Fractures of the Wrist

A Clinical Casebook

Nirmal C. Tejwani
Editor

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ISBN 978-3-030-74292-8 ISBN 978-3-030-74293-5 (eBook)
https://doi.org/10.1007/978-3-030-74293-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to my daughter Rhea, who has been fascinated with distal radius fractures and fall on outstretched hand (FOOSH) from a young age. She has always encouraged me to write about these injuries, so I decided to expand on the subject matter and the result is this book

— Nirmal C. Tejwani

This book is dedicated to my mentors in residency at Harborview Medical Center who fostered in me an appreciation and love for complex wrist injuries

— Jacques Henri Hacquebord

Preface

Injuries to the wrist are common; while most can be treated non-surgically, some are serious enough to merit surgical intervention. A wide variety of injuries are seen at the distal radius, ulna, and the carpus with multiple bones and ligaments injured; as expected, multiple implants and techniques are available for their surgical treatment.

This is based on fracture type and location, soft tissue status, implant access, as well as surgeon experience. With the spectrum of injuries ranging from intra-articular fractures to complex combinations of fracture-dislocations, the treatment methods vary widely. Use of internal or external fixation is described using actual cases as treated by the authors.

The purpose of this book was to give the readers case examples of different injuries and fractures around the wrist and their treatment options. This book is entirely case based and uses clinical case scenarios and attempts to put you in the surgeon's shoes. Each case illustrates different options for treatment with the author thinking process; follow-up is also reported as well as outcomes of options used in treatment. The goal is not to substitute knowledge learning from text books or journals but to provide clinical examples elucidating the translation of theory to practice.

The reader must be aware that not all of these treatment options may be applicable to all situations, but will hopefully make you aware of what is possible.

The creation of this book would have been impossible without the conceptual insight of Kristopher Spring (Editor, Clinical Medicine) and the logistical support of Nishanthini Vetrivel (Project Coordinator), both at Springer. Much gratitude is owed to them for their professionalism and engagement that resulted in the timely execution of the book project.

New York, NY, USA

Nirmal C. Tejwani
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1 Both Bone Forearm Fractures (Distal)

Ajay Kanakmedala and Abhishek Ganta

Case Presentation/History/Examination/Initial Management in ED/Office

A 26-year-old male presented to our hospital after he collided with a truck while riding a motorcycle. Gross deformities of his bilateral upper extremities were noted in the trauma bay. During initial evaluation, he became less responsive and was subsequently intubated in the trauma bay. Examination revealed a 3 cm open wound at the middle of his right dorsal forearm as well as open wounds over his left elbow and radial aspect of his wrist, and he was noted to be neurovascularly intact prior to intubation. Radiographs of his right forearm (Fig. 1.1) showed comminuted fractures of the diaphyseal regions of both the radius and ulna, with extension of the radial fracture into the distal diaphyseal

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_1

Fig. 1.1 Plain radiographs of the right forearm and wrist demonstrate comminuted fracture of the mid-shaft region of both the radius and the ulna. There appears to be a large butterfly fragment on the radial aspect of the ulna, and the radial fracture appears to extend into the distal diaphyseal region area with a large segmental fragment

region. His other injuries included a contralateral left open both bone forearm fracture and elbow dislocation with a medial epicondyle fracture, a subarachnoid hemorrhage, C5 spinous process fracture, and C6 right lamina fracture. Appropriate intravenous antibiotics and tetanus prophylaxis were promptly administered.

Surgical Timing/Planning Including Equipment

After the appropriate clearances were obtained, the patient was taken the same day to the operating room, however, due to the patient needing urgent treatment of his head injury, only an irrigation and debridement was performed on the right upper extremity, which was then splinted with the plan to return to the operating room for definitive fixation.

The following day, the patient was taken back to the operating room for repeat irrigation and debridement and open reduction and internal fixation of his right radius and ulna. This case was performed supine on a hand table with a tourniquet and image intensification. While the contralateral extremity was injured in this case, contralateral radiographs are often helpful for preoperative templating of native radial bow and forearm geometry.

Surgical Tact: Position; Approach, Fixation Technique

Given that both the radial and ulnar fractures were segmental, the radius was approached first to make it easier to flex the elbow to approach the ulna from its subcutaneous border [1]. The volar Henry approach to the radius was utilized, taking care to identify and protect the radial artery. After the pronator teres was elevated off the radial shaft with the forearm in pronation, the fracture fragments were exposed and debrided to remove any interposed soft tissue and periosteum. The segmental fragment was reduced to the proximal fragment and two 2.4 mm lag screws were placed (Fig. 1.2a). A mini-fragment plate was then pre-contoured to

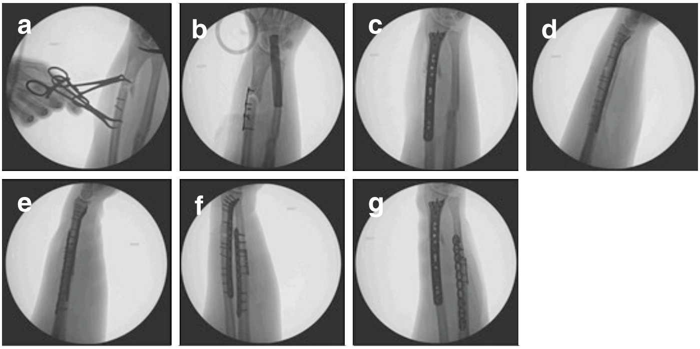

Fig. 1.2 Intraoperative fluoroscopic images showing fixation methods. (**a**) Segmental fragment is secured to the proximal fragment with two 2.4 mm lag screws. (**b**) A mini-fragment plate contoured to the radial bow is used to provisionally hold the radial length and bow. (**c**, **d**) After a metadiaphyseal locked plate is secured to the proximal, segmental, and distal fragments, the provisional mini-fragment plate is removed. (**e**–**g**) A mini-fragment plate is used to reduce and secure the segmental fragment, and a 3.5 mm limited contact dynamic compression plate is then secured to the proximal and distal fragments

match the native radial bow and secured to the distal and proximal fragments. This plate was used to provisionally hold the radius out to the appropriate length and bow (Fig. 1.2b). Given the distal extension of the fracture, a specialized metadiaphyseal plate was utilized to ensure at least 6 cortices of fixation on either side of the fracture. Unicortical locking screws were placed in the distal metaphyseal portion and bicortical screws in the proximal fragment for balanced fixation with appropriate working length. The use of unicortical locking screws distally minimizes potential extensor tendon irritation. The provisional mini-fragment plate was then removed, as retention would overly increase the stiffness of the construct (Fig. 1.2c, d).

The ulna was then addressed through a standard approach over the subcutaneous border. There was a large butterfly fragment that, due to multiple non-displaced fracture lines, was not amenable to lag screw fixation. A small mini-fragment plate was used to reduce this fragment and fixed with two bicortical screws on each side. A 3.5 mm limited contact dynamic compression (LCDC) plate was placed and fixed with 3 bicortical screws in the proximal and distal fragments (Fig. 1.2e–g). Pronation and supination were both checked and noted to be full, and the distal radioulnar joint (DRUJ) was also evaluated and found to be stable. It is imperative to check the DRUJ in these injuries as delayed diagnosis can lead to chronic DRUJ instability and wrist pain [2]. Furthermore, checking that rotation is full as malreduction can lead to assymetric rotation [3, 4].

After both wounds were thoroughly irrigated, the ulnar side was closed first. Due to soft tissue swelling, the volar incision was unable to be closed without undue tension leaving an area of 3 cm × 4 cm that was covered with a wound vac. After 48 h, during which the patient's extremity was maintained in strict elevation, the patient returned to the operating room and his volar wound was able to be closed at this time.

Fig. 1.3 Plain radiographs of the right forearm obtained 8.5 months postoperatively demonstrate healed fractures with maintained anatomic alignment and hardware in position without any evidence of loosening or failure

Postoperative Protocol

With regard to this extremity, the patient was placed in a soft dressing and allowed to range his forearm and wrist as tolerated. He was restricted from lifting more than 5 lbs until 3 months postoperatively when he was allowed to do progressive strengthening once increased bony consolidation was noted on his radiographs.

Follow-Up with Radiographs

The patient was last seen at 8.5 months postoperatively. He has returned to work as a real estate agent. On examination of his right upper extremity, his wounds are well-healed, and there is no tenderness to palpation at his fracture site. His pronation and supination are both 85°, and his wrist flexion and extension are 75 and 60°, respectively. Radiographs (Fig. 1.3) obtained at this visit showed healed fractures with acceptable alignment and hardware in good position.

Tips and Tricks

- It is important to preoperatively counsel all patients with both bone forearm fractures that primary closure may be inadvisable at the time of fixation due to swelling. In these cases, after maintaining strict elevation for 2 days, patients typically return to the OR for primary closure versus split thickness skin grafting.
- Smaller mini-fragment or one-third tubular plates can be used as supplemental or provisional fixation along with stiffer plates for segmental patterns with smaller fragments.
- If only one incision is able to be closed, typically the dorsal incision over the ulna is preferred as this area is less amenable to skin grafting due to less underlying muscle and soft tissue. Negative pressure wound therapy along with retention sutures or vessel loops in a Roman sandal configuration can help maintain tension on the skin edges to prevent retraction.
- It is imperative to stress the DRUJ after fixation in supination and pronation as missed injuries can lead to chronic DRUJ instability and pain and are more challenging to manage.

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2 Galeazzi Fracture Dislocation with Closed Reduction of Distal Radio-Ulna Joint

Nirmal C. Tejwani and Ruchi Tejwani

Case This is a 33-year-old right-hand-dominant male who fell off his bicycle on his outstretched left hand and sustained this injury to his forearm and wrist (Fig. 2.1a–d). He was seen in the emergency room and splinted and followed up for his treatment. These are fractures of necessity and require operative intervention due to their unstable nature and inability to hold these reduced in a plaster.

Radiographs: Standard views of the forearm and wrist are done which demonstrate the injury well. Contralateral wrist radiographs are helpful in assessing the normal relationship between the distal radius and the ulna and allowing for intraoperative comparison assessment of reduction of the injury. We do not recommend any advanced imaging such as CT or MRI unless other complex associated injuries are present.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_2

Fig. 2.1 (**a**–**d**) Injury radiographs of the forearm and wrist demonstrating displaced and shortened radius shaft fracture and dislocated DRUJ

Surgical timing These injuries are best treated acutely, we prefer to operate within the first 7 days if possible. Delay in treatment may make the distal radio-ulna joint difficult to reduce in a closed fashion and may require open reduction.

Surgical Tact

We prefer supine position and the use of a hand table. A standard or a mini fluoroscopy can be used based on surgeon preference, we use the standard one.

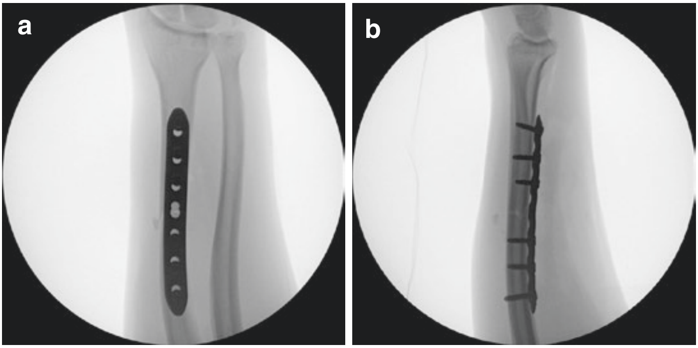

Fig. 2.2 (**a**, **b**) Intraoperative fluoroscopy showing radius shaft fracture fixed with a 7-hole dynamic compression plate on the volar surface

A volar Henry approach centered on the radius fracture shaft is taken. The fracture is exposed and cleared and fracture ends approximated using serrated bone reduction clamps. Based on the fracture pattern, a lag screw may be used to compress the fracture.

