Complex Articular Fractures of the Distal Radius: Classification and Management

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Abstract

Articular fractures of the distal radius require an anatomic reduction, as even minimal step-offs are associated with the development of osteoarthritis. Such fractures are classified on the basis of both the mechanism and the pattern of injury. The comprehensive classification of fractures established by Müller et al defines those occurring from a shearing mechanism and involving part of the articular surface as type B fractures. These are in turn subdivided into group B1 fractures, which involve the radial styloid (chauffeur's fracture); group B2, which involve the dorsal margin of the radius; and group B3, which involve the volar margin of the distal radius (Barton's fracture). Type B fractures are unstable and often require operative intervention. Articular fractures resulting from a compression force on the end of the radius are classified as type C. A group C1 fracture is a two-part fracture without metaphyseal comminution; group C2, a two-part fracture with metaphyseal comminution; group C3, a fracture with more than two pieces, with or without comminution. The operative tactic for compression fractures involves restoration of the four common fragments in sequence. This can often be accomplished by manipulative means alone or with limited exposure of the fracture fragments and stabilization with percutaneous Kirschner wires. Neutralization with an external fixator and use of an autogenous bone graft are often required.

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Fractures at the distal end of the radius are the among the most common of all skeletal injuries.[1] The vast majority are extra-articular fractures that result from a fall from a height. These are effectively treated by closed manipulative reduction and external plaster support. Fractures that involve the radiocarpal articular surface require individual assessment and a treatment program tailored to the specific nature of the injury pattern. In many instances, these fractures can be identified on the basis of the mechanism of injury. Those that occur as a result of shearing of the carpal bones against the anterior or dorsal lip of the radial articular surface are commonly referred to by the eponymic description "Barton's fracture." These articular fractures are inherently unstable and usually require operative exposure and plate fixation.[2-4] In contrast, fractures that result from splitting in a sagittal or coronal direction due to a compression force through the carpal bones are often amenable to manipulation, percutaneous Kirschner-wire fixation of the articular fragments, and adjuvant use of an external skeletal fixation device.[5-7]

Functional Anatomy

The distal end of the radius is the anatomic foundation of the wrist joint. The wrist is dependent on both the osseous and the ligamentous integrity of this foundation for its mobility as well as its capacity to support axial load.

The wrist joint in man is distinguished from that in lower primates by having an exclusive radiocarpal joint. The development of the triangular fibrocartilage complex and the elimination of a well-defined articulation between the ulna and the carpus has enhanced the ability to position the hand in space.[8]

The distal radial articular surface is divided into two hyaline cartilage–covered facets for articulation with the carpal scaphoid and lunate. A well-defined ridge traversing from the dorsal to the palmar surface separates the two facets. Both facets are concave in

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both the anteroposterior and the radioulnar directions.

The palmar surface of the distal end of the radius is relatively flat and extends volarly in a gentle curve. The radioscapholunate ligament arises from a tubercle in the middle of the radiopalmar surface. A smooth impression on the radial styloid process represents the origin of the stout radioscapholunate and radiotriquetral intracapsular ligaments (Fig. 1).

The anatomic relationships of the dorsal radius, the extensor retinaculum, and the six dorsal extensor compartments are extremely important in planning operative approaches and the placement of implants when a dorsal approach is used. The articular end of the radius slopes in an ulnar and palmar direction. The proximal carpal row will thus have a natural tendency to slide in an ulnar direction, resisted for the most part by the intracapsular and intraosseous carpal ligaments.

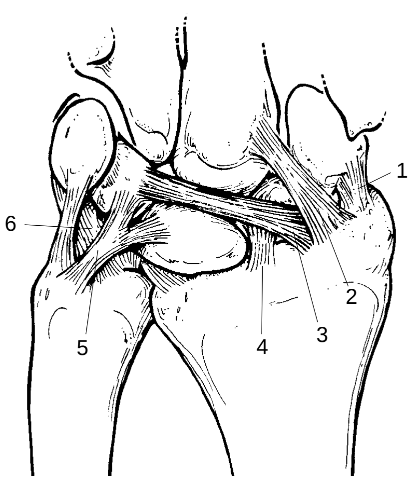


Fig. 1 The palmar aspect of the distal radius is the site of origin of the important radiocarpal intracapsular structures: 1 = radial collateral ligament; 2 = radioscaphocapitate ligament; 3 = radiolunatotriquetral ligament; 4 = radioscapholunate ligament; 5 = ulnolunate ligament; 6 = meniscus homologue.

The other distinct articular surface of the end of the radius is the sigmoid notch. Semicylindrical in shape, it runs parallel to the seat of the ulnar head. The articulation is a trochoid joint.[9] Rotation of the radius about the ulna is accompanied by translation such that, in supination, the ulnar head displaces volarly in the notch, while in pronation it moves dorsally.[9]

The triangular fibrocartilage complex arises at the ulnar aspect of the lunate facet of the distal radius and extends onto the base of the ulnar styloid process, functioning as an important stabilizer of the distal radioulnar joint. Its volar and dorsal margins are thickened, blending into the dorsal and volar radioulnar ligaments.

Stability and mobility are ensured by the design of the radius and its interactions with its carpal and ulnar articulations. Fractures of the distal end of the radius that heal with deformity or disruption of these articulations will have a profound effect on the function of the entire wrist joint.

