Radiographic Evaluation and Classification of Distal Radius Fractures

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Introduction

X-rays are essential to the treatment of distal radius fractures. When combined with the age and baseline level of activity of the patient, the interpretation of a patient’s X-rays significantly influences the type of treatment selected. Radiographs form the basis for nearly every system of classification of distal radius fractures. Moreover, radiographs are also used during procedures to judge residual fragment displacements and determine whether hardware has been placed appropriately. Ultimately, X-rays are the means used to assess the quality of the final reduction and treatment.\(^1\) By improving the interpretation of standard X-rays, a better understanding of the pattern of injury emerges that improves algorithms for treatment and ultimately results in better clinical outcomes.

Radiographic landmarks – PA view

An X-ray image is a two dimensional representation of a three dimensional structure. Orthogonal views, such as a posterior-anterior (PA) and lateral view, show the outline of the cortical profile in two projections perpendicular to one another and reveal fracture lines traversing the cortical profile tangential to the beam. Oblique films may provide additional information by rotating other sections of the cortical outline into profile. However, since the distal radius is not a simple rectangular solid, a more sophisticated analysis of the radiographic images is usually needed in order to create a clear mental image of the components of a particular injury.

The actual X-ray technique directly affects the quality and characteristics of the visual information that is presented on the radiographic image. Unfortunately, it is not unusual to receive injury films that have been poorly positioned or were taken with poor radiographic technique from emergency personnel that were unwilling to move an injured arm for fear of causing additional pain or injury to the patient. Furthermore, X-rays of an unreduced, highly displaced fracture compounds the difficulties of interpretation because of the distortion from abnormal displacement and rotation of fracture components. In some cases, determining the nature of a complex injury is no more complicated than simply obtaining a second set of films after a closed reduction with proper positioning and technique. Finally, articular visualization on the PA view may be improved by angling the X-ray beam 10\(^\circ\) proximally.\(^2\)

The rotational position of the forearm can also change the appearance of the radiographic image (figure 1).\(^3\) On a standard PA view of the wrist with the forearm in neutral position, the cortical bone along the ulnar border of the ulnar styloid connects smoothly with the cortical bone along the ulnar border of the shaft. In addition, the cortical outline of the
ulnar head does not extend behind the ulnar styloid and the lateral border of the distal ulnar shaft has a concave outline on its radial side. Subtle changes occur if this view is taken with the forearm in full supination (typically done as an AP view). In this situation, the position of the ulnar styloid shifts radially to align more toward the central longitudinal axis of the ulnar shaft. In addition, the ulnar shaft shows a more linear appearance along its radial border and the subchondral bone of the ulnar head can be seen behind the ulnar styloid. With the forearm in a position of full pronation the radius crosses over the ulna resulting in an obligate but physiologic shortening of the radius in relation to the ulna. In this position of forearm rotation, a normal loss of about .5 millimeters of radial length is common. In addition, the radial and ulnar shafts appear to converge proximally and the cortical outline of the ulnar head can be identified behind the base of the ulnar styloid. With pronation of the forearm, measured values of radial inclination, volar tilt and radial height decrease; with supination of the forearm, these values increase.4

The radial column is a pillar of bone that forms the lateral border of the distal radius. The radial column is an important structure that maintains carpal length and cradles and guides the kinematics of the carpus during wrist motion from a position of radial deviation and extension to ulnar deviation and flexion. Distally, the radial column forms the scaphoid facet; dorsally, it extends to the base of Lister’s tubercle. Along the volar surface, the radial column merges with the distal radial ridge that forms the distal insertion of the pronator quadratus. Radiographically, the outline of this anatomic structure can be easily recognized on the standard PA view. Oblique X-rays are sometimes used to project the outline of a more volar portion of the radial border into greater profile.
The ulnar border of the radius flares distally to form the sigmoid notch and has been referred to as the intermediate column. Normally, there is a uniform joint interval present between the ulnar head and the subchondral bone of the sigmoid notch; typically this interval measures about 1 millimeter. Separation of the DRUJ joint interval to over 2 millimeters implies that a ligamentous injury to this joint has occurred. Distally, the margins of the sigmoid notch end in a dorsal and volar corner. If the forearm is positioned in significant pronation or supination, the appearance of the DRUJ and joint interval is altered. Finally, if the wrist in neutral position in terms of radial and ulnar deviation, the lunate is normally positioned between the ulnar border of Lister’s tubercle and the radial one third of the ulnar head.

