**Abstract**

**Background** Fractures of the distal radius comprise almost one-sixth of all fracture cases encountered in the emergency department. They are a common injury, particularly in the elderly population. Fractures of the distal radius are limited between the radiocarpal joint and up to 3 cm toward the proximal portion. They are usually closed and the overlying skin is intact. They are considered complex as they usually entail accompanying injuries to the adjacent ligamentous and cartilaginous structures.

**Barton** Barton’s fracture, named after the American surgeon John Rhea Barton is a fracture of the distal end of the radius that involves the dorsal or volar rim and extends into the intra-articular region. Such intra-articular fractures are uncommon, and they are usually associated with either low or high-energy trauma. They constitute only 1.3% of the distal radius fractures [1].

**Management of Distal Radius Fractures**

The basic principle of fracture treatment is to obtain accurate fracture reduction and then to use a method of immobilization that will maintain and hold that reduction. A number of options for treatment are available to prevent the loss of reduction in an unstable fracture of the distal end of the radius.

- **Factors affecting treatment include:**
  1. **Local factors:** bone quality, soft tissue injury, fracture comminution, fracture displacement, and energy of injury.
  2. **Patient factors:** physiologic patient age, lifestyle, occupation, hand dominance, associated medical conditions, associated injuries, and compliance.

- **Radiographic alignment parameters**
  - For acceptable reduction in an active, healthy patient include
    1. **Radial length:** shortening < 5 mm.
    2. **Volar tilt:** neutral tilt (0 degrees), but up to 10 degrees dorsal angulation.
    3. **Intra-articular step-off:** < 2 mm.
    4. **Radial inclination:** < 5 degree loss.[2]

  - **Radial height:** is the distance between two parallel lines drawn perpendicular to the long axis of radial shaft: one from the tip of the radial styloid and the other from the ulnar corner of the lunate fossa. Average=12mm.
  - **Radial inclination:** is the angle between two lines one drawn perpendicular to the long axis of the radius at the ulnar corner of the lunate fossa and the other between the point in the lunate fossa and the tip of the radial styloid. Average=23 degrees.
  - **Ulnar variance:** the difference in the axial length between the ulnar corner of the sigmoid notch of the radius and the most distal extent of the ulnar head on the PA view.[3]
Palmar inclination: is the angle subtended by the line perpendicular to the long axis of the radius and a second line drawn from the dorsal lip to palmar lip of distal radius. Average=11 degrees.

Teardrop angle: is the angle between the line along the central axis of teardrop (U shaped structure which projects 3 mm palmar from radial diaphysis) and a line of the longitudinal radial axis. Average=70 degrees.

Carpal alignment: after distal radius fracture, it may have the most influence on outcome following distal radius fracture. Carpal alignment is measured by the intersection of two lines on the lateral radiograph: one parallel and through the middle of the radial shaft and the other through and parallel to the capitate. If the two lines intersect within the carpus, then the carpus is aligned. If the two lines intersect out with the carpus, then the carpus is malaligned.

Subjective Parameters
In order to try to catch smaller but clinically more important changes, we use a region-specific outcome scoring system; the DASH which is one of the most commonly used region specific scoring Systems for the upper extremity: The shorter Quick DASH, nowadays is more commonly used and consists of eleven questions. For the wrist specifically, a joint-specific outcome instrument exists – the Patient Rated Wrist Evaluation (PRWE), which has a somewhat higher specificity than the DASH.

Recent studies and meta-analysis showed that no difference between conservative treatment and surgical treatment of patient over sixty age at range of motion or pain or higher risk of complication, but only the surgical treated group showed good radiological result.
A) Nonoperative
All displaced fractures should undergo closed reduction, even if it is expected that surgical management will be needed. Fracture reduction helps to limit post injury swelling, provides pain relief, and relieves compression on the median nerve. Cast immobilization is indicated for: nondisplaced or minimally displaced fractures, displaced fractures with a stable fracture pattern expected to unite within acceptable radiographic parameters and low-demand elderly patients in whom future functional impairment is less of a priority than immediate health concerns and/ or operative risks.[9]

