A case of peri-trapezium dislocation (**a**); the CT scan image (**b**); during exploration, the rupture of the STT ligament was apparent (*arrows*). It was reconstructed using a bone anchor inserted at the scaphoid (**c**); fixation using K-wires between trapezium-trapezoid and STT joint (**d**); final X-rays 4 months postoperatively (**e**)

secondary contamination and infection, this may exclude the opportunity to reduce the fracture as a primary or secondary procedure [45].

Preoperatively, intravenous antibiotic and low molecular weight dextran are administered. Extensive debridement of necrotic or non-viable tissues is required, while primary suturing of the wound is rarely necessary or desirable. Surgical treatment also involves restoration of neurovascular and musculotendinous structure damage, as well as immediate skin defect coverage with local or free tissue flaps.

Fig. 10.10 Schematic depiction of the combined axial radial-ulnar dislocation. With permission from [50]

Closed reduction, which is usually achieved by longitudinal traction through the fingers and percutaneous fixation of the displaced bones, is an option for closed injuries and has been used for axial carpal sprains or dislocations with minimal associated injuries that are easily reduced and maintained by cast immobilization [13, 22] or using an external fixator [26]. However, interposed soft tissue or fracture fragments may prevent anatomic reduction, necessitating open treatment [1, 49]. Only 7 out of 56 reported cases before 1989 were treated with closed reduction and cast immobilization. All of them were of the axial-ulnar dislocation type with three pure dislocations and four fracture dislocations [18].

Open reduction with combined dorsal longitudinal (for the reduction of osseous structures) and extended palmar approach through the carpal tunnel (for the evaluation and restoration of soft tissues), is more frequently used. Fixation is typically performed using K wires, while suturing the remnants of interosseous ligaments is rarely feasible. Additional fixation using screws may be considered in selected cases [12, 14]. The use of bone anchors instead of the transosseous holes is preferred, whenever possible [49]. Postoperatively, immobilization, either in a cast or with external fixation, is maintained for approximately 6 weeks depending on the extent of injuries and mobilization commences under physiotherapy supervision.

10.10 Outcome and Complications

Functional results are more dependent upon the associated injuries of soft tissues, than on the osseous injury itself [10, 18, 49].

Fig. 10.11 A variant of combined axial radial-ulnar dislocation. In this case, an axial radial dislocation involving the 1st, 2nd and 3rd metacarpals, which were dislocated from the capitate in a proximal and radial direction, with fracture of the trapezoid and distal pole of the scaphoid. Concomitant injuries were the fracture-dislocations of the 4th and 5th CMC joint, where the bases of the ulnar metacarpals were ulnarly displaced (**a**, **b**). schematic illustration of the injury (**c**). With permission from [50]