A volarly placed non-locking 3.5 mm dynamic compression plate is preferred. The fracture is compressed using eccentric drilling of screws (if no lag screws used). We recommend three bicortical screws on either side of the fracture so as to have stable fixation (Fig. 2.2a, b).

Once the radius shaft is fixed, the DRUJ is assessed both clinically and radiographically. Most often, the joint is reduced once the radius shaft if fixed anatomically. If reduced, the joint is examined for stability, some laxity is usually elicited, but the joint remains well reduced in supination and pronation (Fig. 2.3a, b).

If the joint is reducible, but does not stay reduced (typically with supination), then it should be held reduced, and fixation of the DRUJ with K-wires is recommended in neutral position.

If the joint is not reduced, then re-examine the radius reduction. If the radius is anatomic and the DRUJ is still not reduced, then an open reduction will be needed.

The forearm is splinted in a long arm splint in neutral position for a minimum of 2 weeks if the joint is stable. Post splinting

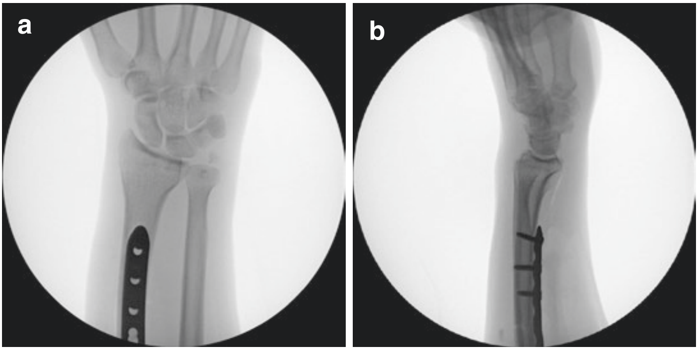

Fig. 2.3 (**a**, **b**) Intraoperative fluoroscopy demonstrating a reduced DRUJ

radiographs are recommended to confirm DRUJ reduction, if there is concern for instability.

If pinning or open reduction of the DRUJ is done, then 6 weeks of immobilization is needed.

Follow-Up

At 2 weeks, the splint was removed and wrist examined. In this patient the DRUJ continued to be stable; we started physical therapy to promote range of motion exercises. He was also placed in a removable splint to be used at night and when not exercising for another 4 weeks.

Radiographs at 6 weeks showed well-aligned fracture and DRUJ, and he was allowed to use his upper extremity as tolerated.

Exercises involving weight bearing, like push-ups, are deferred till bony healing is seen, in this case at 6 months (Fig. 2.4a, b).

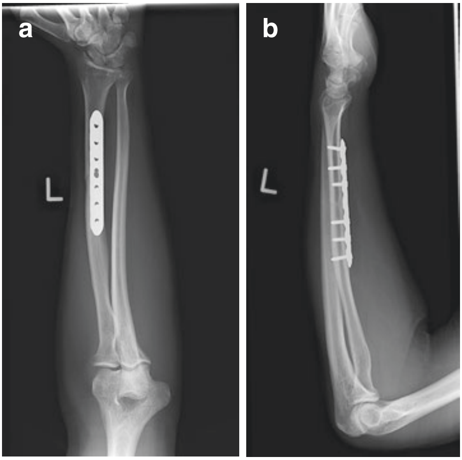

Fig. 2.4 (**a**, **b**) Six-month follow-up with healed radius shaft fracture and a normal appearing DRUJ

Salient Points

Fracture of the radius shaft should raise concern for a Galeazzi fracture.

Contralateral radiographs of the wrist are useful for comparison and assessment of reduction of the DRUJ.

If DRUJ still not reduced after fixation of radius fracture, reassessment of the fracture reduction must be done first to confirm anatomic reduction.

Though the DRUJ is most stable in supination, splinting should be attempted in neutral if possible.

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3 Operative Fixation of Galeazzi Fractures

Abidemi S. Adenikinju
and Sanjit R. Konda

Case Presentation

A 17-year-old male with no past medical history presented to the emergency room after falling from a ladder onto his outstretched left hand. On physical exam, his injury was isolated to his left upper extremity. He had swelling about his forearm with gross deformity and no open wounds. There was tenderness to palpation at the middle of the radial shaft as well as at the distal radioulnar joint (DRUJ). He had no motor or sensory deficits, and there was no concern for vascular injury. Plain radiographs demonstrated a radial shaft fracture. A hematoma block with 1% lidocaine was used to provide local anesthesia. A closed reduction was per-

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_3

formed and the patient's left upper extremity was placed in a long arm splint with posterior and side slabs. The patient was subsequently admitted for operative intervention.

Injury and Post-Reduction Radiographs

AP and lateral radiographs of the left forearm demonstrate a displaced transverse mid-shaft fracture of the radius (Fig. 3.1a). AP, lateral, and oblique radiographs of the left wrist demonstrated normal carpal alignment without evidence of fracture or dislocation. The DRUJ remained reduced with proper alignment (Fig. 3.1b). Post-reduction radiographs demonstrate improved alignment of the radial shaft fracture in the coronal plane with persistent displacement in the sagittal plane (Fig. 3.2).

Treatment and Timing of Surgery

Fractures of the middle to distal one third of the radial shaft with associated distal radioulnar joint disruption are described as Galeazzi fractures. In young children, nonoperative management with closed reduction and immobilization in a long arm cast is the treatment of choice; however, in adults these injuries necessitate operative fixation [1]. Surgical timing is dictated by the amenability of the soft tissue. Excessive swelling may preclude wound

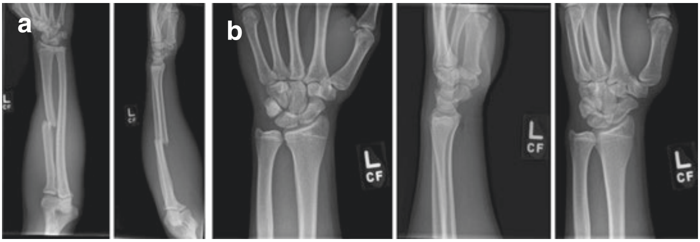

Fig. 3.1 (**a**) AP and lateral radiographs of the left forearm demonstrating transverse radial shaft fracture. (**b**) AP, lateral, and oblique radiographs of left wrist without gross abnormality, DRUJ appears intact

Fig. 3.2 AP and lateral radiographs of the left forearm demonstrating radial shaft fracture after attempted reduction and splinting

closure; therefore, it may be helpful to postpone surgery a few days to allow for the swelling to subside.

Timely reduction resulted in minimal swelling about the forearm in this patient. Therefore, the patient was taken to the operating room for operative fixation on the same day of presentation. The risks, benefits, and alternatives for both operative and nonoperative management were discussed and informed consent was obtained.

In terms of fixation strategy, the radial shaft is typically fixed with plate osteosynthesis using a 3.5 mm limited contact dynamic compression plate of appropriate length to obtain 3 bicortical screws above and below the fracture. The reduction and stability of the DRUJ is then assessed. In instances of persistent instability, the DRUJ is transfixed with K-wires.

Surgical Tact

Position

The patient is positioned supine on an operating room table with the injured extremity on a radiolucent hand table extension. A tourniquet is applied to left upper extremity and set to 100 mmHg above the systolic blood pressure (generally around 250 mmHg). The fluoroscopic C-arm machine is positioned so that it is easily accessible during the case, and the surgical implants and tools are situated on the ipsilateral side.

Approach

An 8 cm longitudinal incision centered over the fracture is made on the volar aspect of the forearm through the skin and subcutaneous tissue. The interval between the flexor carpi radialis, innervated by the median nerve, and brachioradialis, innervated by the radial nerve, is identified. Care is taken to identify the radial artery and protect it for the duration of the procedure. It is important to note that the radial artery transitions from a midline to a radial structure as it passes distally along the forearm. The superficial radial nerve is identified on the undersurface of the brachioradialis and also protected. The flexor pollicis longus is retracted ulnarly, and the pronator teres is elevated to expose the fracture site.

Fracture Reduction and Fixation

The fracture site is irrigated and cleared of loose debris, residual hematoma, and interposed periosteum. The fracture is reduced and held in place using a reduction clamp. A 7-hole 3.5 mm dynamic compression plate is placed along the volar aspect of the radius and fixed with three 3.5 mm bicortical screws distally and then compressed with three 3.5 mm bicortical screws proximally, leaving at least 1 cm of space between the fracture and the closest screw on either side. Fluoroscopy is utilized to confirm the reduction (Fig. 3.3a). The fascia is left open to prevent compartment syndrome.

DRUJ reduction and stability throughout forearm rotation is evaluated under fluoroscopy (Fig. 3.3b). Instability is character-

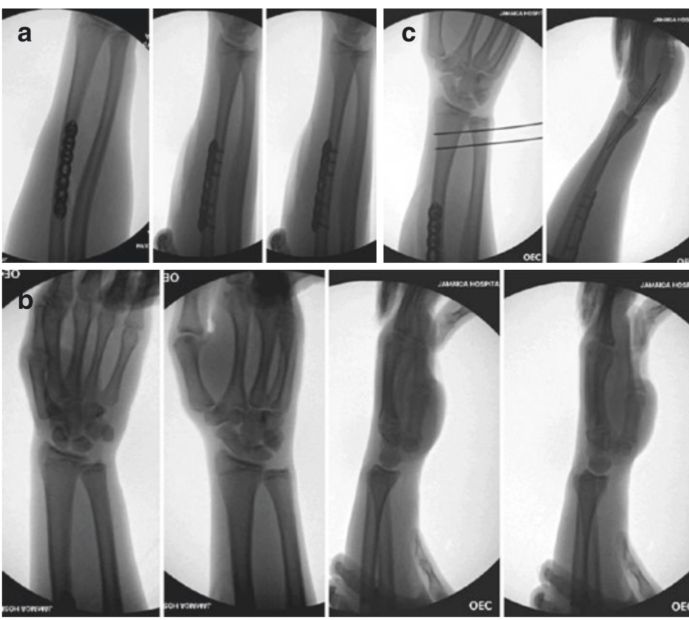

Fig. 3.3 (**a**) AP, lateral, oblique fluoroscopic radiographs of forearm demonstrating plate fixation of radial shaft fracture. (**b**) AP and lateral fluoroscopic radiographs of wrist during stress testing demonstrating DRUJ instability. (**c**) AP and lateral fluoroscopic radiographs of wrist after pinning of DRUJ

ized as anteroposterior translation of the DRUJ with displacement of the ulnar head from the sigmoid notch. The DRUJ is noted to be reduced but unstable in this case. Two parallel 1.6 mm K-wires are placed proximal to the sigmoid notch of the radius, from the ulna to the radius with the forearm in a neutral position. Fluoroscopy is utilized to confirm pin placement and reduction of the DRUJ (Fig. 3.3c). The pins are left proud above the skin level and bent 90° to facilitate removal in the office setting. It can also be useful to leave the pins proud along the radial border to allow for removal in the case of pin failure.

The wounds are copiously irrigated. The subcutaneous tissue is closed with an absorbable braided suture in an interrupted fashion. The skin is closed with nonabsorbable unbraided suture in a running fashion.

Postoperative Plan

Sterile dressing and a long arm plaster splint with a posterior slab and a side slab is applied with the forearm in the neutral position. The patient was discharged home on postoperative day one after a short period of observation. He was prescribed aspirin 81 mg twice daily for 14 days for deep vein thrombosis prophylaxis and was instructed to avoid lifting objects heavier than 2 lbs (2.23 kg) with his left upper extremity for 6 weeks. The patient was told to follow-up in the office in 2 weeks for a wound check and removal of sutures. At the 2-week office visit, the patient was placed into a Muenster cast to protect the distal radioulnar joint repair and prevent forearm pronation or supination as the DRUJ ligaments healed.