Mechanism of Injury

Shearing Fractures

Shearing marginal fractures have been attributed to an axial load imparted to the end of the radius by the carpal bones. King and Lovell[10] postulated that when this impact occurs with the hand and wrist in certain positions, the intrinsic ligamentous support of the lunate is injured sufficiently to permit it to migrate along with the sheared articular fragment of the end of the radius. The extrinsic radiocarpal ligaments arising from the radius and inserting onto the capitate remain intact, in contrast to a true radiocarpal dislocation. The resultant volar and dorsal marginal fractures are more common and are associated with a vehicular-trauma high-velocity impact.[2] Such compressive forces are postulated to occur when the wrist is locked in palmar flexion, as in gripping the handlebars of a motorcycle, or when the wrist is fixed in extension, as in grasping an automobile steering wheel; these forces lead to volar and dorsal shearing fractures, respectively.[4]

Fractures of the radial styloid have been eponymically known as “chauffeur fractures,” due to early observations of their association with cranking automobile engines. These fractures have also been associated with motorcycle trauma and falls from a great height.[11]

Compression Fractures

Reports of compression-type fractures date back to as early as 1842, when Voillemier described such an injury in a patient who fell from a three-story height. In 1920, Stevens described a fracture pattern resulting from the lunate impacting the posteromedial aspect of the articular surface of the radius when the forearm was held in full pronation. Later, Scheck[7] coined the term “die punch” injury for this type of fracture. He hypothesized that in some instances, both compression and bending forces are exerted in the direction of the longitudinal axis of the radius, a concept further expanded by Castaing[12] and Mortier et al.[13]

Melone[14] further extended the analysis of the injury mechanism and concluded that the medial aspect of the radius was most often affected. He used the term “medial complex” to describe the lunate facet as well as the ligamentous attachment with the proximal row of the carpal bones and the ulnar styloid. The fact that the lunate was the focus of the direct compression helped to explain why the dorsal aspect of the lunate facet was more commonly involved than its palmar counterpart. It was suggested that the injury occurred with the hand flat on the ground (wrist extended), thus driving the lunate into the dorsal aspect of the distal radius. With higher-velocity injuries, however, wider separation of the lunate facet could be observed, which at times would result in the palmar medial-facet fragment becoming displaced and rotated as much as 180 degrees.

Diagnostic Techniques

Since 1898, radiographic analysis has formed the foundation for evaluation of distal radial fractures. Standard measurements in the frontal view define the ulnar inclination of the articular surface of the radius, as well as the relationship of the radius to the ulna; sagittal views are used to identify the normal palmar slope of the end of the radius. However, these standard radiographic views may not accurately define the articular disruption, particularly that involving the articular surface. Sennwald and McCormack[15] emphasized the pitfalls of attempting to depict the dorsal and palmar cortical rims in the frontal projection of standard radiographs. As a result, they developed a method for measurement of impaction, as illustrated in Figure 2.

Despite technological advances in computed tomography and magnetic resonance imaging, trispiral tomography remains the most useful imaging technique for obtaining greater definition of complex fractures involving the articular surface of the end of the radius. Anteroposterior and lateral trispiral tomograms provide extremely useful images of even the most complex fracture morphology and should be considered for preoperative planning.

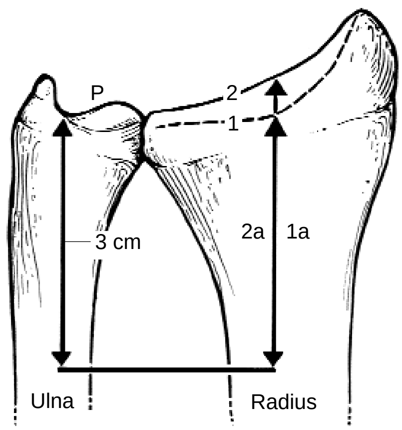


Fig. 2 Method of measuring the dorsal and palmar cortical rims of the radius to determine impaction, devised by Sennwald and McCormack.[15] The articular plateau of the ulna (P) serves as a fixed reference point. A straight line is drawn down its longitudinal axis; 3 cm proximal to the articular surface, a perpendicular is drawn to this line, which crosses the radius. The intersection serves as a reference point from which the distance to either the palmar lip (1) or the dorsal lip (2) of the articular surface can be measured. This measurement is always made on a line drawn along the longitudinal axis of the radius. By comparison with a similar measurement on the noninjured side, one can accurately measure the degree of shortening and/or displacement of an articular fragment (1a or 2a).

While less frequently required, computed tomography may be of use in defining the fracture lines of some complex articular injuries or in defining an injury to the distal radioulnar joint. Reconstructions in the sagittal and coronal planes can be useful for evaluation of metaphyseal comminution as well as impaction of the articular surface.

On routine posteroanterior radiographs, the articular surfaces of the carpal bones should be parallel, and the joint spaces of similar width. A broken arc, as described by Gilula,[16] or overlapping of the normally equally spaced joint lines is highly suggestive of injury to the supporting ligaments, the carpal bones, or both. When viewing routine radiographs of articular fractures of the end of the radius, the physician should be cognizant of the potential for an associated intercarpal ligamentous injury. In addition, a sign described by Fernandez as the "axial scaphoid shift sign" should be sought after the application of longitudinal traction in the process of reducing a radial fracture[5] (Fig. 3).