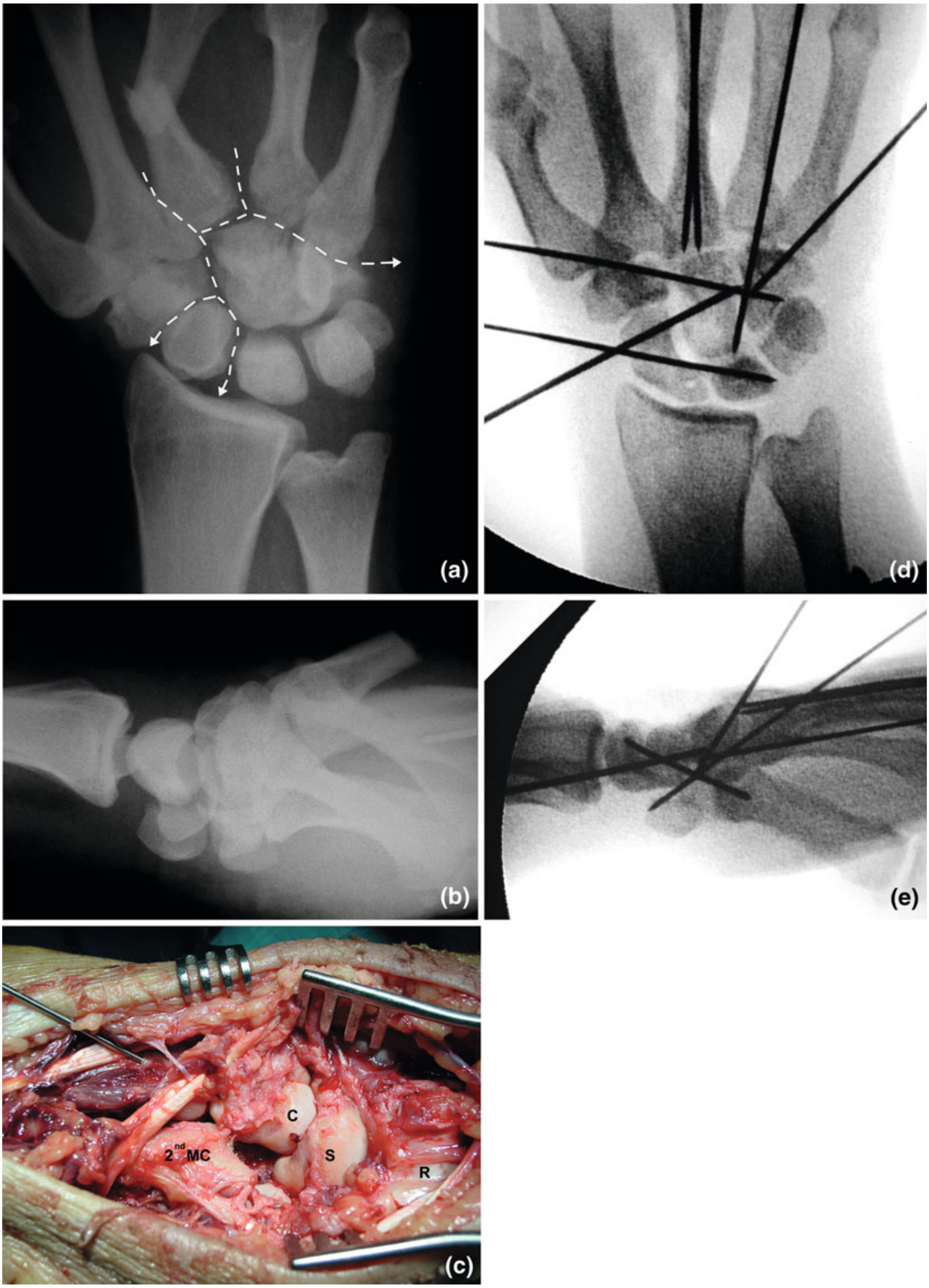

Fig. 10.12 A case of axial radial dislocation with disruption of the central column, in which the applied force is spreading to the proximal carpal row, around the scaphoid. The ulnar CMC joints are also disrupted (**a**, **b**), during exploration, the axial-radial injury comprising the scaphoid is apparent (*C* capitate, *S* scaphoid, *R* Radius) (**c**), internal fixation with K-wires is shown in fluoroscopy image (**d**, **e**)

Of the 40 cases published before 1989, 71 % of the patients presented an excellent or good result, while 29 % presented a moderate or poor result. Conversely, out of the 16 patients of the Mayo Clinic study, 73 % had a moderate or poor result and only 27 % had a good result. These adverse results were attributed to the fact that this group of patients presented more significant soft tissue injury.

Inability to reduce the transverse carpal arc will confidently lead to flattening of the palm, dissociation of the carpometacarpal joints, muscle weakness and restriction of movement [45].

The most common complications reported in the literature are: first web space contractures secondary to fibrosis of the thenar muscles, adhesion of the tendons and nerves, stiffness of the fingers, residual carpal instability, compartment syndromes and vascular insufficiency necessitating amputation of the hand [1, 18, 19].

Nerve injury was the most predictable factor in the poorer results, while patients who had axial-ulnar dislocations had a three times greater incidence of nerve injury compared with those who had axial-radial dislocations [9, 10].

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