The carpal facet horizon is a radiodense line that appears on a normal PA view near the distal articular surface and extends from the ulnar side of the radius across most of the width of the bone (figure 2). In a normal wrist, the carpal facet horizon is inclined at an angle of about 10 degrees to a perpendicular of a line extended from the longitudinal axis of the radius. The carpal facet horizon is a radiographic landmark that is produced by the X-ray beam as it crosses a portion of the curved arc of dense subchondral bone that is tangential to the axis of the beam. Since a normal distal radius has a volar tilt of 5-8 degrees, under normal circumstances the volar portion of the subchondral plate is the part of the articular surface that is parallel to the X-ray beam. As a result, in a PA view of a normal wrist the carpal facet horizon identifies the volar rim of the lunate facet and extends ulnar to the volar corner of the sigmoid notch. In addition, close inspection of a PA view of a normal wrist will often reveal the dorsal rim and dorsal corner more distally overlying the proximal articular surface of the scaphoid and the lunate. On the other hand, if a fracture has caused the distal fragment to rotate dorsally, the curved arc of the subchondral plate displaces into dorsal tilt. In this situation, the dorsal portion of the curved subchondral plate becomes aligned tangential to the longitudinal axis of the X-ray beam and the carpal facet horizon will instead identify the dorsal rim. In this case, this finding can be used to distinguish the volar rim (A1) from the dorsal rim (B). Also note the distal radioulnar joint interval (C).

Identification of the carpal facet horizon has several clinical applications. Discontinuity of this landmark suggests the presence of a separate intra-articular fracture component. For
example, isolated volar shear fractures with proximal and volar displacement of a free volar rim fragment can show an obvious step-off in the carpal facet horizon on the PA projection and imply the presence of an articular fragment (figure 3). The carpal facet horizon is also used to identify whether a particular fragment on the PA view involves the dorsal rim or volar rim. In fractures that are volarily displaced in which there is volar tilt of the articular surface on the lateral X-ray, the carpal facet horizon will identify the volar rim of the lunate facet. In fractures that are dorsally displaced in which there is dorsal tilt of the articular surface on the lateral X-ray, the carpal facet horizon will identify the dorsal rim of the lunate facet. Determining whether a particular articular fragment is located dorsally or volarily on the PA view can be of critical importance in assessing the pattern of instability as well as in considering surgical approaches (figure 4).

**Radiographic landmarks – lateral view**

The lateral X-ray is normally taken with the forearm in neutral rotation. The accuracy of obtaining a true lateral film can be checked by noting the position of the pisiform in relation to the distal pole of the scaphoid on the lateral view. On a true lateral X-ray, the pisiform is located directly over the distal pole of the scaphoid (figure 3). If the pisiform lies dorsal to the distal pole of the scaphoid, the forearm is rotated into pronation and the X-ray is more oblique. Although this type of oblique view can put the volar portion of the radial column in profile, it also results in suboptimal visualization of the volar rim.

**Fig 3. Step-off in the Carpal Facet Horizon**

*Left,* The step-off in the carpal facet horizon is caused by an articular fracture component (A). Note the overlap of the proximal carpal row over the intact portion of the carpal facet horizon. *Right,* The lateral view shows the displaced volar rim fragment (B) with volar subluxation of the carpus into the palmar soft tissues. The position of the pisiform over the distal pole of the scaphoid (C) confirms that this view is a true lateral x-ray.