Classification Systems

Among the early attempts to define the varying patterns of articular fracture of the distal end of the radius were those of Castaing[12] in 1964 and Frykman[17] in 1967. Although the latter classification has been widely used in the English-language literature, it fails to give critical information about the extent and direction of articular fracture displacement. Melone[14] identified the impaction-type injury of the end of the radius, observing four basic components: the radial shaft, the radial styloid, the posteromedial portion of the lunate facet of the distal radius, and the palmar medial portion of the lunate facet.

Perhaps the most versatile and detailed classification system is the comprehensive classification of fractures established by Müller et al.[18] The fundamental principle of this classification is the division of all fractures of a bone segment into three types, with a further subdivision into three groups, each with subgroups. The classification is arranged in ascending order of severity according to the morphologic complexities, the difficulties inherent in treatment, and the prognosis of the fracture. Type A distal radial fractures are those not involving the articular surface.

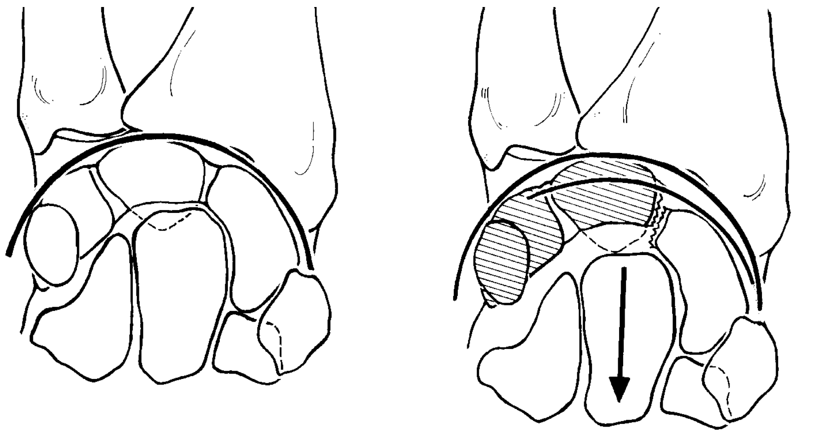


Fig. 3 Fernandez described the "axial scaphoid shift sign" to identify scapholunate ligament injury associated with an articular fracture.[5] **Left,** Heavy line represents the normal line of the proximal carpal row. **Right,** With scapholunate ligament injury, the scaphoid migrates distally, disrupting the normal carpal line.

Articular fractures are divided into those involving part of the articular surface (type B) and those involving all of the articular surface (type C). Type B partial articular fractures are subdivided into three groups: group B1 fractures involve the sagittal plane; group B2, the dorsal rim (Barton's fracture); group B3, the volar rim (reverse Barton's fracture) (Fig. 4). These are in turn further subdivided.

Compression fractures are more accurately considered type C fractures, which are subdivided into three groups. Group C1 fractures are two-part articular fractures without metaphyseal fragmentation; group C2, two-part articular fractures in which the metaphysis is multifragmentary; group C3, fractures involving comminution of the articular surface (Fig. 5). These are also further subdivided.

Accurate classification of complex fracture patterns may not always be possible from preoperative radiographs or even tomograms. Nevertheless, the classification will prove extremely useful not only in understanding the operative management of these fractures but also in the evaluation of outcome. One has only to read the classic studies of Gartland and Werley[19] and Scheck,[7] among others, to recognize that these types of fractures must always be separated from extra-articular fractures, as