Outcome

The patient was followed for 3 months postoperatively. At 2 weeks, the patient was transitioned to a Muenster cast. Radiographs at this time demonstrated a well-aligned fracture and

Fig. 3.4 Two-week postoperative radiographs: AP and lateral left forearm

Fig. 3.5 Six-week postoperative radiographs: AP and lateral of left forearm and AP, lateral, oblique views of left wrist status post cast and pin removal

DRUJ without hardware complications (Fig. 3.4). The cast and DRUJ pins were removed in the office at the 6-week postoperative visit, with radiographs at that time demonstrating appropriate healing of the radial shaft fracture with DRUJ alignment maintained (Fig. 3.5). At the 3-month postoperative visit, the patient had no pain complaints and had returned to most of his normal activities. His pronation and supination range of motion were both 90° and his DRUJ was clinically stable. Radiographs demonstrated a healed radial shaft fracture with an appropriately aligned DRUJ (Fig. 3.6).

Fig. 3.6 Three-month postoperative radiographs: AP and lateral left forearm and AP, lateral, and oblique views of left wrist

Salient Points/Pearls

- Galeazzi fractures are fractures of the middle to distal radial shaft with associated DRUJ disruption. In adults, these injuries necessitate operative fixation [1, 2].
- DRUJ instability is often missed, and so careful clinical and radiographic examination of radial shaft fractures is paramount. Radiographic findings include widening of the DRUJ on an AP view, subluxation or dislocation of the radius relative to the ulna on a true lateral view, asymmetry compared to the contralateral uninjured side, shortening of the radius >5 mm compared to the distal ulna, and fracture of the base of the ulnar styloid [1].
- Open reduction and internal fixation with plating along the volar aspect of the radius is the preferred mode of fixation of radial shaft fractures. Ensure that the radial bow is restored in order to maintain the normal anatomy of the forearm which in turn allows for full pronation and supination.
- Intraoperative assessment of the DRUJ should be conducted after fixation of the radius to assess DRUJ reduction and stability. Unstable DRUJ injuries are amenable to transfixation with two K-wires. Triangular fibrocartilage complex repair does not appear to confer an advantage to pinning alone [1].

- Because of the significant role the ulnar styloid plays in DRUJ stability, ulnar styloid fractures should be fixed (prior to transfixation pinning) via open reduction and internal fixation when present [1, 2].
- The position in which the forearm is immobilized (e.g., supination vs. pronation vs. neutral) has not been shown to affect the outcome [1].

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Open DRUJ Reduction

4

Marie T. Morris and David M. Brogan

Case Presentation

History

A 33-year-old male was involved in a motorcycle crash after being hit by an SUV. He was launched approximately 35 feet in the air and sustained an injury to his left upper extremity including open distal radius and ulna fractures with distal radioulnar joint (DRUJ) disruption, as well as an ipsilateral terrible triad elbow injury with elbow dislocation (Fig. 4.1). Left upper extremity was notable for a transverse, volar, ulnar wound over the distal ulna and deformity at the wrist and elbow. Antibiotics were administered on arrival in accordance with proper open fracture management [1], and the patient's wounds were irrigated and

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_4

Fig. 4.1 Posteroanterior (PA) and lateral views of the wrist demonstrating a comminuted, intra-articular distal radius fracture and open distal ulna fracture with incongruency of the DRUJ

closed with 3-0 nylon suture. Closed reductions of his distal radius and ulna fractures and ipsilateral elbow dislocation were performed. He was placed into a plaster sugar-tong splint with a posterior slab splint extension to include the elbow to provide provisional stability.

Radiographs/CT

Surgical Timing, Planning, Equipment

Incision Planning

The patient's transverse traumatic wound over the distal ulna was extended longitudinally on either end into a subcutaneous approach to the distal ulna (Fig. 4.2). A dorsal approach to the distal radius was used for reduction and planned dorsal bridge plating with cancellous allograft. Care is taken to maximize intact skin between the incisions to minimize risk for skin necrosis.

Fig. 4.2 The patient's transverse and oblique traumatic wounds were incorporated into the surgical incision to expose the distal ulna through a subcutaneous approach

Equipment

- Radiolucent hand table
- Sterile finger traps and rope
- Weights
- Freer elevator/dental pick
- Dorsal bridge plate (only needed for concomitant distal radius fracture)
- Cancellous bone allograft chips
- 2-0 Fiberwire
- K-wires
- Intraoperative fluoroscopy (optional for pure soft tissue repair)

Preoperative Plan and Order of Fixation

1. Irrigation and debridement of traumatic wounds and fracture
2. Placement of suture within the TFCC and passage of sutures through drill holes in distal ulna

3. Open reduction internal fixation of distal ulna fracture with distal ulnar plate
4. Open reduction internal fixation of distal radius fracture with dorsal spanning bridge plate
5. Tie previously placed TFCC sutures to complete TFCC repair

Surgical Tact

Patient Positioning

Patient was placed supine on a hand table to allow for access to the wrist both dorsally and volarly, as well as access to the elbow. A nonsterile tourniquet was placed high above the elbow.

Approach

The traumatic wound was incorporated into an extensile direct ulnar approach over the distal ulna proximally and distally. A dorsal approach to the radius was used for planned dorsal bridge plate.

Fixation Technique

TFCC injury In this patient, the ulnar head was completely stripped of all attachments of the TFCC, contributing to the instability of the DRUJ [2]. A 2 mm drill was utilized to drill 2 bone tunnels from the fovea insertion to the lateral cortex, and a 2-0 FiberWire suture was then utilized to place a mattress stitch through the TFCC and along and around the ulnar styloid (Fig. 4.3). The ends of the FiberWire suture were passed through the bone tunnels using a Hewson suture passer. Sutures were tied after fixation of the distal radius and ulna, to ensure appropriate soft tissue tensioning after reduction of the bony fragments [3].

Distal Ulna A distal ulna 2.3/3.5 mm locking plate was adapted to the distal portion of the ulna, on the volar side, and secured with

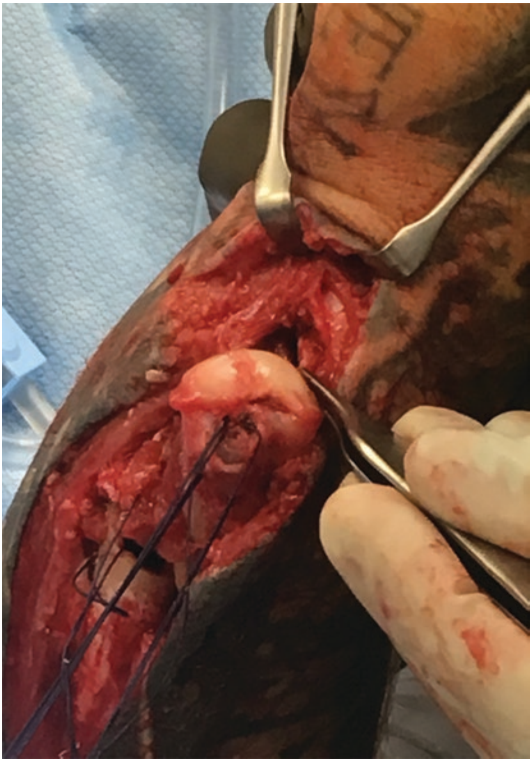

Fig. 4.3 The ulnar head is exposed and found to be stripped of all TFCC attachments. Two bone tunnels are created and Fiberwire passed through for later fixation of the TFCC

a bicortical nonlocking screw in the distal fragment. The diaphysis was then reduced to the plate, and the plate secured proximally with an additional three 3.5 mm bicortical nonlocking screws. Two additional 2.3 mm locking screws were then placed in the distal fragment. Intraoperative fluoroscopy was utilized to assess fracture reduction and hardware placement.

Distal Radius A longitudinal incision in line with the third metacarpal and just ulnar to Lister's tubercle was used for the dorsal approach to the distal radius. Finger traps were applied along with 10 pounds of traction to help reduce the distal radius fracture. Cancellous bone allograft was placed through the metaphyseal void left in the dorsal distal radius and used to elevate the depressed articular surface. Once provisional reduction of the articular surface was obtained, a dorsal spanning plate was then secured distally to the third metacarpal with 2.7 mm bicortical screws, as previously described [4]. The forearm was supinated and a clamp placed to secure the plate proximally. Traction was removed and 3.5 mm bicortical screws were applied proximally, followed by removal of the clamp.

Final fluoroscopic images were obtained, and ballotment of the DRUJ in pronation, supination, and neutral demonstrated no evidence of persistent instability (Fig. 4.4). Attention was then

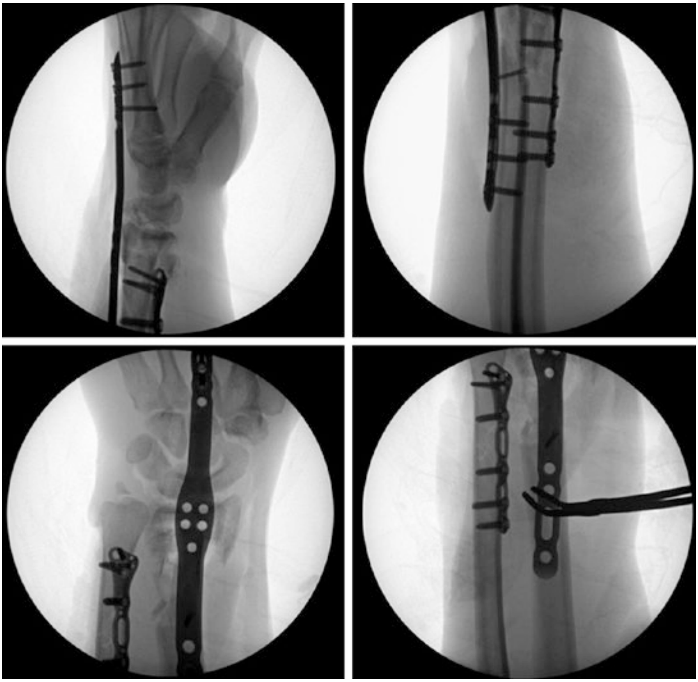

Fig. 4.4 PA and lateral intraoperative fluoroscopy images demonstrating final fixation of the distal radius and ulna fractures with restoration of height of the distal radius fracture

turned to treatment of the elbow injury, which is beyond the scope of this chapter.

Postoperative Protocol

Postoperatively, the patient was placed in a posterior slab plaster splint with the forearm in pronation for immobilization of the wrist and elbow.

In an isolated wrist injury, a sugar-tong splint in neutral would have been applied immediately postoperatively.

In the initial postoperative period, aggressive passive and active digital range of motion is emphasized to prevent digital stiffness. Two doses of postoperative antibiotics (first-generation cephalosporin) are administered for patients kept in the hospital overnight. No additional antibiotics are given beyond this for open fractures, unless the wound is highly contaminated.

Sutures are removed at 2–3 weeks after surgery, at which time the patient is transitioned to a removable Muenster splint. Forearm rotation is initiated 6 weeks after surgery.

Follow-Up with Radiographs

At most recent follow-up, approximately 6.5 months postoperatively from definitive fixation of his wrist, the patient had notable stiffness at his PIP and DIP joints, but excellent MCP motion. He continued to work with therapy to work aggressively on PIP and DIP motion as well as left elbow range of motion. Degree of digital stiffness is generally related to the overall insult to the extremity. A multiply injured extremity will suffer from more severe swelling and associated digital stiffness than an isolated DRUJ injury. Nonetheless, the principles of rehabilitation remain the same, focusing first on digital range of motion, with gradual liberalization of forearm rotation. Final follow-up X-rays of the wrist demonstrated progressive consolidation of his distal radius fracture with incomplete healing of his ulnar styloid (Fig. 4.5). Note that styloid union does not correlate with DRUJ instability after surgery.