**Fig 4. Clinical Application of the Carpal Facet Horizon**

*Top panel,* In the dorsal injury, the distal fragment has rotated dorsally causing the dorsal portion of the subchondral bone to align with the axis of the x-ray beam. In this case, the carpal facet horizon (A₁-A₂) identifies the dorsal rim of the lunate facet. Note the position of the dorsal ulnar corner (A₂) and the volar corner of the sigmoid notch (V). Discontinuity of the carpal facet horizon indicates an additional free articular fragment. *Bottom panel,* In the volar injury, the distal fragment has rotated volarly. As a result, the volar rim of the lunate facet is aligned with the x-ray beam, and the carpal facet horizon (B₁-B₂) identifies the volar rim. Note the position of the volar corner (B₁) and dorsal corner (D) of the sigmoid notch. Also note the irregularity of the carpal facet horizon indicating a separate volar rim and radial column fragment.
In addition to a standard lateral view, the 10\(^\circ\) lateral view provides a sharper image of the articular surface. The 10\(^\circ\) lateral is so named because the ulnar two-thirds of the articular surface is normally at an inclination of about 10\(^\circ\) to a perpendicular of a line extended along the longitudinal axis of the radius. In some patients this angle may be greater to correspond to variations in the tilt of the ulnar two-thirds of the articular surface.\(^5\)\(^6\) The technique for taking the 10\(^\circ\) lateral view is simple. The forearm is initially positioned horizontally on the plate as if to take a standard lateral X-ray and then elevated 10\(^\circ\) off the horizontal plane. If done properly, the articular outline of the ulnar two-thirds of the radiocarpal joint is placed into sharp relief (figure 5). It should be noted that this view positions the outline of the radial styloid more proximally than is normally seen on the standard lateral view and may affect the appearance of hardware placed on or into the radial styloid.

Although the radius and ulna overlie one another on the lateral projection, in most cases it is not difficult to follow the cortical outline of each forearm bone in order to distinguish one from the other. Furthermore, if the film has been properly exposed, the superimposed outline of the radial styloid over the scaphoid can be identified. On the lateral view, the volar surface of the radial column can be seen to project volar to the outline of that part of the cortical shaft proximal to the lunate facet. As a result, the volar portion of the radial column can be distinguished from the volar cortex of the radial shaft on the lateral view.

The teardrop is a dense, 'U' shaped outline seen at the distal end of the radius on the lateral view and is formed from the confluent outlines of the distal shaft and distal radial ridge, and terminates in the volar rim of the lunate facet (figure 6). The thickness of the cortical bone that forms the base of the teardrop is noted to be significantly greater than the thickness of the dorsal cortical bone and reflects the greater loading forces that normally occur along the volar surface of the radius. In addition, a line that is extended from the volar cortex of the radial shaft lies nearly bisects the curve of the articular surface (typically passes just volar to the center of the articular surface on the lateral view), suggesting that the carpal load is nearly balanced along the volar cortex.

The distal articular surface of the radius on a normal wrist has an arc of curvature that matches the arc of curve of the proximal pole of the lunate; this uniform joint interval is more clearly seen on the 10\(^\circ\) lateral X-ray. Fractures that result in a joint interval that is

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**Fig 5.** 10-Degree Lateral X-ray A standard lateral X-ray is taken with the forearm in the horizontal plane and crosses the articular surface obliquely. As a result, incongruity and displacements of the articular surface are obscured, and assessments of fracture reduction or hardware placement are less accurate. With the 10-degree lateral x-ray, the forearm is elevated off the horizontal plane to place the ulnar two thirds of the articular surface into profile, resulting in a more accurate image of the subchondral bone.
non-uniform from the dorsal to volar margin or show incongruent arcs of curvature between the articular surface of the distal radius and the proximal pole of the lunate imply discontinuity between the volar and dorsal joint surfaces with independent articular fracture components (figure 7).

Carpal alignment is also an important feature to observe on the lateral X-ray. With a wrist in neutral to slight dorsiflexion, a line extended from the volar cortex of the radial shaft should be nearly collinear with the center axis of rotation of the proximal pole of the capitate (figure 6). Fractures with dorsal angulation or displacement cause translation of the carpus dorsally, resulting in dorsal migration of the proximal pole of the capitate relative to the volar cortex of the radial shaft (figure 8). Fractures that displace to the volar side result in volar migration of the capitate from its normal alignment with the radial shaft and are highly unstable. Significant displacement of the carpus in either direction changes the functional moment arm of tendons that cross the wrist and may contribute to adverse affects on grip strength.
Radiographic parameters are measured values used to quantify the amount of displacement or amount of angulation that has occurred with a distal radius fracture. Although recommendations are often made to define indications for operative treatment based on threshold values of individual parameters, in nearly all fractures abnormalities of multiple parameters are often present and may act synergistically in terms of the functional impairment caused by the total deformity. As a general rule abnormalities of a single parameter should not be considered in isolation but rather in the context of the entire fracture pattern before committing to a particular approach for treatment. Our understanding of which combinations of abnormal parameters have the greatest clinical significance continues to evolve. In addition, since there is a certain amount of normal variation of most parameters within a typical population, it can be quite helpful to take X-rays of the normal contralateral wrist in order to establish baseline values.