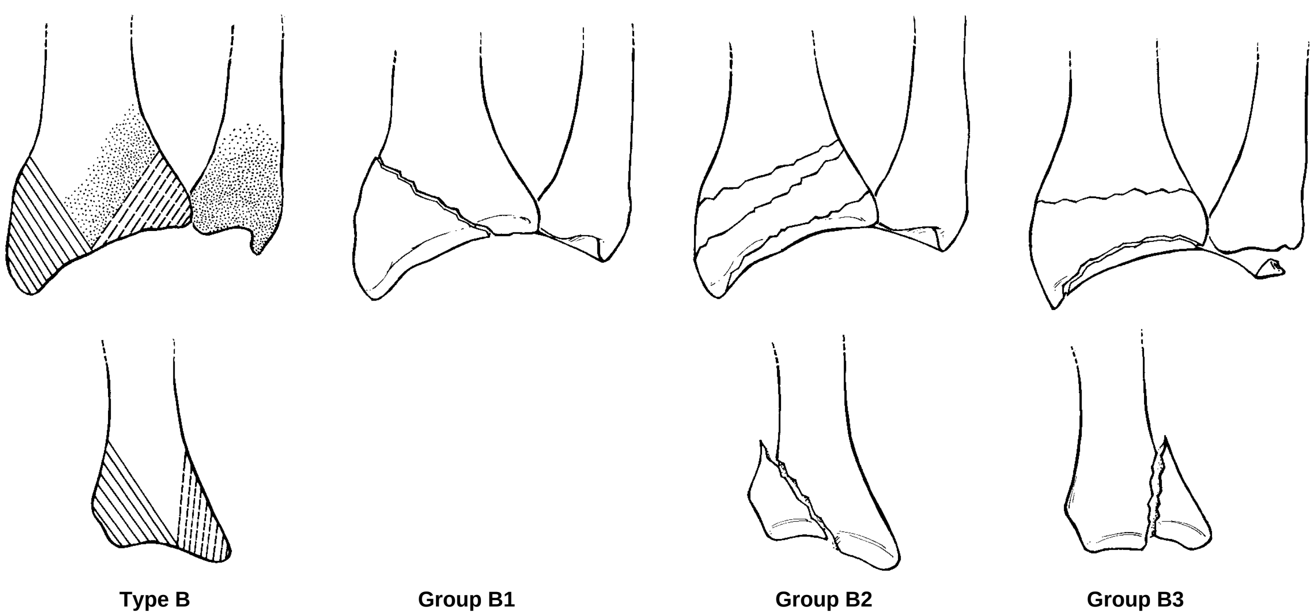


Fig. 4 Type B (shearing) fractures according to the comprehensive classification of fractures of Müller et al.[18] These partial articular fractures are subdivided into three groups: group B1 fractures involve the sagittal plane; group B2, the dorsal rim (Barton's fracture); group B3, the volar rim (reverse Barton's fracture).

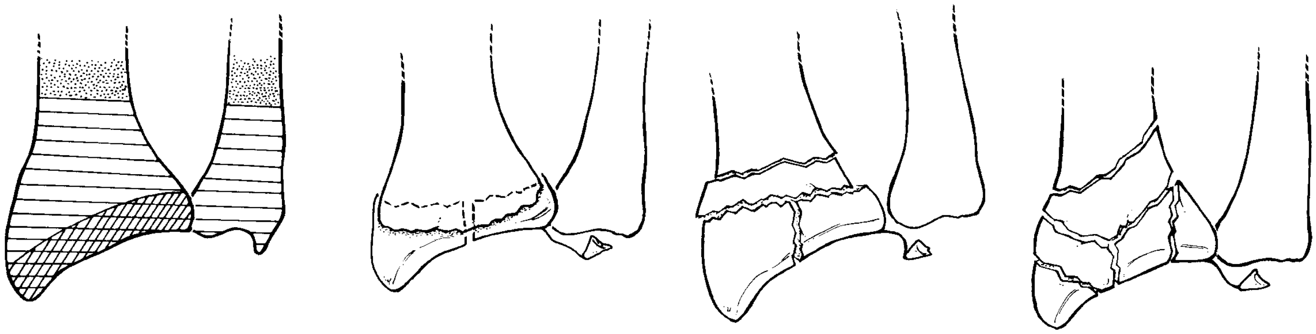


Fig. 5 Type C (compression) fractures, according to the comprehensive classification of fractures of Müller et al.[18] Group C1 fractures are two-part articular fractures without metaphyseal fragmentation; group C2, two-part articular fractures in which the metaphysis is multifragmentary; group C3, fractures involving comminution of the articular surface.

their response to treatment and the functional outcomes are quite distinct.

Treatment of Shearing Fractures

There are three major types of shearing fractures: group B1 are styloid fractures; group B2, dorsal fractures; group B3, anterior fractures. The treatment options and tactics vary according to the type of fracture.

Styloid Shearing Fractures (Group B1)

The goals of treatment of group B1, or styloid, fractures are not only to restore the articular congruity of the end of the radius but also, by doing so, to restore the length, alignment, and integrity of the supporting volar capsular ligaments of the wrist (Table 1). If a shearing fracture involving the radial styloid has only a single fragment, it is classified as subgroup B1.1; if it is comminuted, it is classified as subgroup B1.2. Subgroup B1.3 fractures, which involve a vertical shear fracture of the lunate facet, are uncommon.

Nondisplaced fractures can be treated with immobilization in an above-elbow cast with the forearm in supination and the wrist in slight ulnar deviation. Displaced fractures tend to be unstable; if treated by closed reduction and plaster immobilization alone, radiographs should be obtained frequently during the initial 6 weeks. Given the inherent instability of these fractures, however, it has been my preference to percutaneously place two oblique Kirschner wires or cannulated screws, even when an anatomic reduction is obtainable by closed manipulation.

The radial styloid lies anterior to the midaxis of the distal radius. Percutaneous wires or the guide wires for cannulated screws should be placed into the styloid aiming proximally, ulnarly, and somewhat dorsally to gain sufficient purchase in the proximal dorsoulnar cortex

Table 1
Diagnosis and Treatment of Styloid Shearing Fractures

Pitfalls	Recommendations
Failure to appreciate ligamentous injury	Consider dorsal arthrotomy or intraoperative arthroscopy
Failure to recognize articular comminution	Lateral and anterior tomography may be useful
Inadequate internal fixation	Appreciate the anterior position of the styloid Aim the screws or Kirschner wires in a dorsal, proximal, and ulnar direction
Failure to appreciate associated carpal injuries	Traction views may reveal either carpal fractures or ligamentous injury

of the radius. Given the proximity of the branches of the radial sensory nerve in this area, drill sleeves are mandatory during this procedure.

If an anatomic reduction cannot be achieved by closed reduction or if a radial styloid fracture is associated with carpal injuries, operative reduction and internal fixation is advisable. A longitudinal incision is made over the dorsoradial aspect of the wrist, and particular care is taken to identify and protect the superficial radial nerve, the radial artery, and the extensor pollicis longus tendon in the vicinity of the anatomic snuffbox. Styloid fractures that involve more than one fragment require a dorsal capsulotomy of the wrist to ensure an anatomic reduction.