♦ Technique of closed reduction (dorsally tilted fracture):
The distal fragment is hyperextended. Traction is applied to reduce the distal to the proximal fragment with pressure applied to the distal radius. A well-molded long arm (“sugar-tong”) splint is applied, with the wrist in neutral to slight flexion. One must avoid extreme positions of the wrist and hand. The cast should leave the metacarpophalangeal joints free. Once swelling has subsided, a well-molded cast is applied.[9]

The ideal forearm position, duration of immobilization, and need for a long arm cast remain controversial; no prospective study has demonstrated the superiority of one method over another. Extreme wrist flexion should be avoided, because it increases carpal canal pressure (and thus median nerve compression) as well as digital stiffness. Fractures that require extreme wrist flexion to maintain reduction may require operative fixation. The cast should be worn for approximately 6 weeks or until radiographic evidence of union has occurred. Frequent radiographic examination is necessary to detect loss of reduction.[10]

B) Operative:
♦ Indications
1) Articular step-off: It has been reported that the development of post-traumatic osteoarthritis in 100% of wrists with articular incongruities of 2.0 mm or more. However, other investigators found that displacement of even 1.0 mm resulted in pain and stiffness of wrist.[5,12]
2) Secondary loss of reduction: Several factors have been associated with redisplacement following closed manipulation of a distal radius fracture:
   - The initial displacement of the fracture: The greater the degree of displacement, the more energy is imparted to the fracture making closed treatment most likely will be unsuccessful.
   - The patient’s age: Elderly patients with osteopenic bones tend to displace, particularly late.

Figure (3): Above elbow cast for non-operative treatment of distal radius fracture.[11]
- The extent of metaphyseal comminution (the metaphyseal defect).
  Displacement following closed treatment is a predictor of instability, and repeat manipulation is unlikely to result in a successful radiographic outcome.[13]

  3) Metaphyseal comminution or bone loss.
  4) DRUJ incongruity.
  5) Open fractures.
  6) Articular margin fractures.

† In these cases operative is the treatment of choice. [8]

**Operative Techniques:**

**Open reduction and internal fixation:**

There are two groups of fractures for which open reduction and internal fixation is advisable. The first group includes the two-part shear fracture (Barton fracture), which actually is a radio-carpal fracture dislocation. Although anatomical reduction is possible by closed means in some cases, these fractures are very unstable and difficult to control in plaster. The second group includes complex intra-articular fractures in which the articular fragments are displaced, rotated or impacted and are not amenable to reduction through a limited operative exposure. [14]

![Figure (4): Left: volar Barton fracture. Right: intra-articular distal radius fracture.][15]

**A) Dorsal plating:** This has several theoretic advantages. It is technically familiar to most surgeons, and the approach avoids the neurovascular structures on the palmar side. The fixation is on the compression side of the fracture and provides a buttress against collapse. Dorsal plating has been associated with extensor tendon complications, but this complication is overcome by low profile plates.[16]

The surgical approach of dorsal plate involved a dorsal incision immediately ulnar to Lister’s tubercle. The dorsal retinaculum was opened with a Z incision and the retinaculum elevated from the second to the fifth dorsal compartments. Direct and indirect reduction of the fracture fragments is performed and confirmed with fluoroscopy. Provisional reduction of the articular surface was obtained and maintained temporary with Kirschner wires. Placement of the plate may be facilitated by removal of Lister’s tubercle. Plate then
was contoured and the articular surface then was stabilized with 2.4-mm screws and the proximal segment was fixed with 2.7-mm screws. The plate then fixed with suitable sized screws. In dorsal platting of comminuted or impacted articular fragments it is important to use of iliac bone graft or an appropriate structural bone graft substitute.[17]

B) Volar plating:

a) Non-locking: the primary indication is a buttress plate for the shear fracture of the volar Barton. This construct may be unable to maintain fracture reduction in the presence of dorsal comminution.

b) Locked plating: Locked volar plating has increased in popularity because this implant has been shown to stabilize distal radius fractures with dorsal comminution. It has surpassed external fixation as the most popular mode of fracture fixation of the distal radius. The dorsal side of the radius may be accessed through an extension of the volar approach.[18]

c) Fragment specific plating: Has been advocated for more complex fracture patterns involving several aspects of the radial and ulnar columns.[19]