Radial inclination and ulnar variance are two parameters measured on the PA view that often are defined using the most distal corner of the ulnar border of the distal radius as a point of reference. As discussed previously, this radiographic landmark does not correspond to a single anatomic structure but may vary, representing either the dorsal corner of the sigmoid notch or the volar corner of the sigmoid notch depending on whether the distal articular surface has a volar or dorsal tilt. Since these measurements should ideally remain independent of the tilt of the articular surface on the lateral view, a central point of reference (CRP) should be used for the measurement of both radial inclination and ulnar variance. The CRP can be identified by determining the center of a line that is drawn between the volar and dorsal corners on the AP view (figure 9). Since the CRP coincides with the coronal center of the distal edge of the sigmoid notch, it is relatively independent of changes in the volar tilt of the articular surface. Using the CRP is particularly important for assessing ulnar variance since this measurement can be significantly affected by changes in volar tilt.

Radial inclination is a parameter that is defined as the angle between a line drawn from the tip of the radial styloid to the CRP and a line perpendicular to the long axis of the radius (figure 10). In normal wrists, radial inclination measures about 24°. As a general rule, displaced fractures of the distal radius reduce radial inclination; radial inclination less that 15° is a relative indication for operative treatment.
Ulnar variance is a parameter used in the context of distal radius fractures to help quantify the loss of radial length. Ulnar variance is determined by measuring the distance between two lines drawn perpendicular to a reference line extended along the axis of the radial shaft where one perpendicular intersects the distal edge of the ulnar head and the second perpendicular intersects the CRP (figure 10). Negative values indicate that the radius extends beyond the ulna; positive values indicate that the ulna extends beyond the radius. Ulnar variance is normally -0.6 millimeters with a standard deviation of 1 millimeters. Shortening of more than 5 millimeters is a relative indication for operative treatment.

Radial height is another parameter that can be used to assess the loss of radial length. This measurement is made by measuring the distance between two lines drawn perpendicular to a reference line extended along the axis of the radial shaft where one perpendicular intersects the tip of the radial styloid and the second perpendicular intersects the CRP. The normal value for radial height is 11.6 millimeters. Radial height is related to the loss of radial inclination as well as the width of the bone.

Articular step-off is a parameter used with intraarticular fractures to measure discontinuity in height between two adjacent articular fragments. Generally, articular step-off of greater than 1-2 millimeters is considered a relative indication for operative treatment. Residual articular step-offs greater than these values has been associated with a high incidence of osteoarthritis in young patients. In addition, if significant depression between the scaphoid and lunate facet is seen on the PA view, a high index of suspicion for scapholunate injury should be entertained.

The radiocarpal interval is the distance that separates the base of the scaphoid from the base of the scaphoid facet. Normally, this interval measures 2 millimeters. This parameter
can be particularly useful in the context of a spanning external fixator in order to judge the relative degree of distraction across the joint. A radiocarpal interval greater than 3 millimeters suggests excessive distraction across the wrist joint.

**Radiographic parameters – lateral view**

On the lateral view, volar tilt is used to measure the angular change of the articular surface. Volar tilt is defined as the angle between a line perpendicular to the central axis of the radial shaft and a line that connects the corner of the dorsal rim and the corner of the volar rim on the lateral view (figure 11). Normal wrists have about 10° volar tilt; dorsally angulated fractures with greater than 10° of dorsal tilt are a relative indication for reduction. On the other hand, fractures displaced to the volar side often show an increase in volar tilt. These fractures tend to be highly unstable and require some form of stabilization.
The AP distance is the point to point distance between the corner of the dorsal rim and the corner of the volar rim on the lateral view (figure 12). Normal AP distance measures 20 mm in men and 18 mm in women. Elevation of the AP distance over 21 mm in men and 19 mm in women suggests discontinuity across the lunate facet with a separate dorsal and volar fragment. Marked widening of the AP interval may be the only evidence of sigmoid notch involvement that would be otherwise difficult to visualize on standard X-rays. It is usually better to measure the AP distance on the 10° lateral projection.