Dorsal Shearing Fractures (Group B2)

An isolated dorsal marginal fracture is extremely uncommon. The combined lesion of a radial styloid fracture and a dorsal marginal fracture (subgroup B2.2) is considerably more common. Because of a similar appearance on lateral radiographs, such an injury may well be misdiagnosed as an extra-articular fracture. Preoperative planning is enhanced by obtaining lateral and anteroposterior trispiral tomograms (Table 2).

Because of the shearing mechanism and the obliquity of the fracture lines, the outcome with closed reduction and cast immobilization is unpredictable. For this reason, even if a closed manipulative reduction can be maintained, the placement of percutaneous pins protected by an external fixation device has been my treatment of choice.

The goal in the management of these fractures is both to restore the normal radiocarpal relationships and to restore the articular surface to within 1 to 2 mm of congruence. In many instances, this goal can be achieved only by operative reduction and internal fixation. These fractures can be approached through a dorsal longitudinal incision. The extensor retinaculum is opened between the second and third extensor compartments, with care taken to elevate and mobilize the extensor pollicis longus tendon. The initial tactic, particularly with comminuted fractures, involves restoration of the radial styloid fragment followed by reduction of the dorsal-lip fragment. This is accomplished under direct vision through a dorsal capsulotomy of the wrist. In some cases, after reduction and fixation of the articular fragments, a defect will be present in the metaphyseal bone, which can be filled with autogenous cancellous graft. Depending on the size of the dorsal-rim fracture fragment, a small T or L plate or a larger plate may be required to achieve stable fixation and to prevent recurrence of the deformity.[3]

Anterior Shearing Fractures (Group B3)

Due in large part to the obliquity of the fracture line and the loss of palmar support of the carpus, anterior shearing fractures tend to be intrinsically unstable. Shortening and palmar displacement of the fragments are always associated with volar subluxation of the carpus. A careful assessment of the surrounding soft tissues and the neurologic status is mandatory, as these fractures can be the result of high-energy trauma (Table 3). Median nerve compression or elevated intracompartmental pressure in the forearm may be coexistent, which would mandate a more expeditious operative intervention. When the standard radiographs suggest the possibility of more than one fracture fragment, lateral and anteroposterior trispiral tomography is especially helpful in identifying the presence and location of small impacted articular fragments.

Operative reduction and stable internal fixation will more reliably ensure the realignment not only of the articular surface of the radius but also of the radiocarpal articulation. For most of these fractures, the operative approach can be through an anterior incision along the radial border of the distal forearm (Fig. 6). The fracture is exposed through the interval

Table 2
Diagnosis and Treatment of Dorsal Shearing Fractures

Pitfalls	Recommendations
Failure to recognize the fracture as a marginal shearing fracture	Lateral tomography or axial computed tomography will accurately define the fracture
Failure to appreciate subgroup B2.2 fractures with a radial styloid component	A more extensile dorsal surgical approach is preferred for the complex fracture patterns
Lack of definitive implant for dorsal surface of the distal radius	Have available small and mini implants as well as external fixation devices

Table 3
Diagnosis and Treatment of Anterior Marginal Shearing Fractures

Pitfalls	Recommendations
Failure to recognize a split or comminuted shearing fracture	Anteroposterior tomography can help in preoperative planning
Inability of the buttress plate to secure the entire fracture fragment	Consider Kirschner wires or a cannulated screw through the radial styloid
Elevation of an impacted articular fragment	Avoid opening the volar capsule Elevate the fragment from within the fracture Support with autogenous bone graft

between the flexor carpi radialis tendon and the radial artery, with detachment of the pronator quadratus along its radial border. When the fracture is associated with symptoms of an acute median nerve compression, a second incision may be made in the palm in line with the ring finger to release the transverse carpal ligament. This approach is preferable to extending the radial incision across the volar wrist crease onto the palm, which places the palmar cutaneous branch of the median nerve in jeopardy.

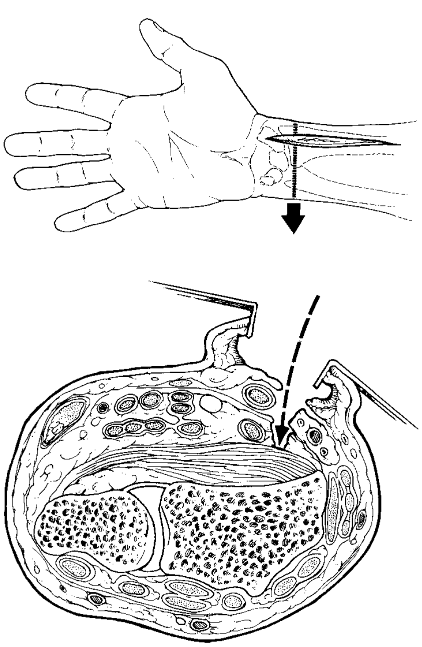


Fig. 6 The anterior operative approach to the volar shearing fracture.

When dealing with volar shearing fractures without evidence of intra-articular comminution, reduction can be achieved by realigning the metaphyseal fracture lines. This is facilitated by hyperextending the wrist over a rolled towel, with the forearm in maximal supination. It is imperative not to open the volar wrist capsule to visualize the articular surface, as this can lead to injury of the volar radiocarpal ligaments and postoperative instability.