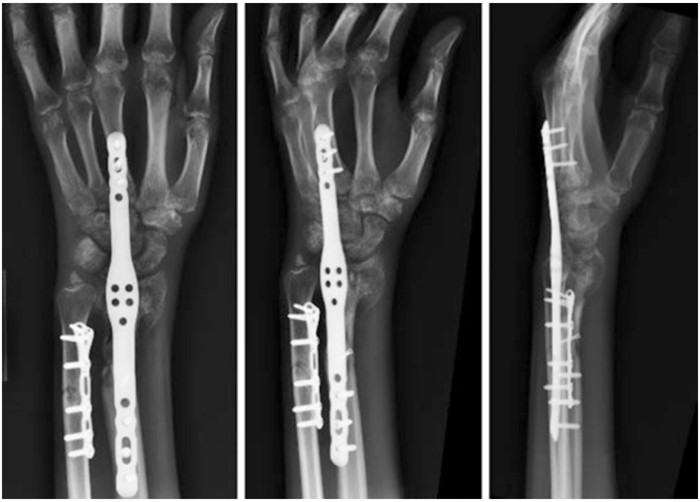

Fig. 4.5 Three views of the left wrist demonstrate healing of the distal ulna, and radius fractures and reduction of the DRUJ with nonunion of the ulnar styloid are also noted

Tips and Tricks

1. Make a generous distal incision to allow satisfactory visualization of the TFCC.
2. Protect the dorsal sensory branch of the ulnar nerve, which crosses the wrist from volar to dorsal at the level of the ulnar styloid.
3. Place one or two horizontal mattress sutures in the TFCC and tunnel these through the distal ulna prior to fixation of any associated fractures, as the visualization and ease of suture placement will be optimal prior to fracture reduction.
4. Tie the sutures placed through the TFCC over transosseous tunnels after reduction and fixation of all fractures to ensure appropriate ligamentous tensioning.
5. Ensure satisfactory restoration of radial height and sigmoid notch articulation if associated distal radius fractures are identified.

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5 Distal Radius Fracture: Volar Plating – Shear Fractures

Toni M. McLaurin

Clinical History

A 75-year-old right-hand-dominant woman sustained an injury to her left wrist when she lost her footing on a slippery, wet sidewalk and fell onto her outstretched left arm. She noted immediate onset of left wrist pain, but thought she had only sprained her wrist. However, due to continued pain, swelling, and ecchymosis extending up her arm, she presented to the emergency department 3 days after injury. At the time of presentation, she denied any other injuries, and a secondary exam confirmed this. The patient had diffuse swelling and ecchymosis over her left wrist, an obvious deformity, and tenderness to palpation over the wrist. She was neurovascularly intact in her left upper extremity.

Injury Radiographs

Anteroposterior (AP), lateral, and oblique views of the left wrist demonstrate a shear fracture of the volar aspect of the distal radius (Fig. 5.1). There are four radiographic parameters used to assess

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_5

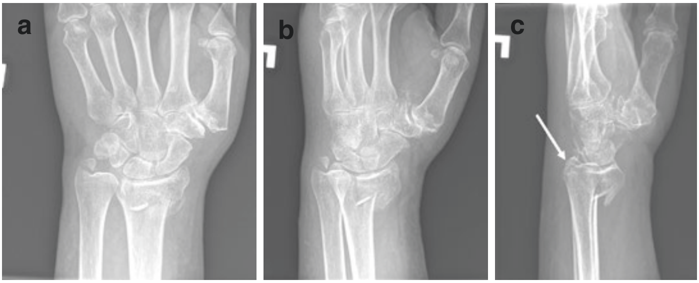

Fig. 5.1 Anteroposterior (**a**), mortise (**b**), and lateral (**c**) radiographs showing a left distal radius fracture with an intra-articular fracture in the coronal plane and volar displacement of the carpus along with the volar fracture fragment (**c**). Also noted is the intact dorsal cortex noted on the lateral (**c**) view (white arrow)

distal radius alignment: radial height, radial inclination, ulnar variance, and volar tilt. There are also the Lafontaine criteria which are used to evaluate the inherent stability of the fracture pattern itself which include dorsal angulation >20°, dorsal comminution, extension of the fracture into the radiocarpal joint, an associated ulnar fracture, and age over 60 years [1]. However, these are more pertinent to the evaluation of intra-articular fractures that do not also include a coronal shear component as seen in this patient. In fact, radial height and inclination can initially appear within acceptable limits due to the intact dorsal cortex. On the lateral radiograph, an intra-articular fracture in the coronal plane is noted with the carpus displaced in a volar direction along with the volar fracture fragment (Fig. 5.1c). In this case, Fig. 5.2 does show in the AP view that there is loss of radial height (8 mm) and inclination (17°), along with positive ulnar variance (+3 mm). This fracture represents a shear fracture of the distal radius, commonly referred to as a volar Barton's or volar shear fracture [2].

The most important radiographic finding is the volar displacement of the carpus which accompanies the fracture fragment due to the intact volar radiocarpal ligaments. The fact that these volar ligaments are stronger than the dorsal radiocarpal ligaments makes this an inherently unstable pattern that cannot be adequately treated by closed means as the carpus will continue to redisplace in the volar direction, resulting in loss of wrist range

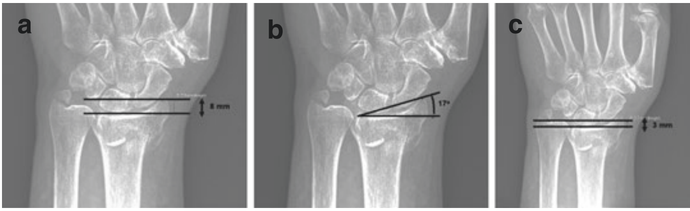

Fig. 5.2 The injury AP X-ray shows decreased radial height of 8 mm (**a**), decreased radial inclination of 17° (**b**), and positive ulnar variance of 3 mm (**c**)

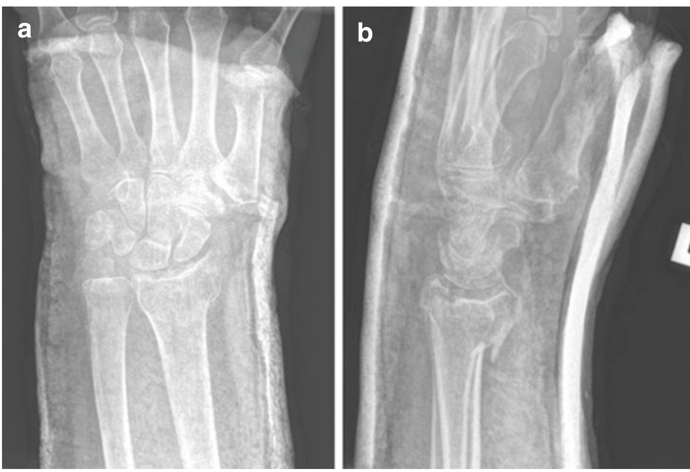

Fig. 5.3 Initial post-reduction AP (**a**) and lateral (**b**) radiographs show slight improvement of the volar displacement, but with persistent malalignment

of motion and grip strength should it go on to heal in this position. Despite this, there should be an attempt at closed reduction to improve the position of the fracture with the understanding that this is an operative injury. In this case, initial post-reduction radiographs do show slight improvement in alignment and volar displacement (Fig. 5.3), but by the time the patient followed up in the office 1 week after reduction, the volar displacement had recurred (Fig. 5.4). Attention also needs to be paid to a careful neurological examination as the median nerve is at risk due to

Fig. 5.4 One-week post-reduction lateral radiograph shows increased volar displacement compared to the initial post-reduction lateral seen in Fig. 5.3b

this volar displacement. Any carpal tunnel symptoms persisting for more than 48 h should result in operative intervention in a more expeditious fashion than what may otherwise be indicated for routine operative fracture management.

Treatment Considerations and Timing of Surgery

Although it is well-established that most distal radius fractures in the elderly can be managed nonoperatively, as lower demand elderly patients better tolerate malunion than younger patients [3, 4], volar shear fractures are in a subset of distal radius fractures that do not do well with nonoperative management due to their unstable nature [3, 5]. Therefore, the decision was made to proceed with operative treatment in this patient. Given the closed nature of this injury, and the absence of any carpal tunnel symptoms, after closed reduction and splinting, the patient was discharged home from the emergency department and surgery was scheduled on an outpatient basis. Based on the radiographs showing a volar shear distal radius fracture with no additional intra-articular involvement, the plan was to proceed with open reduction and internal fixation with a buttress plate.

Surgical Tact

Positioning

The patient is positioned supine on the operating room table with the arm extended onto a radiolucent hand table and the forearm supinated. A tourniquet is placed on the arm. The back table is placed at a 90° angle to the hand table, and either the large or mini C-arm can be used. If the large C-arm is used, it is positioned to come in at the end of the hand table when needed. This is only possible when using a hand table that is suspended freely from the operative table and does not have a table leg extension on the end of the table. If there is a leg extension, then the C-arm needs to come in obliquely from either side of the table leg. If a mini C-arm is available for use, it can easily be brought into and out of the surgical field from any direction with the assistance of the circulating nurse.

Approach

A tourniquet is used, but prior to inflation of the tourniquet, an Allen Test should be performed to ensure that the palmar arch is patent and there is adequate blood flow into the hand through both the radial and ulnar arteries. The arm is then exsanguinated and the tourniquet inflated. The author uses a modified volar Henry approach to the distal radius, placing the incision over the flexor carpi radialis (FCR) tendon, taking care not to violate the tendon sheath. The sheath is then incised over the tendon, the FCR tendon retracted medially, and the floor of the FCR sheath incised. Note that the palmar cutaneous branch of the median nerve is potentially at risk, as it does run within the sheath of the FCR tendon, so should be protected. The flexor pollicis longus (FPL) is bluntly dissected and mobilized to enter the space of Parona and expose the pronator quadratus (PQ). The FPL is retracted medially and the brachioradialis retracted laterally. The PQ is frequently significantly disrupted with this fracture pattern and often only the remnants of the muscle need to be debrided off the underlying fracture. If the PQ is still intact, it needs to be incised transversely just proximal to the volar radiocarpal ligaments, and then longitudinally along its radial border. It is then sharply dissected off the radius, exposing the proximally displaced fracture fragment.

Fracture Reduction and Fixation

Once exposed, the proximal edge of the displaced fragment is sharply debrided of any interposed periosteum and the fragment gently elevated off the underlying radial shaft to expose the bed of the fracture on the intact proximal aspect of the radius. Once mobilized, the fracture is reduced by extension of the wrist. The fracture can be provisionally fixed with K-wires but will frequently shorten even with this provisional fixation. Maintenance of the reduction can be aided by holding the wrist in an extended position over a tightly rolled towel to neutralize the pull of the volar ligaments.

After an acceptable provisional reduction is obtained without concern for a few millimeters of shortening, the plate is positioned on the distal radius, and appropriate placement confirmed fluoroscopically, ensuring the plate is distal enough and centered on the radius. Although most distal radius plates include locking and nonlocking options, a bicortical, nonlocking screw placed just proximal to the apex of the fracture should be the first screw placed in this pattern. This will allow the plate to act in a buttress fashion, with the plate pushing the fracture fragment distally and dorsally, resisting the shear moment on the fracture and resulting in realignment of the carpus over the radial shaft (Fig. 5.5) [6]. A second bicortical screw is then placed in the shaft and then locking screws are placed through the plate into the distal fragment with the number and position of the screws used dependent on the quality of the bone and the amount of comminution in the distal fragment. The wound is closed in a layered fashion and the forearm placed in a plaster volar wrist splint postoperatively.