The teardrop angle is used to measure the angular position of the teardrop, or volar rim of the lunate facet, on the lateral view. In extra-articular fractures with dorsal angulation, the depression of the teardrop angle is directly proportional to the change in volar tilt and does not add any new information. In contrast, in intra-articular fractures with axial compression, impaction of the lunate into the lunate facet can generate a free volar rim fragment that is driven by the carpus into significant dorsiflexion. As a result, significant depression of the teardrop angle can occur which is often independent and greater than the loss of volar tilt. If correction of the teardrop angle is not addressed in the context of a dorsiflexed volar rim fragment, significant residual intra-articular incongruity and dorsal subluxation of the carpus may go unnoticed. For instance, simple buttress plate application on a dorsiflexed volar rim may aggravate an existing depression of the teardrop angle.

The teardrop angle is determined by measuring the angle between a line extended along the longitudinal axis of the radial shaft to a line that is drawn down the center of the teardrop; if the complete cortical outline of the teardrop is difficult to determine, a line drawn parallel to the subchondral bone of the volar rim can be used instead (figure 13). Depression of the teardrop angle below 45° indicates significant dorsiflexion deformity of the volar rim of the lunate facet and should be corrected.

**Fragmentation patterns**

Over the past five decades, many different classifications of distal radius fractures have been proposed for distal radius fractures, both as a suggestion for guidelines to treatment as well as a predictor of the natural history of different patterns of injury.

Traditional classification of the distal radius fractures were based on early descriptions of simple extra-articular fractures by Colles, Barton, and Smith. These initial observations described angulation of the distal fragment in a volar or dorsal direction. Further iterations of these descriptions incorporated the presence of comminution, involvement of the radial articular surface, and displacement, direction of displacement and degree of articular surface involvement, length of the radial styloid, presence of dorsal angulation and extent of metaphyseal comminution. Frykman identified the presence of radiocarpal joint, radioulnar joint, and ulnar styloid involvement. Later classification systems such as the Melone and Mayo classification have underscored the importance of basic fragmentation patterns of the articular surface.

More recently, the AO and Fernandez/Jupiter classifications have proposed grouping patterns by the mechanism of injury. The AO system broadly divides fractures into bending, shear, and axial loading categories, with the Fernandez/Jupiter system adding carpal avulsions and high energy trauma as additional categories. Although the AO
classification further divides patterns into 27 subcategories, there is poor interobserver and intraobserver correlation beyond the three basic types.17, 18, 19

The fragment specific classification system is based on the observation that fracture lines in distal radius fractures generally propagate along recurrent pathways, resulting in five basic fracture components: the radial column, ulnar corner, dorsal wall, volar rim, and free intraarticular fragments (figure 14). The radial column fragment is often a major fragment along the radial border of the wrist and is important to maintain radial length and provide support to the carpus across the radioscaphoid joint. The ulnar corner fragment involves both the dorsal side of the lunate facet and the dorsal portion of the sigmoid notch and typically migrates dorsally and proximally; significant displacement of this fragment can adversely affect movement and function of the distal radioulnar joint. Dorsal wall fragmentation is often a contributing factor in dorsal instability. The volar rim fragment is formed by the distal radial ridge and the volar portion of the lunate facet and is often a major element of fracture instability. This fragment can either displace volarly into the palmar soft tissue or impact axially, rotating into dorsiflexion with depression of the teardrop angle and dorsal subluxation of the carpus. Finally free intraarticular fragments may displace and rotate into the metaphyseal cavity creating articular stepoffs and joint incongruity.

Fig 14. Fragment Specific Classification
Articular fractures of the distal radius tend to propagate along recurrent pathways, resulting in generation of five basic fracture components: radial column, ulnar corner, dorsal wall, free intra-articular, and volar rim. In addition to these distal radius fracture elements, impaction of the metaphyseal bone, distal radioulnar joint and distal ulna injuries, and intracarpal pathology may affect the natural history of a particular fracture pattern. Degrees indicate a dorsiflexed volar rim fragment. Dorsal translation of carpal alignment is routinely present with significant depression of the teardrop angle.
Fractures of the distal ulna are usually classified based on the position of the fracture.\textsuperscript{20} Simple avulsions of the tip of the styloid are rarely clinically important, although they may be associated with more significant tears of the triangular fibrocartilaginous complex (TFCC). Fractures through the base of the ulnar styloid may be associated with instability of the distal radioulnar joint, particularly if widely displaced with the carpus in a radial direction. Ulnar head fractures may involve the congruency of the articular surface of the DRUJ and cause dysfunction or late arthritis if left unreduced. Fractures through the neck or shaft of the ulna can compromise rotational stability of the forearm.