Figure (5): Different types of plates used for distal radius fracture fixation.[20]
Complications of distal radius fracture:

1. Compartment Syndrome:
   Compartment syndrome associated with distal radius fractures is rare, with an incidence of 1% and can occur up to 54 hours after the initial injury. It occurs more frequently in younger patients who are more likely to sustain higher energy injuries. McQueen and coworkers reviewed 6395 cases of distal radius fracture to determine the risk of developing compartment syndrome. They found an overall incidence of 0.25%, with a mean age of 26 years. They also reported that the incidence in patients younger than 35 was 1.4% and in those over 35 years of age it was 0.04%. Of the 16 patients who developed compartment syndrome, 15 were male. Also, 15 of 16 cases involved the volar forearm compartment, and one involved the hand.[21]

2. Tendon-related complications
   Tendon irritation and rupture are known complications after operative and non-operative treatment of distal radius fractures (DRFs). The extensor tendons, specifically the extensor pollicis longus (EPL), is in close proximity to the bony architecture of the dorsal distal radius and therefore is at risk for injury. At the wrist, flexor tendons can also be at risk after surgical fixation.

Non-displaced fractures
   EPL tendon ruptures are not infrequent after minimally or non-displaced DRFs treated with immobilization. The mechanism for this injury is unknown but likely related to the direct apposition of the tendon over the distal radius as it passes through the third dorsal wrist compartment. Patients should be made aware of this potential complication in the outset. The treatment is either intercalary tendon grafting or an extensor indicis proprius (EIP) tendon transfer. Both options have been shown to be successful treatment alternatives.[22]

Volar-locked plating
   As the use of volar-locked plating (VLP) systems has become commonplace, extensor and flexor tendon-associated complications have been increasingly recognized, both in the form of tenosynovitis and ruptures. When the flexor tendons are affected, the flexor pollicis longus (FPL) is most commonly involved given its anatomic proximity to the volar surface of the distal radius. One series examined 141 patients treated with VLP of which nine required hardware removal due to flexor tenosynovitis [23]. The incidence of volar plate hardware removal was 10% in a pooled series of 374 patients treated by five different surgeons, mostly due to tendon related complications [24]. Flexor tendon ruptures can occur over a year after the index procedure, with three cases of flexor tendon ruptures reported in a series of 73 patients at an average of 20 months after the fracture repair. One factor associated in VLP flexor tendon complications is placement of the volar plate too distally, which can lead to mechanical impingement of the flexor tendons. The distal radius watershed line is a horizontal ridge on the volar distal radius just proximal to the articular surface that is not covered by the pronator quadratus (PQ) muscle [25].
   This anatomic landmark should be used as the distal most margin of VLP placement to avoid hardware impingement on the flexor. A classification system assessing the placement of volar plates was devised by Soong and his team using radiographic criteria. The grading scheme is based on a line drawn tangential to the volar rim of the distal radius parallel to the longitudinal axis of the radial shaft. Grades 0, 1, and 2 were assigned to the level of prominence of the distal radius volar plate at the watershed line. The higher the grade, the higher the incidence of flexor tendon related complications. There are several treatment options in cases of FPL rupture that can restore thumb interphalangeal joint flexion. Ring or long finger flexor digitorum superficialis (FDS) tendon transfer to the FPL tendon has been shown to reliably achieve adequate thumb flexion [26,27].

[21,22,23,24,25,26,27]
An intercalary tendon graft has also been described with good outcomes using the palmaris longus (PL) tendon [35]. If, however, there is some concern of distal FPL stump scarring or in the presence of underlying degenerative joint disease, an interphalangeal joint arthrodesis can be considered. Extensor tendon injuries have been reported with the use of VLP, mostly due to hardware prominence on the dorsal surface of the radius. Standard imaging can be inaccurate in determining dorsal prominence of volarly placed screws. The overall incidence of these injuries are estimated to be 3% to 5%, mostly involving the EPL tendon [23,28]. A large retrospective study examined 576 patients with DRFs treated with VLP fixation. The authors noted 12 extensor tendon ruptures (2% complication rate), and tendon irritation in another 1.7% of the cohort [29]. Although many mechanisms of injury have been hypothesized, prominent screws are noted to be a common cause [30].