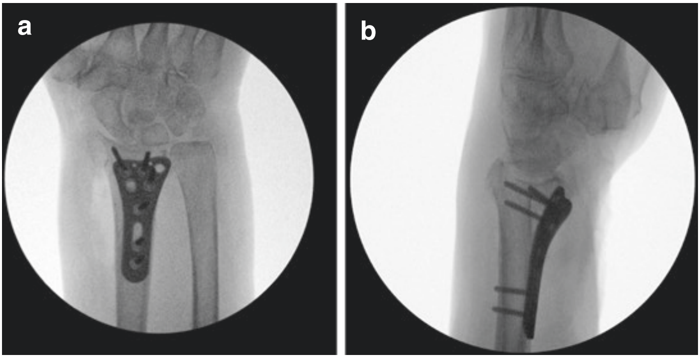

Fig. 5.5 Intraoperative AP (**a**) and lateral (**b**) fluoroscopic views show restoration of radial height and inclination, and reduction of the volar fragment with realignment of the carpus over the long axis of the radial shaft

Postoperative Protocol

At 2 weeks, sutures are removed and a removable wrist is placed to allow range of motion exercises. The patient is instructed on active and active-assisted range of motion exercises, and physical therapy is initiated to prevent wrist stiffness with the only restriction being a lifting limitation of no more than 2 pounds. The patient is instructed to wear the splint for comfort with no specific timeline for how long it should be used. At 6 weeks, radiographs are obtained and the patient instructed to discontinue use of the wrist splint as tolerated.

Follow-Up

The patient was followed in the office for 3 months with radiographs obtained at 6 weeks and 3 months postoperatively. Three-month postoperative radiographs shown in Fig. 5.6 demonstrate union of the distal radius with no evidence of any hardware complications. Of note, although there is significant positive ulnar variance (greater than +3 mm), this is actually equal to what is

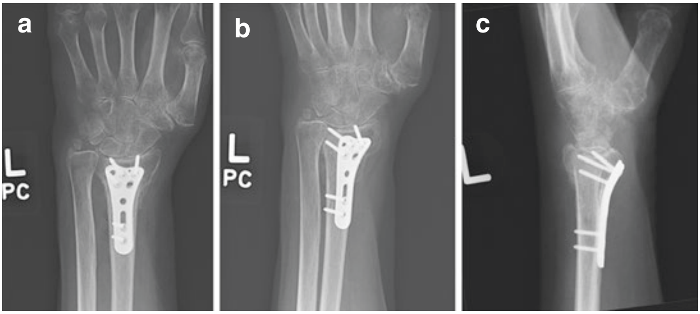

Fig. 5.6 Three-month postoperative AP (**a**), mortise (**b**), and lateral (**c**) radiographs show a healed fracture with maintained alignment

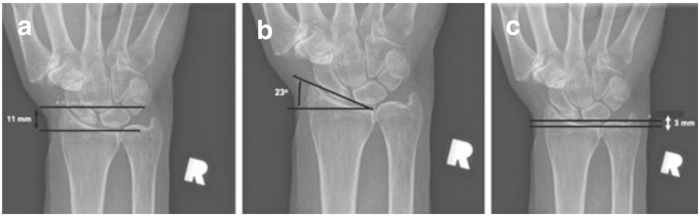

Fig. 5.7 Contralateral right wrist X-rays show 11 mm of radial height (**a**), 23° radial inclination (**b**), and positive ulnar variance of 3 mm (**c**), equal to the injured left wrist

seen on her contralateral wrist (Fig. 5.7), which illustrates the importance of obtaining contralateral wrist radiographs preoperatively so it is clear what the appropriate parameters should be for each individual patient. Clinically, the patient is able to extend her wrist to 40°, flex to 30°, has 70° of supination, and 80° of pronation. Despite the limitations in her range of motion, she states she is able to perform all of her ADLs, has no complaints of pain, and is happy with her progress.

Pearls/Salient Points

Distal radius fractures with a volar shear component are unstable fractures that should be treated with open reduction internal fixation:

- Radiographs show volar subluxation of the carpus as it accompanies the volar shear fracture fragment due to the intact strong volar radiocarpal ligaments.
- The usual radiographic parameters used to assess reduction and determine stability of distal radius fractures are not applicable with volar shear fractures as the intact dorsal cortex may not show the true extent of the injury as seen on the lateral radiograph and, regardless of parameters, this is an unstable injury.
- With so much current emphasis on locking plate technology, it is important to remember the basic fracture fixation principle of buttress plating which should be utilized in the fixation of any fracture with a shear component such as volar shear distal radius fractures.
- The cortical shaft screw placed at the apex of the fracture aids in reduction of the distal fragment and prevents volar and proximal redisplacement of the shear component.
- Early motion should be initiated postoperatively (2 weeks or earlier) to prevent stiffness.

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6 Volar Plating of Distal Radius Fractures

Christian A. Pean and Philipp Leucht

Case Presentation

This is the case of a 44-year-old patient who sustained a left wrist injury after a trip and fall onto their outstretched arm (Fig. 6.1). They sustained an isolated closed distal radius fracture and were indicated for surgical fixation in the form of open reduction internal fixation via volar plating.

Radiographs

Standard initial radiographs should include a posteroanterior (PA), oblique, and lateral view of the injured wrist and were obtained in our patient. It is our practice to also obtain contralateral films of the uninjured wrist to understand the patient's individual anatomy with respect to distal radius alignment. The three parameters typically noted when assessing distal radius fractures are as follows with normal values in parentheses [1]:

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https://doi.org/10.1007/978-3-030-74293-5_6

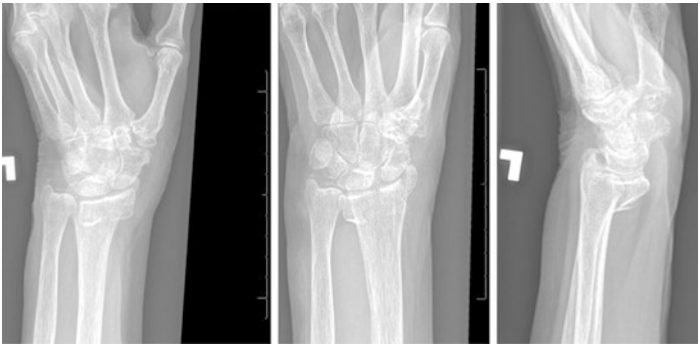

Fig. 6.1 Radiographs of a comminuted distal radius fracture with volar displacement of the carpus in relation to the radial shaft

1. Volar tilt (11°)
2. Radial height (13 mm radial height)
3. Radial inclination (23°)

In our case (Fig. 6.1), radiographs of the patient's injury revealed a volar displace distal radius fracture with loss of radial height and intraarticular extension noted at the lunate facet with an articular step off of greater than 2 mm. The patient was indicated for surgical fixation in the form of left distal radius open reduction internal fixation. Surgical treatment offers an opportunity to address articular incongruity which has been correlated with posttraumatic arthritis and to restore alignment of the wrist. Further, surgical treatment confers the benefit of rapid mobilization for the patient and earlier return to daily activities.

Surgical Timing and Planning

Distal radius fractures indicated for surgery can be managed on an outpatient basis with initial diagnosis, reduction, and splinting typically conducted in the emergency room or urgent care setting and surgical fixation planned within 5–14 days of the initial injury.

Indications for more urgent surgical management include open fracture and present or evolving carpal tunnel syndrome as a sign of median nerve compression.

Surgical Tact

Volar plating is indicated for the majority of intraarticular distal radius fractures. This construct functions as a volar buttress and addition of locking screws confer properties of a fixed angle device.

Position and Equipment

- Position: Supine with a hand table extension. The patient's body should be brought to the lateral edge of the OR table toward the side of the injury. The shoulder is abducted 90° and the wrist centered over the hand table extension
- Equipment/implants: Precontoured volar locking plate and screws, K-wires, cordless drill, fluoroscopy, and minifragment plates and screws. Pneumatic tourniquet on the ipsilateral arm, if desired can be applied.

Approach Volar Direct FCR Approach

Prior to incision, an Allen test is performed to ensure the patient has collateral ulnar circulation, and the contralateral DRUJ is examined for stability in order to be able to compare it to the injured wrist after successful fixation. The incision is centered over the FCR tendon with the distal extension ending just proximal to the wrist crease. The FCR sheath is incised, the FCR tendon retracted ulnar and floor of the sheath incised as well. The flexor pollicis longus muscle belly is elevated with a freer or similar blunt instrument to visualize the pronator quadratus. The pronator quadratus is incised at the radial border and the watershed line and then elevated exposing the distal radius volar surface. The brachioradialis tendon can also be released from its insertion on the radial styloid to neutralize deforming forces and facilitate reduction with minimal adverse effect on elbow or wrist function [2].

Reduction and Fixation Technique

The preliminary use of longitudinal traction taking advantage of ligamentotaxis is recommended to restore length. Simultaneous palmar translation of the carpus aids in restoration of palmar tilt and slight pronation neutralizes the common supination deformity present in distal radius fractures. A roll of sterile towels placed under the carpus or fingers also aids restoration of palmar tilt. Provisional fixation of the reduction is achieved using a K-wire drilled from the distal tip of the radial styloid in an ulnar and proximal direction across the fracture site and into the ulnar cortex of the radius. This can be done under fluoroscopic guidance (Fig. 6.2).

Fig. 6.2 K-wire placed into the radial styloid is utilized intraoperatively for provisional fixation. A 23° tilt from the operative table relative to the fluoroscopy machine allows visualization of the articular surface

After reduction and provision fixation with K-wires, it is our preference to place an initial cortical screw in the central aspect of the oblong hole of volar plate. Usually this screw is between 12 and 16 mm in length, and it is tightened enough so as to secure the plate, but not so much as to initiate compression at the plate-bone interface. This way small proximal and distal adjustments of the plate can still be made.

Watershed Line

The watershed line is an area on the volar distal radius at which the flexor tendons come into contact with the volar cortex approximately 3 mm proximal to the articular surface. The volar plate should extend distal enough on the distal radius to properly buttress the volar hook without impinging on this anatomic landmark. Assessment of the distal extension of the distal radius is made on a lateral radiograph [3].

Intraoperative Radiographs

To assess articular reduction and restoration of length, alignment, and rotation in distal radius fractures, it is crucial the operating surgeon routinely conduct a series of intraoperative fluoroscopic radiographs.

Boyer et al. described the anatomic tilt radiograph in 2004. A posterior-anterior radiograph of the wrist tilted 11° cephalad and a lateral view in 23° of cephalad tilt allow better visualization of the articular surface (Fig. 6.3). These views facilitate intraoperative assessment of intraarticular screw penetration during fracture fixation [4]. The dorsal horizon view is used to assess screw penetration on either side of Lister's tubercle potentially irritating the extensor tendons. It is obtained by hyperflexion of the wrist and directing the image beam along the axis of the radius (Fig. 6.4) [5]. In our patient, final radiographs demonstrate acceptable articular reduction and plate position without evidence of intraarticular or dorsal cortex screw penetration.

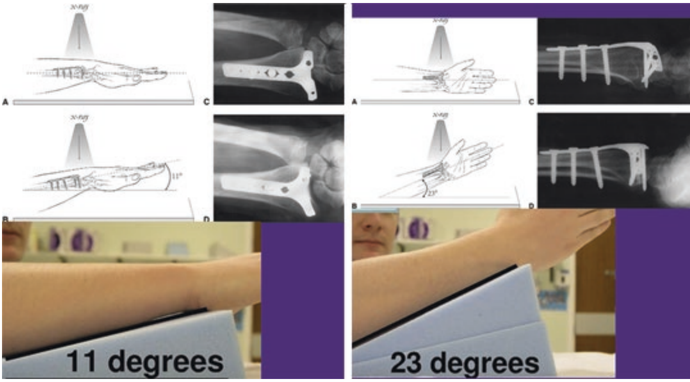

Fig. 6.3 Positioning for the anatomic tilt views as first described by Boyer et al.