One contemporary approach to distal radius fractures is to combine the fragment specific classification system with a characterization of fracture 'personality' which is based on mechanism, magnitude, and direction of injury.\textsuperscript{1} Since forces on the volar side of the radius are typically much higher than forces along the dorsal side, the direction of displacement of the distal fragment can significantly affect the characteristics and natural history of a particular fracture pattern. For this reason, extra-articular fractures with dorsal displacement from a dorsal bending mechanism are considered different from extra-articular fractures with volar displacement from a volar bending mechanism. Similarly, dorsal shear fractures have different characteristics in terms of prognosis and treatment from volar shear fractures. Finally, axial loading injuries may result in several different patterns based on the magnitude and direction of applied force (Table 1).

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Table 1. Distal radius fracture personalities.

Dorsal bending injuries occur from a dorsal bending moment and result in compressive failure on the dorsal side and simple tensile failure on the volar cortex (figure 15). Characteristically they present as a large single distal fragment that includes the articular surface of the radiocarpal joint and fragmentation of the dorsal wall along with compression of the metaphyseal cavity. In many cases, apposition of the volar cortex at a single fracture line between the proximal and distal fragment provides a stable fulcrum on which to hinge the reduction. In this situation, the amount of dorsal comminution and metaphyseal impaction is the primary determinant of the degree of dorsal instability. Although ligamentous damage to the distal radioulnar joint may be also present, often DRUJ stability is restored simply by reduction of the distal fragment. Although supination of the distal fragment relative to the proximal fragment is typically present, this deformity is difficult to assess radiographically. In dorsal bending injuries, a particular focus of the X-ray evaluation should be directed at determining the degree of dorsal wall fragmentation and metaphyseal involvement as well as the extent of DRUJ involvement. Loss of length and
radial inclination are characteristic features. In addition, dorsal subluxation of the center of rotation of the base of the capitate is usually observed. Although depression of the teardrop angle is a typical characteristic of the X-ray findings in dorsal bending injuries, in this situation it simply reflects and is proportional to the loss of volar tilt.

In contrast to dorsal bending injuries, displaced volar bending injuries are nearly always unstable and are subject to an entirely different environment of deforming forces (figure 16). In this fracture personality, the distal fragment and carpus displace into the palmar

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**Fig 15. Dorsal Bending Injury** This dorsally angulated extra-articular fracture shows loss of radial inclination, dorsal tilt of the articular surface, and positive ulnar variance from loss of length. Note the dorsal wall fragment has rotated to align with the x-ray beam and is seen as a horizontal radiodense line on the posteroanterior view and in a vertical attitude on the lateral view (arrows).

**Fig 16. Volar Bending Injury** Note the significant volar subluxation of the carpus with the distal fragment, the loss of length, and volar wall comminution in this highly unstable volar bending pattern.
soft tissues and stable reduction across the volar cortex is often impossible with closed methods of management. Rotational deformities are difficult to assess radiographically. Unlike dorsal bending injuries in which the volar cortex can often be used as a fulcrum for balancing the dorsal instability pattern against the strong pull of the flexor tendons, the deforming pull of the flexor tendons in volar bending injuries results in palmar and proximal migration of the carpus and distal fragment. Volar bending injuries are characterized by volar subluxation of the rotational center of the base of the capitae in relation to the volar cortex of the shaft. In some cases, additional fragmentation of the volar wall may also be observed. In addition, displaced volar bending injuries show proximal carpal migration with loss of overall length and radial inclination. Volar tilt may be increased and disruption of the DRUJ is commonly observed. Typically, these injuries will require some type of operative intervention in order to achieve a stable reduction.

In volar shear fractures, the carpus is driven into the volar rim of the lunate facet resulting in volar and proximal translation of this fragment (figure 3). The carpus is carried by the volar rim fragment and dislocates off the remaining intact dorsal rim of the lunate facet. Volar and proximal migration of the teardrop occurs and overlap of the dorsal rim and the carpus is seen on the PA view. As noted previously, discontinuity of the carpal facet horizon may also be noted on the PA view. On the lateral view, displacement of the carpus and volar rim are usually obvious and increased AP distance frequently noted. Particular focus should be focused on examination of the volar rim component for additional secondary fracture lines within the volar rim. Fragmentation into the radial column may also be present. In addition to injury views, post reduction X-rays should confirm that the center of rotation of the base of the capitae is restored to its normal relationship to a line extended from the volar cortex of the shaft, indicating that complete correction of volar subluxation of the carpus has been obtained. X-rays should also confirm that reduction has brought the volar rim back out to length, resulting in complete correction of the carpal facet horizon to its normal spatial alignment on the PA view.