Definitive fixation of group B3 fractures is generally achieved with a 3.5-mm T plate applied to the anterior cortex. The plate should be contoured in such a way that there remains a small space underneath the midportion of the plate. The most proximal screw is applied first and tightened securely. The introduction of the second screw just distal to the first screw will firmly compress the plate against the radial shaft. This will in turn compress the articular fracture fragment against the intact radius, enhancing the buttress effect (Fig. 7).

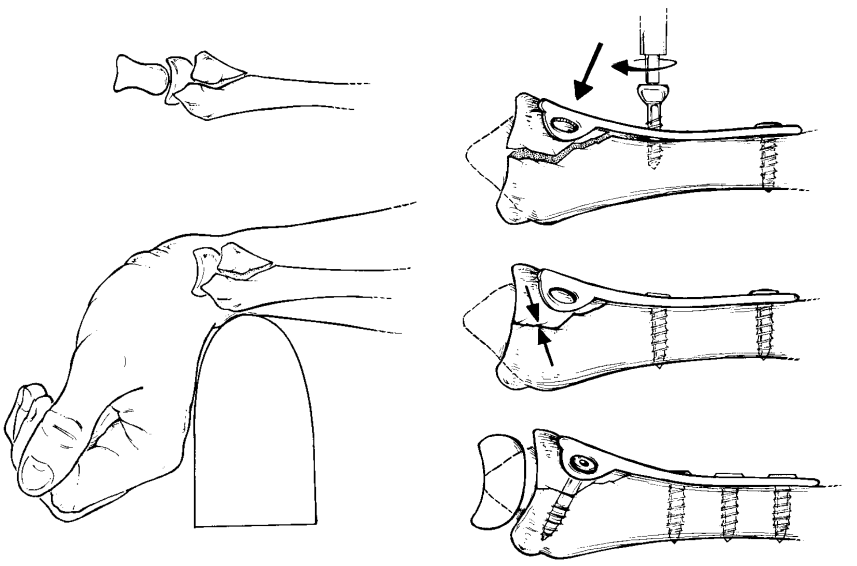
Additional stability of the fracture may be desirable when more than one fragment is identified (subgroup B3.3). In such instances, screws can be placed into the distal radius either through the plate or separately into specific fracture fragments.

When approaching shearing fractures operatively, either dorsally or palmarly, the wound is closed over a suction drain, and a bulky dressing and a volar splint are applied. The splint is left in place for 14 days, after which the sutures are removed. A removable splint is then worn for an additional 2 to 3 weeks. The patient is permitted to use the involved hand for activities of daily living, but manual work and sports are forbidden until fracture healing is assured, usually by 2 months after injury.

Treatment of Articular Compression Fractures

The goals of treatment of articular compression fractures involve not only relocation of displaced articular fragments but also restoration of the normal angulation of the distal metaphyseal segment of the end of the radius in addition to maintenance of its length in relation to the distal ulna (Table 4). The treatment approaches are based on the recognition that compression fractures of the distal radius commonly produce certain distinct fragments, specifically, the radial styloid, the radial shaft, and the lunate facet (which is often split) (Table 5).

Articular compression fractures without comminution of the underlying metaphyseal bone are best approached by manipulative reduction, either with longitudinal traction alone or with percutaneous



A B

Fig. 7 Operative technique for fixation of a volar shearing fracture involves **(A)** extending the wrist over a rolled towel and **(B)** applying the buttress plate, with placement of the most proximal screw first.

fracture manipulation and subsequent pinning of the fracture fragments.[5,6] These fractures should be treated in the operating room with appropriate anesthesia to permit a careful and controlled procedure. The iliac crest is prepared and draped as well as the involved limb in case autogenous bone graft is required. An image intensifier is necessary. Initially, a closed manipulative reduction is performed by using longitudinal traction combined with palmar flexion and ulnar deviation of the hand and wrist. Alternatively, longitudinal traction may be effectively gained with the use of sterile finger traps or a small distractor.

If there is a displaced radial styloid fragment, manipulation and fixation of the fragment should be accomplished in a manner similar to that described for group B1 shearing fractures. I prefer to place 0.062-inch smooth Kirschner wires obliquely into the more proximal radius[20] (Fig. 8, A).

When the fracture also includes a die-punch component of the lunate facet, which is reduced by longitudinal traction, this fragment should also be stabilized with the placement of a percutaneous 0.062-inch Kirschner wire directed transversely from the radial styloid toward the sigmoid notch. The wire is directed to lie just beneath the subchondral bone to, in effect, buttress the reduced lunate facet fragment. Care must be taken to avoid having the wire penetrate the sigmoid notch into the distal radioulnar joint.

In the event that satisfactory reduction of the die-punch fracture fragment cannot be achieved by closed manipulative techniques, the fragment may be maneuvered into position with use of a pointed awl or small elevator inserted through a small (1- to 2-cm) incision (Fig. 8, B). Intraoperative fluoroscopy is needed both to guide the placement of the awl and to confirm the reduction. When an impacted fragment is elevated, it may be useful to consider placing autogenous bone graft into the deficit created in the metaphyseal bone. As only a small amount of bone graft will be required, obtaining the bone graft from the iliac crest can easily be accomplished with trephine biopsy needles, which will minimize morbidity of the iliac crest as a donor site.[5]

An articular fracture may involve a sagittal split of the two major fragments. In this instance, interfragmentary compression is possible with use of a large pointed bone-reduction clamp. One point of the clamp is placed through a dorsal medial incision into the lunate facet fragment; the other secures the radial styloid percutaneously (Fig. 8, C). The fragments