The most important factor in preventing extensor tendon associated complications in VLP is the intraoperative identification of dorsal screw protrusion. There have been several methods to reduce the incidence of dorsally prominent hardware with VLP. The use of dorsal tangential views combined with oblique views can reliably detect screws protrusions 2 mm or more in second, third, and fourth extensor compartments [31]. Using multiple views intraoperatively can aid to better assess dorsally prominent screws such as the skyline view, horizon, and Hoya views [32-33]. However, no radiographic view can routinely assure proper screw length. A cadaveric study has demonstrated that distal screws spanning only 75% of the bicortical length provide similar primary stability to 100% screw length [34]. While additional attention to intraoperative fluoroscopic views during placement of hardware can minimize the risk of hardware prominence, avoiding bicortical fixation and using shorter screw lengths during VLP appears to be a reliable solution.

3. Nerve complications

Nerve injury after DRF is not uncommon. Incidence ranges from 2 to 8%. The median is injured most frequently, but radial and ulnar nerve injuries can occur as well. Nerve injuries may be the result of direct injury from the fracture, hematoma/swelling, over-distraction (particularly with external fixation or spanning plate fixation), or may occur during surgical fixation. Reduction with the wrist in a position of flexion increases the pressure substantially within the carpal tunnel and is to be avoided [36].

Median nerve injury

Median nerve symptoms that occur in the acute setting after injury may be either contusion of the nerve or acute carpal tunnel syndrome (aCTS). Differentiating between the two is critical, as aCTS is a surgical emergency whereas median nerve contusions are expected to resolve with time. Symptoms of aCTS include progressively worsening pain and numbness which develop over time, whereas with a median nerve contusion, symptoms begin at the time of injury and remain static. Initial management of a patient with acute median nerve symptoms includes a reduction of the fracture (with the wrist in a neutral position), splitting the cast if needed, and close observation. If symptoms persist or progress despite the above, urgent carpal tunnel release is performed. Dyer et al. [37] reported that patients with ipsilateral upper extremity trauma, women less than 48 years of age, and patients with greater than 35% fracture translation were at increased risk for aCTS. Performing prophylactic carpal tunnel release in patients without median nerve symptoms remains controversial, with some authors reporting increased rate of complications and others reporting favorable outcomes [38].
Radial nerve injury
Symptoms referable to the superficial branch of the radial nerve (SBRN) can occur after DRFs and is also most commonly associated with iatrogenic injury. This can result from direct trauma to the SBRN during percutaneous K-wire insertion, or during half pin insertion for external fixation[39]. Small incisions with gentle retraction of the soft tissues, direct visualization of the starting point on bone, and oscillating (Kwires) during insertion can help minimize this complication. A 14-gauge angiocatheter can also be used as a soft tissue sleeve during K-wire insertion to minimize the risk of wrapping up the soft tissues.

Ulnar nerve injury
Injury to the ulnar nerve is rare. Its reported incidence is approximately 1% to 6%. Acute compression occurs in Guyon’s canal and may result in sensory, motor, or a combination of deficits based on the site of compression. It results from a markedly comminuted and dorsally angulated fracture. Late ulnar neuropathy in Guyon’s canal is similar to median nerve neuropathy and is usually due to malunion. [40]

4. Fracture malunion
Malunion of DRFs can be extra-articular, intra-articular, or both. It occurs when a fracture heals with improper alignment or articular incongruity [51]. Extra-articular malunions may be in any of the three planes. Commonly in the sagittal plane, the malunion results in loss of the palmar tilt. In the coronal plane, the malunion presents as loss of radial inclination and radial shortening. Rotational deformities or displacement in the axial plane can occur and is best appreciated with a CT scan [41]. A clear definition of malunion has not been established, thus making it difficult to compare outcome studies. Malunion has been defined by different authors as radial inclination of less than 10–15°, dorsal tilt equal or greater than 10°, radial height (length) less than 10 mm, ulnar variance of greater or equal to 2–3 mm, and articular step-off greater than 2 mm [42].