A pure dorsal shear fracture is a more uncommon pattern of injury. In this pattern, the impact of the carpus against the dorsal rim of the lunate facet results in a shear failure with varying degrees of dorsal subluxation and proximal migration of the carpus (figure 17). In dorsal shear fractures, significant articular step-offs are present in the sagittal plane, producing a sharp edge that can grind against the proximal pole of the lunate during flexion movements of the wrist. In volar shear fractures, the predominant clinical concern is correction of the significant volar instability of the carpus caused from the strong pull of the flexor tendons. In contrast, in dorsal shear fractures the predominant clinical concern is the restoration of a smooth and congruous articular surface, eliminating deep articular offsets dorsally that may result in accelerated wear of the lunate during flexion movements of the wrist. On the PA view, dorsal shear fractures may show a reduction in the radiocarpal interval as the carpus shifts proximally from the dorsal subluxation. On the lateral view, dorsal subluxation of the carpus is easily noted along with an increase in the AP distance. The DRUJ interval may or may not be affected. Dorsal wall fragments and an ulnar corner fragment are typically present; free intraarticular fragments may also be impacted within the metaphysis. Articular offset is often observed on the lateral view.

Simple three part distal radius fractures consist of a proximal shaft fragment, and ulnar corner fragment, and a large distal articular fragment that contains both the radial column
and volar rim (figure 18). Although this injury pattern is often described as the result of axial loading, it is probably the result of a combination of both axial loading and simple bending mechanisms. The ulnar corner fragment often involves the dorsal portion of the sigmoid notch and usually includes the insertion of the dorsal ligament of the DRUJ. Three part fractures usually show some loss of radial length and radial inclination on the PA view. On the lateral view, dorsal angulation of the distal fragment is frequently observed. Dorsal and sometimes proximal displacement of the ulnar corner fragment may occur. In addition, fragmentation of the dorsal wall is often seen.

Complex articular fractures tend to occur in two patterns, based on the direction and instability of the volar rim of the lunate facet. These complex axial load injuries can generate any or all of the five basic fracture components, resulting in significant step-offs or separations within the articular surface. In one pattern of injury, the impact of the carpus causes the articular surface to explode peripherally, resulting in displacement of the volar rim fragment volarly and proximally. In this pattern, volar or proximal migration of the carpus is observed. An independent radial column fragment is almost always present. In addition, free intra-articular fragments may be impacted into the metaphysis and ulnar corner and dorsal wall fragments are commonly present (figure 19). Depressed radial inclination, widened AP interval, and incongruity of the articular surface are frequent radiographic findings with this injury. An inconsistent joint interval between the distal radius and proximal pole of the lunate on the lateral view can indicate articular disruption across the lunate facet. Dorsal or excessive volar tilt may also be present and depend on the principal direction of injury.

In a second comminuted articular pattern, the carpus impacts axially into the articular surface, resulting dorsiflexion of the volar rim of the lunate facet and dorsal subluxation of the carpus. In addition to the radiographic abnormalities discussed previously, these
Injuries also present with depression of the teardrop angle and dorsal subluxation of the carpus. Widening of the AP distance is also a consistent feature of this pattern. Correction of the dorsiflexion deformity of the volar rim of the lunate facet should be an integral part of a complete reduction of the articular surface.

Comminuted articular fractures of the distal radius may also affect the ulna and/or distal radioulnar joint that may further complicate the injury pattern (figure 20). Significant disruption of the DRUJ may occur with volar or dorsal subluxation of the distal ulna in relation to the distal radius. In some cases, excessive widening of the DRUJ may be noted. These fractures are usually associated with extreme comminution of the articular surface and malalignment of the carpus on the lateral view. Widening of the AP distance and a non-uniform joint interval on the lateral view are often features of this pattern. In addition to reconstruction of the articular surface, restoration of stability of the distal radio-ulnar joint is required and may include soft tissue reconstruction of the ligamentous structures.