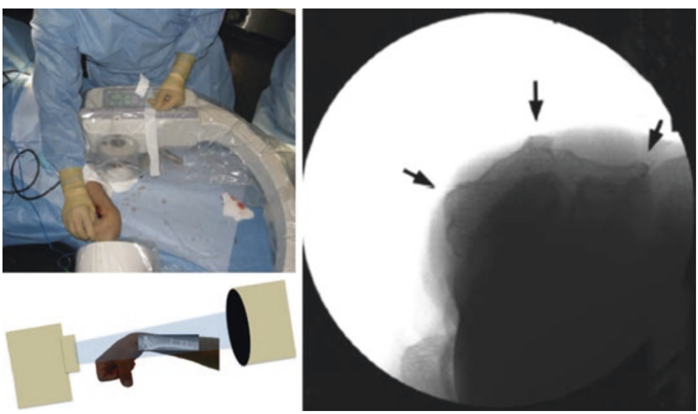

Fig. 6.4 The dorsal horizon view demonstrated in diagrams and fluoroscopic depiction to ensure screws lengths do note extend into the dorsal cortex

DRUJ Stabilization and Fixation

Routine assessment of the distal radioulnar joint is recommended in all patients undergoing operative fixation of the distal radius. One method of evaluation includes flexing the elbow to 90° and

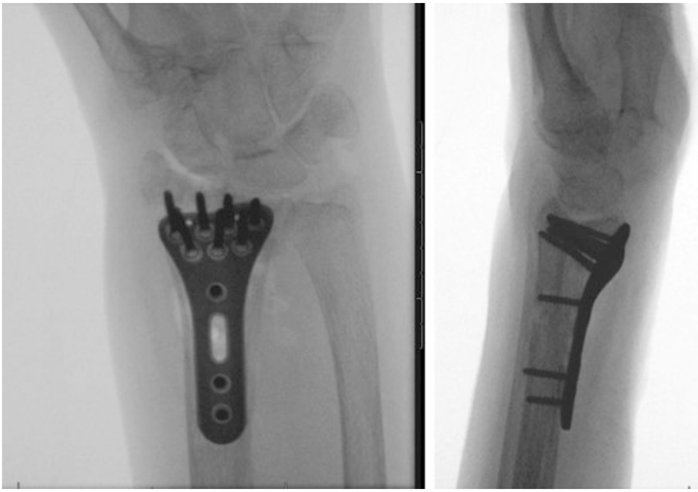

Fig. 6.5 Final fluoroscopic radiographs demonstrate a well-positioned implant and anatomic reduction with restoration of relevant radiographic parameters

displacement in the dorsal and palmar directions are tested with the neutral rotation of the forearm. This maneuver is repeated with the wrist in radial deviation, which stabilizes the DRUJ, if the ulnar collateral complex (TFCC) is not disrupted.

In this case, after reduction and volar plating of the distal radius, the DRUJ was stable and additional fixation was not required. Final radiographs demonstrate a well-reduced fracture with hardware in acceptable alignment (Fig. 6.5).

Postoperative Protocol

In the postoperative period, it is our preference to permit immediate range of motion of the wrist and hand with application of a removable brace or limited volar splint and soft dressing for the first 2 weeks after surgery. No lifting of objects heavier than two pounds is permitted for a period of 6 weeks with the option to extend the duration of restrictions as needed based on fracture healing noted in postoperative radiographs. Wrist range of motion exercises and formal occupational therapy program can be prescribed or patients who experience postoperative stiffness beginning at 2 weeks following surgery. Strengthening exercises are initiated at the 6-week postoperative visit if significant atrophy and residual stiffness are appreciated. Most patients are able to return to their regular activities within 3–6 months of surgical intervention.

Follow-Up

We recommend seeing patients at regular intervals for up to 6 months after surgery. The utility of radiographs at the 2-week follow-up visit is limited and we routinely acquire radiographs at 6 weeks, 3 months, and 6 months follow-up visits from the date of surgery.

Tips and Tricks

1. Adequate positioning and intraoperative radiographs assessing the articular surface are crucial to assessing reduction.
2. Allen test prior to surgical incision to confirm ulnar collateral circulation is recommended.
3. Pitfalls include failing to assess DRUJ stability, placement of the volar plate distal to the watershed line, and dorsal perforation of distal locking screws resulting in extensor tendon irritation.
4. K-wire provisional fixation through the radial styloid facilitates final fixation.
5. Postoperative early mobilization and range of motion exercises are necessary to avoid stiffness,

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7 Distal Radius Fracture Treated with Spanning External Fixation and K-Wires

Nirmal C. Tejwani and Ruchi Tejwani

Case We present the case of a 31-year-old right-hand-dominant male who sustained an injury to his right wrist when he fell off his motorcycle (Fig. 7.1a, b). He was seen in the emergency room and underwent closed reduction and splinting (Fig. 7.2a, b). He was indicated for surgery due to the complex and unstable distal fracture pattern. Treatment options considered and discussed with the patient included fragment specific fixation, spanning plate, or external fixation with K-wires for supplemental fixation.

In this particular case, we chose to use external fixation to allow for fracture reduction using ligamentotaxis due to the nature of the fracture; and to avoid any internal implants per patient preference; and finally to prevent second surgery for implant removal.

Radiographs Standard anterior-posterior, lateral, and oblique views demonstrate the injury well. CT scan is useful for complex fracture patterns or those with articular depression. We also routinely obtain contralateral radiographs due to variations in dis-

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_7

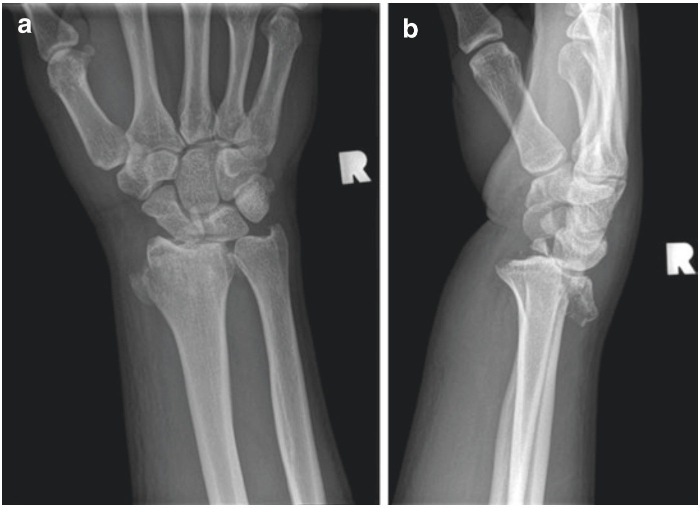

Fig. 7.1 (**a** and **b**) Injury radiographs demonstrating distal fracture with displacement

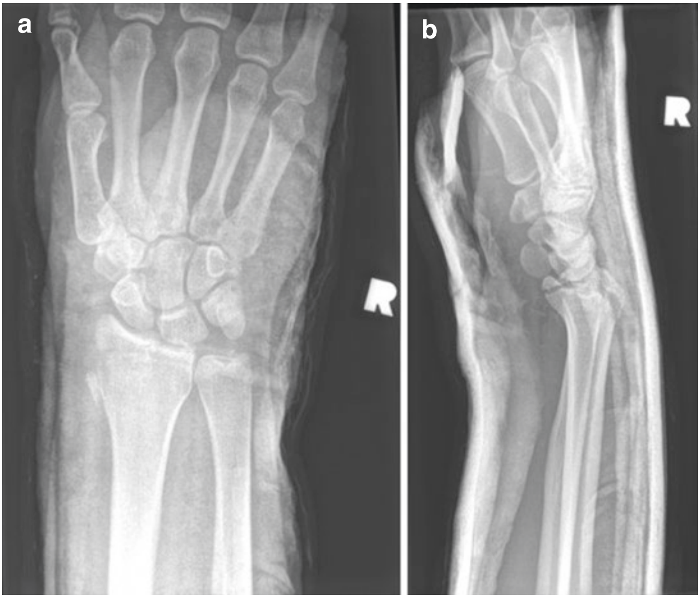

Fig. 7.2 (**a** and **b**) Post-reduction radiographs in splint

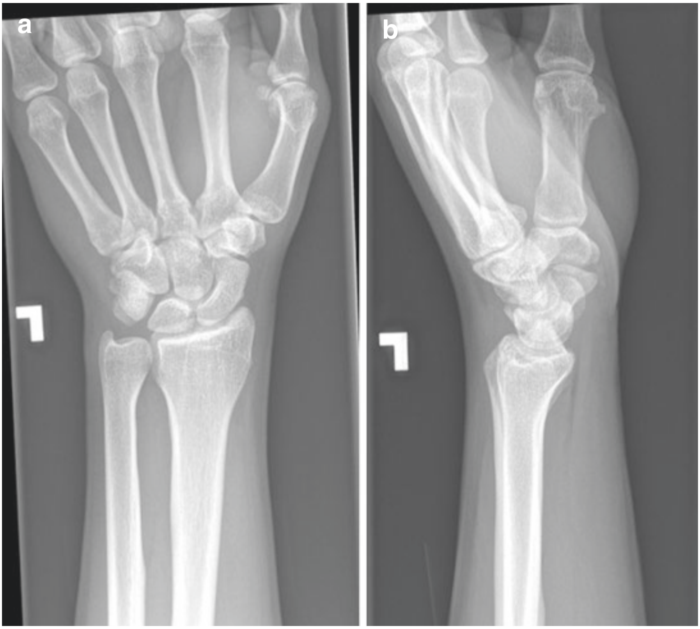

Fig. 7.3 (**a** and **b**) Contralateral radiographs for comparison

tal radius anatomy, allowing us to match our reduction to the intact side (Fig. 7.3a, b).

Surgical Timing These fractures can be safely fixed acutely; however, if delayed more than 10–14 days, they may require open reduction as fracture healing may preclude closed reduction techniques.

Surgical Tact We prefer using a hand table with supine position and a tourniquet for application of external fixator pins. Based on surgeon preference, one can use a mini C-arm or standard fluoroscopy; we prefer using the mini C-arm as it is easily maneuvered.

Based on the fixator used, the location of the clamps and pins is identified based on the length of the fixator and allowing for further length with traction. Two partially threaded pins each are placed after drilling in the distal forearm and second metacarpal base. Both these are placed through open incisions, after identifying the superficial radial nerve.

Proximally, the bare area is identified and the pronator elevated to drill for the pins. We recommend pre-drilling external fixator pins to prevent thermal injury to the bone.

Distally, care is taken to avoid the extensor tendons with subperiosteal dissection and placement of small retractors.

We prefer using 3 mm external fixator pins. An important point here is to place the pins at 45° to the radial and metacarpal shafts to allow the fixator to be placed out of plane of the radiographs. Bicortical placement is confirmed on fluoroscopy.

The surgical wounds should be closed before application of the external fixator and clamps to allow for easier closure.

Once in place, traction is applied to regain length at the fracture site. K-wires are now used to fix individual fractures. In our experience, typically three K-wires are needed, one from the radial styloid extending medially to engage the cortex, one from the dorso-ulna piece going volarly to engage the cortex, and one radial to medial subchondrally to buttress the articular reduction.

Use of Kapandji technique of intra-focal pinning may be useful adjunct for fracture reduction. Supplemental K-wires may be added as needed to fix different fragments.