Table 4
Recommendations in the Treatment of Articular Compression Fractures

Pitfalls	Recommendations
Inadequate reduction of a die-punch fragment	Percutaneous elevation with pointed awl Use of a large pointed reduction clamp
Displaced anterior lunate facet fragments	Open reduction with volar ulnar approach, buttress plate, and bone graft
Late loss of articular reduction	Autogenous bone graft Leave external fixator or Kirschner wire for minimum of 6 weeks

Table 5
General Guidelines for Treatment of Articular Compression Fractures

Fracture Type	Treatment
Two-part articular with no metaphyseal comminution	Closed reduction, percutaneous Kirschner-wire fixation, and cast
Two-part articular with metaphyseal comminution	Closed and / or percutaneous reduction and external fixation, with or without autogenous bone graft
Three- or four-part articular with metaphyseal comminution	Open reduction, external fixation, and autogenous bone graft

are gently compressed together, and a transverse Kirschner wire is placed (Fig. 8, D).

When two-part articular compression fractures can be treated by closed means or with limited operative exposure and application of Kirschner wires, an above-elbow plaster cast is used for approximately 3 weeks, followed by a short-arm plaster cast for an additional 3 weeks. The Kirschner wires are left in place for the duration of this time. In the event that there is concomitant soft-tissue swelling or impaction of the articular fracture fragments, which requires elevation and bone grafting, as a general rule it is best to apply an external skeletal fixation device rather than plaster as a means of protecting the percutaneously placed Kirschner wires from the displacing force of the carpal bones. The external fixation should be left in place for a minimum of 4 weeks (in some cases, 6 weeks).

When the metaphyseal support of the articular fracture fragments is further compromised by comminution, there is a greater need for both external fixation and autogenous bone graft. Without this support, it is not uncommon to see loss of the articular reduction as late as 8 to 12 weeks after fracture.

When the articular fracture pattern involves a split of the lunate facet, reduction by closed or even percutaneous means becomes less predictable. The volar part of the medial complex described by Melone[14] has a tendency to rotate as longitudinal traction is applied. In these instances, operative reduction through an anterior approach will be necessary. As with two-part articular compression fractures, in most cases longitudinal traction will restore axial length and realign the radial styloid fragment. External fixation will be extremely useful in providing continuous traction during the operative intervention. The radial styloid is stabilized with percutaneously placed Kirschner wires.

Operative reduction of the displaced volar fragment is recommended through an extensile anterior approach. To facilitate exposure, the transverse carpal ligament

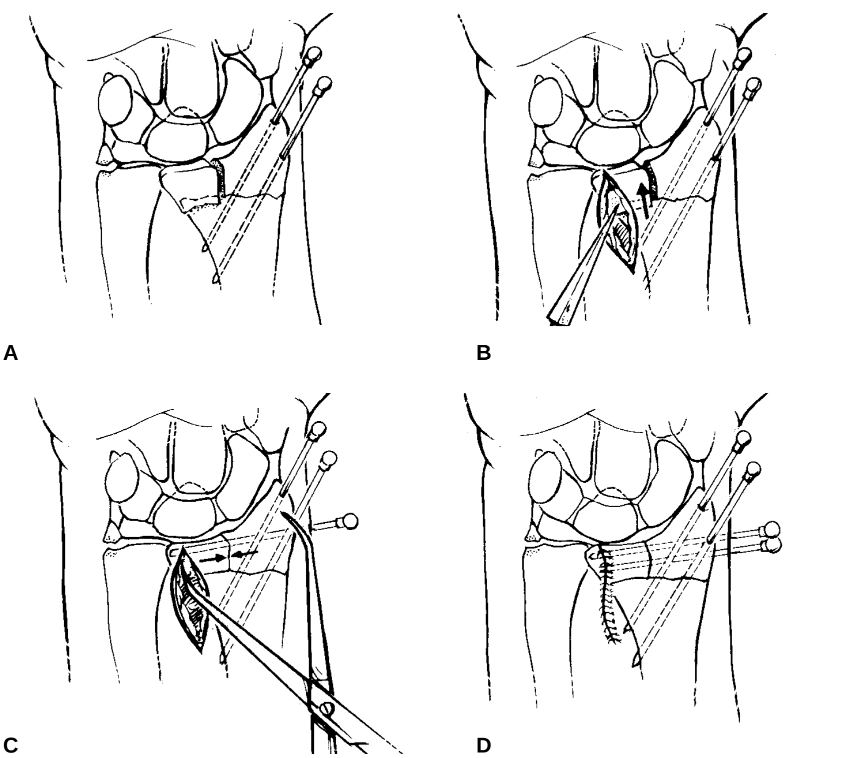


Fig. 8 Technique for treatment of a compression fracture with a displaced radial styloid fragment. **A,** The radial styloid is restored to the metaphysis with Kirschner wires. **B,** The lunate facet is elevated percutaneously with a pointed awl. **C,** The articular fragments are compressed together with a large pointed clamp. **D,** Transverse wires are placed across the articular fragments. An external fixation device is also used in most cases.

can be opened. The distal portion of the pronator quadratus can be approached through the interval between the ulnar neurovascular bundle and the flexor tendons. The pronator quadratus is partially incised and elevated from the displaced volar aspect of the radius. Reduction of the displaced fragment is performed without additional soft-tissue dissection, taking care to avoid disturbing the soft-tissue attachments to the fragment. If the fragment is small, fixation is carried out with a single Kirschner wire introduced obliquely from the volar surface of the fragment across the metaphysis and retrieved through the dorsal skin of the forearm. In most instances, however, the fragment will be large enough to be supported by a small (2.7-mm) L or T plate. When the four-part articular fracture pattern is associated with comminution of the metaphysis, external fixation and autogenous bone graft are important to prevent loss of reduction (Fig. 9).