**Fig 19. Comminuted Articular Fracture**
This injury is the result of an axial loading mechanism and shows a depressed, free intra-articular fragment (A) and an increased anteroposterior distance (horizontal arrows, right panel). The lunate has collapsed within the central articular defect into the metaphysis. Note the incidental signs of degenerative arthritis with spurring of the tip of the radial styloid and chondrocalcinosis of the radiocarpal joint medially.

**Fig 20. Comminuted Articular Fracture with Dorsiflexion of the Volar Rim and Disruption of the Distal Radioulnar Joint**
In this injury, note the significant widening of the distal radioulnar joint interval indicating severe ligamentous disruption (A). An ulnar corner fragment is noted dorsally (B). The volar rim of the lunate facet has rotated into dorsiflexion (C), allowing the carpus to displace dorsally. A free dorsal wall fragment also is present (D). Note the sharp edge of the volar metaphysis (E) that puts the median nerve at risk of injury.
Radial shear fractures are an unusual form of distal radius fractures. In radial shear fractures, translation of the carpus results in a shear fracture across the tip of the radial styloid rather than the radial column type of injury seen with other fracture patterns. Radial translation of the carpus may be observed along with ulnar styloid injuries that have displaced toward the radius. In these fractures, the extent of articular surface damage is often underestimated by the radiographic findings and supplemental arthroscopic evaluation may be required to fully assess the degree of joint damage. Marked widening of the DRUJ or bones of the forearm may implicate syndesmotic disruption; these injuries are particularly unstable in terms of DRUJ function (figure 21). In addition, particular focus should be directed at assessing these injury patterns for additional intracarpal ligament pathology.

Carpal avulsions and high energy trauma have also been included as forms of distal radius fractures, although these injuries have their own distinct features. Carpal avulsions are primarily ligamentous injuries to the carpus in which osseous fragments are avulsed from the radius. High energy trauma injuries are associated with highly comminuted fractures of the distal articular surface of the radius along with extension well up into the shaft of the radius and/or ulna. Although these injuries may have an extensive osseous component, it is not unusual to have a substantial soft tissue component completely overshadow the clinical treatment of these fracture patterns.

![Fig 21. Radial Shear Fracture](image)

*Left, A transverse fracture of the radial styloid (B) has a different appearance from the more common radial column fragment. Significant widening of the distal radioulnar joint is noted (A), and may suggest syndesmotic rupture in addition to disruption of the dorsal and volar ligaments. Note the marked irregularity of the articular surface on the posteroanterior view, which often underscores the extent of articular damage. Right, On the lateral view, dorsal subluxation of the carpus (C) and dorsal fragmentation (D) are seen. Note the dorsal displacement of the lunate out of its normal position adjacent to the teardrop (E).*
Conclusions

In many respects, the treatment of distal radius fractures really begins with the X-ray examination. There is a wealth of information present on standard views that can significantly influence the decision and type of treatment that is ultimately selected. Although radial inclination and volar tilt are well known parameters used to assess the angulation of the distal fragment in the coronal and sagittal planes, several other landmarks and parameters should be routinely evaluated as part of every injury assessment. On the PA view the carpal facet horizon can help distinguish whether a fragment on the ulnar border of the radius is actually the volar or dorsal corner. Radial translation of the carpus or excessive widening of the DRUJ can imply instability along the ulnar column. Significant offset of the articular surface, particularly between the scaphoid and lunate facet may increase the possibility of an intercarpal ligament disruption. On the lateral view, a non-uniform joint interval or increased AP distance suggests disruption and discontinuity across the lunate facet. Depression of the teardrop angle and subluxation of the central rotational axis of the capitate may alter the approach to treatment.

In addition to an awareness of the essential radiographic landmarks and parameters, radiographic evaluation of distal radius fractures also requires an understanding of the basic patterns of injuries in order to appreciate both the anatomy of the injury and the mechanical basis of instability. Recognizing which fracture elements are present allows a mental picture of the injury to be developed. Categorizing the mechanism, direction, and magnitude of injury as one of several fracture personalities provides clinically useful information that relates to the source of instability and the possible modes of failure. With improved understanding of the structural anatomy and biomechanical basis of the injury, better treatment and clinical outcomes must surely follow.

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