Once the fixation is completed, fluoroscopy is done to assess fracture reduction (Fig. 7.4a, b). Care must be taken to avoid over-

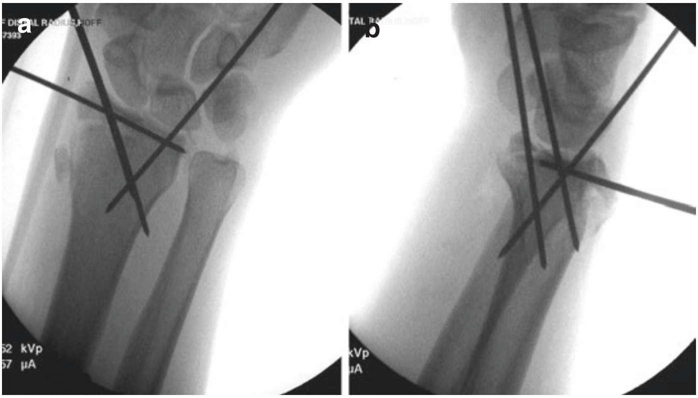

Fig. 7.4 (**a** and **b**) Intraoperative radiographs showing reduction and fixation

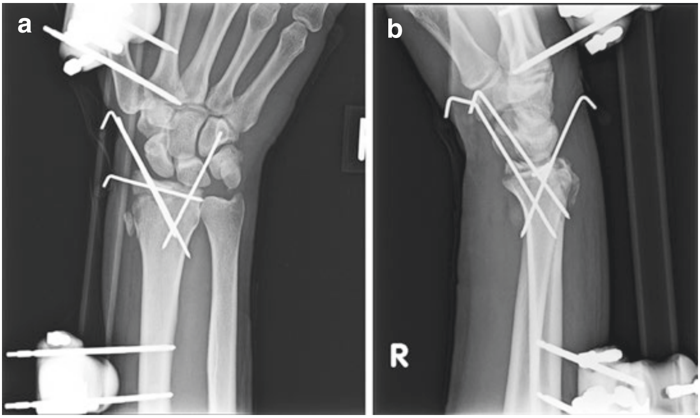

Fig. 7.5 (**a** and **b**) Two- week radiographs to confirm maintenance of reduction

distraction, both at the wrist and carpus (as noted, with increased intercarpal space). An easy way to judge appropriate distraction is the ability to fully flex all fingers passively.

Pin sites are dressed with Vaseline gauze (xeroform or adaptic) and then over wrapped with a fine bandage (kerlix). We prefer a short volar slab for the first 2 weeks to allow for pain control and wound healing. We do not use any postoperative antibiotics; however, if pin sites are a concern for drainage, then a short course of oral antibiotics may be used.

Postoperative Plan: Patient is encouraged to start immediate range of motion exercises of fingers, elbow, and shoulder. Suture removal is typically performed at 10–14 days (Fig. 7.5a, b).

The patient is allowed to wash and shower, keeping pin sites clean and dry. No special pin care is recommended.

The K-wires are typically removed at 6 weeks based on radiographic healing, and the external fixator is removed at 8 weeks. Both these procedures are done in the office setting, with local anesthesia if needed (Fig. 7.6a, b).

Hand therapy is started at 2 weeks with emphasis on finger range of motion and once the fixator is removed, wrist and forearm motion is possible.

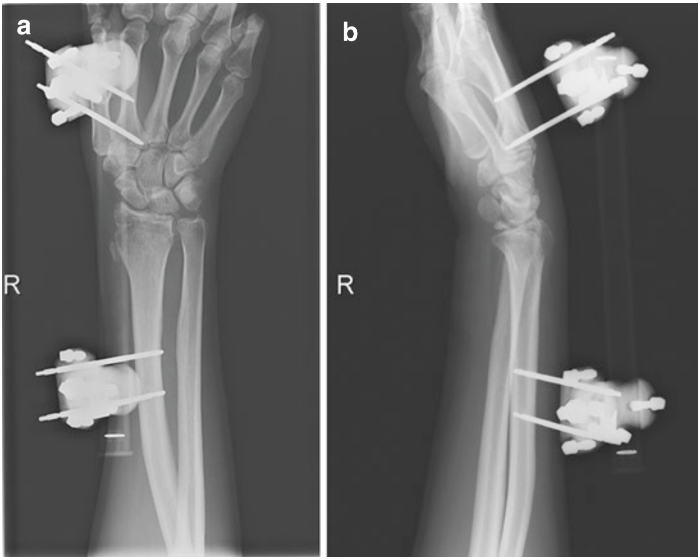

Fig. 7.6 (**a** and **b**) Six-week follow-up with K-wire removal

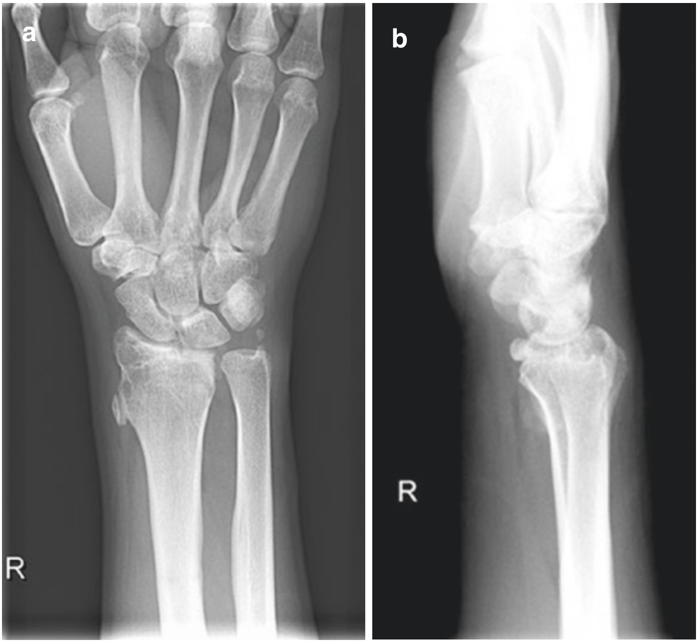

Fig. 7.7 (**a** and **b**) Six-month follow-up with complete healing of fracture

Fig. 7.8 (**a–d**) Clinical pictures showing regaining of full range of motion

This patient was followed up till 6 months and final radiographs and clinical pictures show well-healed fracture (Fig. 7.7a, b); he had regained full range of motion (Fig. 7.8a–d) and had returned to all his usual activities.

Salient Points

Use of oblique films and/or CT scans will allow better understanding of the fracture pattern. Obtaining contralateral films is useful in determining individual differences in distal radius anatomy.

Use of external fixator allows closed reduction using ligamentotaxis, but K-wires are needed to maintain the reduction and length.

Use of open incision for external fixator pin placement allows for protection of superficial radial nerve and prevents muscle binding.

Avoid over-distraction, by ensuring that the fingers can be flexed fully in the operating room, we recommend that you release traction and restore length after K-wires have been inserted.

Immediate postoperative rehab for fingers is recommended to avoid stiffness.

Removal of external fixator and K-wires can easily be accomplished in the office setting, thus avoiding second procedure in the operating room

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8 Fragment-Specific Distal Radius Fixation

Megan Fracol, Jennifer Bai, and Jason H. Ko

Case Presentation

The patient is a 55-year-old left-hand-dominant male who presented to the hand surgery clinic 6 days after falling from a ladder. He initially sought care in the emergency room due to immediate pain and swelling in the right wrist, where X-rays demonstrated a comminuted, displaced intra-articular distal radius fracture (Fig. 8.1). Reduction was attempted in the emergency room but was unsuccessful. The patient was placed in a sugar-tong splint and instructed to follow up in hand surgery clinic. Additional CT imaging work-up was obtained at that time (Fig. 8.2).

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Fig. 8.1 Preoperative X-rays from the patient's initial presentation to the emergency department demonstrating a comminuted distal radius fracture. From left to right: anteroposterior; oblique; lateral views

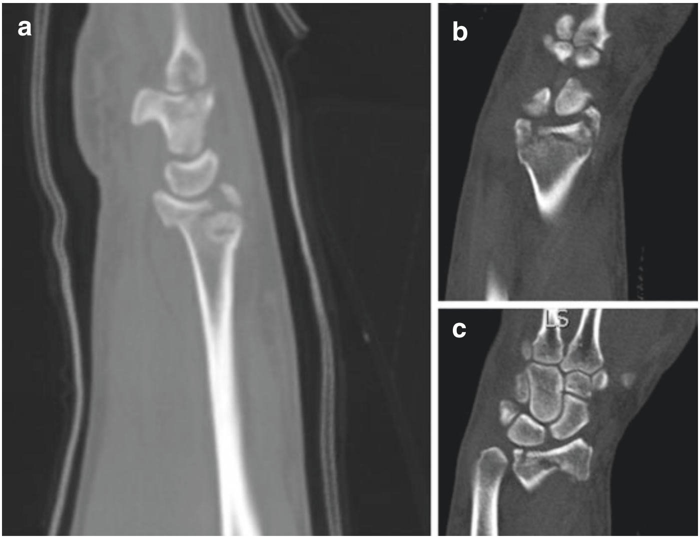

Fig. 8.2 Preoperative CT scan demonstrating separate fracture fragments of the volar and dorsal lunate facet (**a**) as well as at the scaphoid facet (**b**) in the sagittal plane. Fracture fragments at both areas are demonstrated in the coronal plane (**c**)

Preoperative Imaging

Surgical Plan

- Supra-clavicular nerve block with monitored anesthesia care (MAC)
- Tourniquet
- Supine position with a hand table
- TriMed fragment-specific distal radius set
- Fluoroscopy

Surgical Procedure

A supra-clavicular nerve block was performed by anesthesia. Tourniquet was used. The comminuted fracture had three major parts to be addressed sequentially: the volar ulnar rim, the radial styloid, and the dorsal rim. The volar ulnar rim was exposed first as these fracture fragments were relatively large. A standard FCR approach was used. A brachioradialis tenotomy was performed, fracture fragments were identified, and a lamina spreader was placed between the radius and ulna to reduce the proximal radial shaft. The radial styloid fragment was reduced with percutaneous K-wires placed retrograde from the styloid to the radial shaft and from the radial styloid to the ulnar corner. Reasonable reduction of the fracture fragments was confirmed with fluoroscopy and a TriMed volar hook plate was brought into the field. Provisional fixation was placed with the volar hook plate.

Next, attention was turned to the radial styloid. A longitudinal incision over the first dorsal compartment was made. The APL and EPB were retracted dorsally. Sub-periosteal dissection was performed, and a radial styloid pin plate was placed and provisionally secured with K-wires.

Next, the dorsal rim was exposed. A longitudinal incision just ulnar to Lister's tubercle was made. The third dorsal compartment was exposed and the EPL was retracted radially. A posterior interosseus neurectomy was performed. Sub-periosteal dissection was performed to expose the fracture fragments, which were small and comminuted. These fracture fragments were provisionally secured with multiple K-wires.

Now that all fracture fragments had provisional stabilization, reduction was again confirmed with fluoroscopy. With adequate reduction of all fracture fragments, attention was turned back to the volar hook plate. The provisional fixation was removed and this was secured in place with screws. Similarly, the K-wires were removed from the radial styloid, and the radial styloid pin plate was secured with screws.

With the volar and radial fragments fixated, attention was turned back to the dorsal rim. The radial dorsal fragment was relatively large compared to the other dorsal rim fragments. Thus, a dorsal hook plate was placed on this fragment to secure it in place. Finally, an ulnar pin plate was brought into the field and used to control the dorsal ulnar rim fracture fragment. After all this hardware was in place, there still remained one floating fracture fragment along the dorsal rim that was not captured by any of the plates. This was secured in place with a single K-wire.

Fluoroscopy confirmed good reduction of all fracture fragments with adequate alignment of the radiocarpal joint. The DRUJ was assessed and found to be stable in supination and pronation. The carpal tunnel was also assessed and felt to be soft; thus, no carpal tunnel release was performed. The patient was placed in a short arm splint.