Complications

Inadequate reduction, loss of internal fixation, loss of wrist or forearm motion, and problems related to overlying nerves or tendons have all been identified with operative management of unstable shearing or compression fractures. A number of studies with follow-up beyond 2 years have addressed the outcome of treatment of fractures with displaced articular fragments and have identified a distinct association with the development of posttraumatic arthrosis and residual articular incongruity.[21-24]

Two studies have considered the problem of inadequate restoration of the articular and extra-articular anatomy with anterior shearing fractures. Both Keating et al[24] and Fernandez and Jupiter[6] have identified a particular situation in which unrecognized fragmentation of the metaphysis led to loss of the normal palmar tilt of the distal radius in a number of instances.

Outcome

Several studies have provided some insight into the results of the operative management of articular fractures of the end of the radius. Bradway et al[22] reported on their experience with operative treatment of articular fractures, in which they achieved good to excellent results in approximately 80% of their patients. In a report on the use of limited open reduction and internal fixation to treat compression fractures of the articular surface, Fernandez and Geissler[5] noted that 38 of 40 patients were able to return to their former occupation with a grip strength approximating 85% of that in the opposite wrist. In a study of articular fractures associated with high-energy injury, Hastings and Leibovic[3] found that loss of extension and flexion was approximately 40 degrees compared with the noninjured wrist, that the grip strength was 72% of that on the opposite side, and that fractures associated with high-energy trauma and comminution of the metaphyseal bone stock had an excellent or good result in 62% of cases and a fair or poor result in 38%. In a study of compression fractures associated with higher-energy trauma, Jupiter and Lipton[23] found both wrist motion and grip strength in treated wrists to be about 75% of those on the opposite side.

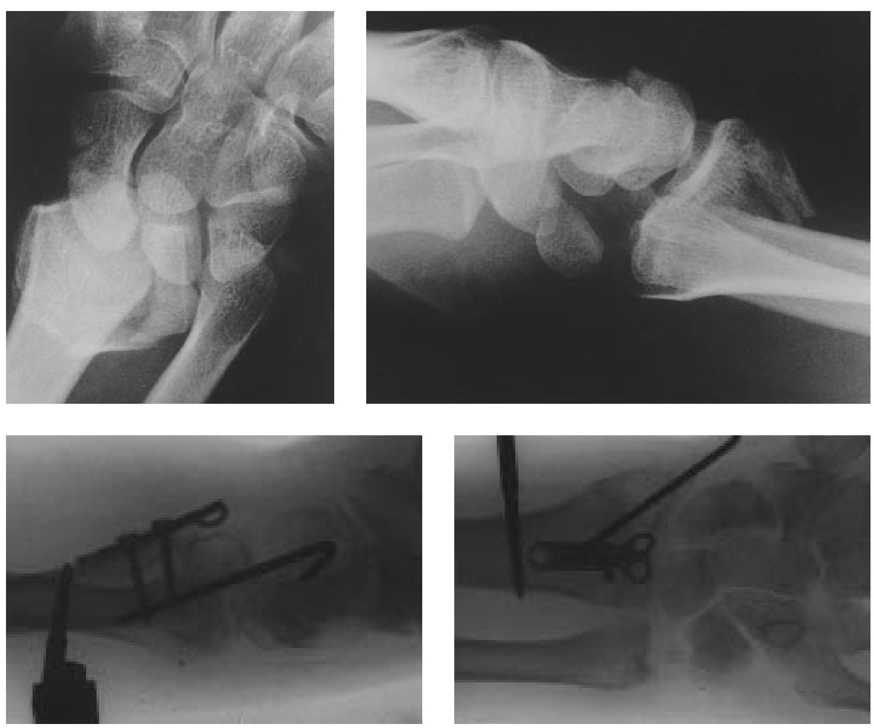


Fig. 9 A four-part compression fracture **(top)** required operative exposure and stabilization of the rotated anterior fragment, Kirschner-wire fixation of the remaining articular fragments, and application of an external fixation device **(bottom)**.

Summary

Fractures involving the articular surface of the end of the radius occur in specific patterns, which are based in part on the mechanism of injury. Shearing fractures involve part of the articular surface; the remainder of the articular surface and the metaphysis remain intact. Some can be treated by closed manipulative reduction, but most are inherently unstable and require either percutaneous fixation or operative exposure and stabilization.

Fractures that are the result of a compression or axial-loading force disrupt the end of the radius into specific fragments (i.e., the radial styloid, the lunate facet, and the remaining radial shaft). The lunate facet fragment may be split; if the anterior fragment is displaced, it is frequently rotated and cannot be reduced by manipulation. Compression fractures can often be manipulated into place in a closed or limited open manner and stabilized by percutaneous Kirschner-wire fixation; however, such fractures frequently need neutralization with an external fixator.

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