5. Fracture nonunion
Nonunion of the distal radius fracture (DRF) is rare. Open fractures, those with severe comminution, devascularized bone fragments, soft tissue interposition, and medical conditions including diabetes and smoking are predisposing factors. Most nonunion are synovial. There are several reports in the literature detailing nonunion incidence. Bacorn and Kurtzke report a DRF nonunion rate of 0.2% in a study of 2000 New York workman’s compensation patients. Segalman presented a series of 12 distal radius nonunion in 11 patients during a 24-year period. Prommersberg et al. reported operative repair of 23 distal radius nonunion by comparing 10 with distal fragments less than 5 mm of subchondral bone supporting the articular distal radius to the nonunion site with a group of 13 patients with larger fragments [43].

6. Loss of reduction
Most fractures of the distal radius can be treated without surgery. This is most often achieved by splinting, bracing, or casting based on surgeon preference and predicated on the nature of the fracture with or without a closed reduction. However, close follow-up with serial radiographs is necessary to ensure maintenance of the reduction. Predictive criteria for the instability and ensuing loss of fracture reduction have been proposed by Lafontaine [44]. These include (1) dorsal tilt > 20°, (2) dorsal comminution, (3) intra-articular fracture, (4) concomitant ulnar fracture, and (5) age > 60 years. The presence of three or more of these factors are predictive of fracture displacement prior to healing. Would predict collapse and displacement of the fracture.

7. Infection
As the paradigm has shifted in the management of DRFs from pin fixation and external fixation to internal fixation with VLP and to some extent dorsal bridge plate technology, the infection rate has also decreased. In a large meta-analysis looking at 1520 operative DRFs, the infection rate was 11% for those treated with external fixation and 0.8% for those treated with internal fixation. When percutaneous fixation is used, chlorhexidine sponges and standard pin site care with hydrogen peroxide were both ineffective at preventing pin site infections [45].

8. Complex regional pain syndrome
Complex regional pain syndrome (CRPS) can occur with both surgical and non-surgical treatment of DRFs. CRPS is characterized clinically by pain and objective findings of sympathetic nervous system dysfunction such as swelling, stiffness, vasomotor changes such as hyperhidrosis and alldynia. CRPS is classified as type 1 (occurring after a noxious stimulus such as surgery or trauma) or type 2 (associated with a definable nerve injury, including compression neuropathies). Prevention of CRPS type 1 is paramount. Avoiding over distraction, prolonged immobilization, and undue tightness of cast immobilization can help minimize this occurrence [46].

9. Posttraumatic arthritis
Posttraumatic arthritis (PA) can occur after fractures of the distal radius, with increased incidence with intra-articular fractures, and those that heal in a malunited position. The classification for PA according to Knirk and Jupiter for DRFs includes grade 0 representing no signs of PA, grade 1 slight narrowing of the joint surface, grade 2 demonstrating marked narrowing with osteophyte formation, and grade 3 representing bone-on-bone PA with osteophytes and cysts [47].

10. Intercarpal Ligament Injury
Ligament injuries of the wrist associated with distal radius fractures are often unrecognized. The diagnosis of intercarpal ligamentous injury in the absence of a gross deformity is difficult with plain radiographs, ultrasound, arthrograms, and even magnetic resonance imaging (MRI). Some investigators propose that the most accurate method of diagnosis is arthroscopic visualization. The reported prevalence of ligament injuries about the carpus is up to 98% in distal radius fractures. An injury to the triangular fibrocartilage complex (TFCC) and the scapholunate ligament has been reported in various studies to be as high as 78% and 54% respectively.[48]

![Figure (6): Distal radius fracture with scapholunate dissociation][49]

11. Dupuytren’s disease

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The development of Dupuytren’s disease following a distal radius fracture was first noted by Goyrand, in 1935 and since then has been reported sporadically in the literature. The causal relationship between the two has not been elucidated, and its reported incidence in literature is highly variable, ranging from 0.2% to 11%. It usually occurs within 6 months following a distal radius fracture. The most common findings are nodules and skin pits, with the disease being mild in nature with minimal contractures. In most patients, the disease tends to occur in the palm along the fourth ray, and its progression ceases after its appearance. The contractures are usually mild [50]

Figure (7): Dupuytren’s contracture [50].

References


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