Postoperative Protocol

The patient remained in a short arm splint until his 2-week postoperative visit. X-rays obtained at the 2-week postoperative visit demonstrated maintained reduction of the fracture fragments so the patient was provided with a custom forearm-based removable splint. He began active range of motion exercises of the digits and

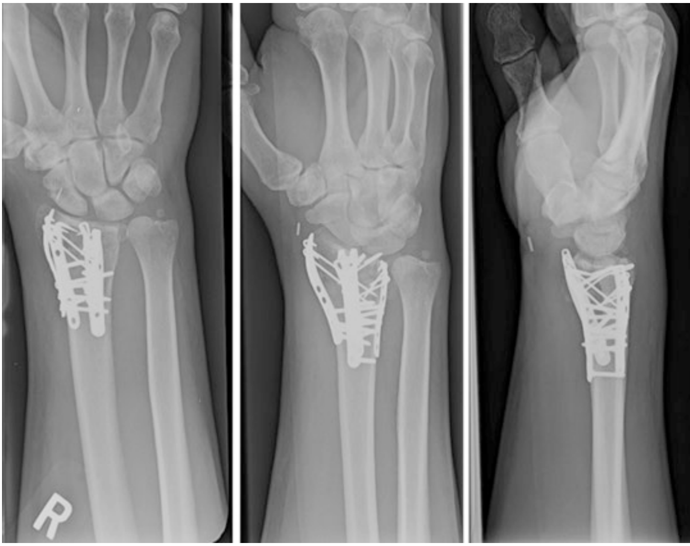

Fig. 8.3 This 6-week postoperative X-ray demonstrates maintained alignment of reduced fracture fragments with restoration of the radial-carpal articular congruity. From left to right: anteroposterior; oblique; lateral views

gentle active range of motion of the wrist with occupational therapy at that time. At 6 weeks postoperative, he was advanced to passive range of motion with therapy. At 8 weeks postoperative, he was advanced to strengthening exercises with therapy. By 12 weeks postoperative, all restrictions were lifted. Figure 8.3 demonstrates the patient's 6-week postoperative X-rays.

Postoperative Imaging

Tips and Tricks

- Identify the primary fracture fragments. (5 major fragments are radial styloid, the dorsal wall, the dorsal ulnar corner, the volar rim fragment, and impacted articular fragments) [1].

Understanding the classification system developed by Robert Medoff is very helpful [2].

- Two or more plates at 50–90° angles from each other in the axial plane provide greater stability than other traditional methods of fracture fixation with single plate constructs or external fixation devices [3, 4].
- The radial styloid is considered a key fragment that when properly reduced imparts stability to the other fracture fragments.
- Be cautious of sensory branches of the superficial branch of the radial nerve that cross the incision over the radial styloid
- Intra-articular fragments can be reduced by freeing up the comminuted dorsal wall and lifting those impacted fracture fragments up, rather than exposing those fracture fragments through the joint itself.
- Traction applied via finger traps can be very helpful to obtain reduction.
- It is vital to adequately reduce the volar rim fragment, also commonly known as the "teardrop" fragment. This fragment provides stability to the volar lunate facet and prevents volar subluxation of the entire carpus [5].

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9 Distal Radius Fracture: Combination of Volar Plating/Dorsal Bridge Plate

Babar Shafiq and Erik A. Hasenboehler

Case Presentation

Patient is a 26-year-old, right-hand-dominant male, who was seen to have a seizure and fall 6 feet from a loading dock striking his outstretched left arm and face to the pavement. Examination revealed a closed injury to the left wrist with deformity (Fig. 9.1). Sensation was intact. Fracture detail can be better appreciated with traction films (Fig. 9.2). He was closed reduced and splinted (Fig. 9.3). Surgery was performed by colleagues (Fig. 9.4).

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https://doi.org/10.1007/978-3-030-74293-5_9

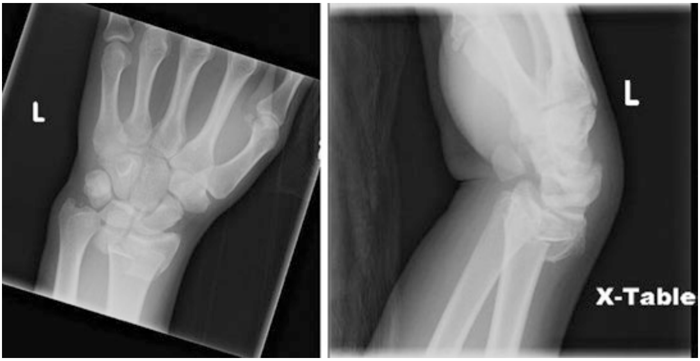

Fig. 9.1 Injury PA and lateral

Fig. 9.2 Traction PA and lateral

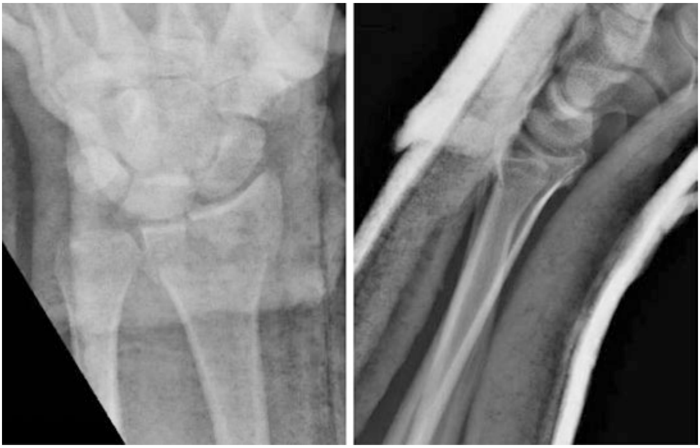

Fig. 9.3 Post-reduction/splint PA and lateral

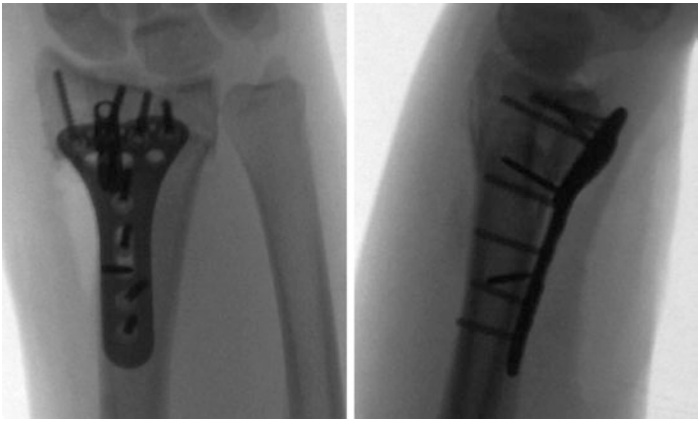

Fig. 9.4 Intraoperative fluoroscopic images at index surgery

Radiographs

Surgical Planning (Index Surgery)

Due to collapse of ulnar column with progressive displacement (Fig. 9.5), the patient was referred by our colleagues for revision.

Physical Examination, Assessment, and Plan 2 Wrist was shortened and slightly radially deviated when compared to the intact, right side. Subsidence of the lunate facet and residual deformity was observed. Given his young age, his employment as a laborer and the increased likelihood of posttraumatic arthritis due to joint incongruity, revision surgery was planned. In addition, due to the duration of time post-injury, prior fixation holes and the risk of seizures, fixation stability was a concern, and recurrent loss of reduction was considered at higher than typical risk.

As such, a fragment-specific construct via the original approach augmented with a dorsal bridge plate (DBP) was planned.

Dorsal Bridge Plate Outcomes In a recent meta-analysis by Wang and Ilyas comparing the DBP with external fixation, the DBP had statically significant lower rates of infection (2% vs. 10%), complex

Fig. 9.5 Postoperative follow-up images at 2-week follow-up

regional pain syndrome (1% vs 4%), higher rates of hardware failure (4% vs. 1%), and better outcomes scores with the Gartland and Werley outcome score. They found no difference in the Disabilities of the Arm, Shoulder and Hand (DASH), radiographic parameters or unplanned reoperations. They concluded that both methods appear to be comparable distal radius spanning constructs with the DBP having a potentially fewer complications [Ilyas] [1].

Rationale for the DBP in this case The specific challenge in this case is loss of reduction with collapse of the ulnar column with a relatively small ulnar fragment. Nearly 5 weeks have passed since injury, and this fragment was osteopenic and likely difficult to render stable with internal fixation alone. Furthermore, the patient has seizures and is at risk for further injury. Revision open reduction is required to mobilize the fragments and will allow the opportunity for revision internal fixation. The DBP will protect the repair given the small fragment, osteopenia after disuse and fracture, and the additional risks specific to possible seizure [Mithanil] [2–4].

Surgical Planning

Equipment

DePuy Synthes Trauma®

1. LCP-VA 2.4 mm distal radius plates
2. Modular hand-set with 1.5/2.0/2.4 mm
3. Foot compressor-distractor device
4. Low profile 2.4 mm wrist spanning plate

Surgical Tact

Position Supine position and hand table. A tourniquet was used.

Anesthesia Regional brachial plexus block and conscious sedation.

Approach Reduction and Fixation Technique: A volar approach to the distal radius was performed utilizing the surgical approach done a few weeks prior. The interval between the radial artery and the brachioradialis was redeveloped. The flexor pollicis longus and pronator quadratus were mobilized ulnarly and the volar plate was removed. The distal radius fracture callus and calcium phosphate bone substitute placed at the initial surgery were debrided.

A 2-pin distractor utilizing 2.0 mm K-wires was applied to the index metacarpal and the radial shaft. The metacarpal pin was placed percutaneously and the radius pin was placed through the incision made dorsoradially for the dorsal bridge plate application [5].

The wrist was distracted to improve distal radial height and inclination via ligamentotaxis. The distractor is very powerful and was chosen in this case due to the chronicity of the fracture. After debridement and distraction, a significant bone defect was revealed involving both the radial and ulnar columns. The lunate facet fragment was manipulated and elevated through the metaphyseal defect to obtain articular reduction. The reduced fragments were held with 1.25 mm K-wires, and reduction was verified using fluoroscopy. The metaphyseal defect was filled with cancellous allograft chips.

Considering the significant metaphyseal bone defect and previous screw holes in the distal radius, 3 mini-fragment plates were utilized for fragment-specific fixation of the radial styloid and lunate facet fragments away from the previous screw tracts. Two 2.0 mm modular hand plates were applied to the radial column and secured with bicortical non-locking screws. An additional plate was applied to support the lunate facet fragment (Fig. 9.6). This fixation was deemed inadequate to resist postoperative deforming forces of the flexor and extensor musculature as well as rotation; therefore, a dorsal bridge plate was selected to neutralize these forces.

Fluoroscopic images were obtained and anatomic reconstruction was appreciated, with proper radial height and tilt. Now, while maintaining wrist distraction, we proceeded with dorsal bridge plate application. A 3 cm incision was made dorsally, centered over the third dorsal compartment. The retinaculum over the

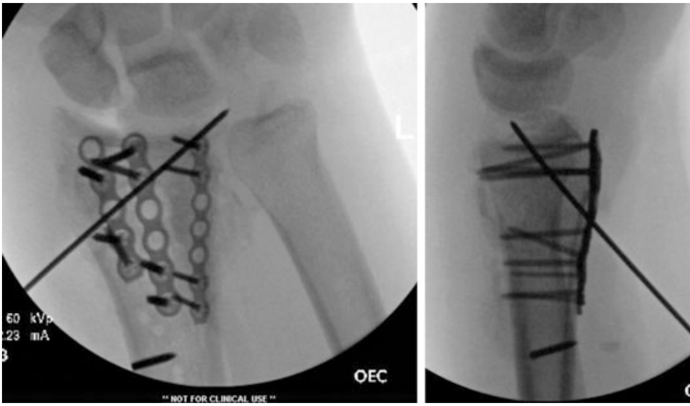

Fig. 9.6 Prior plate removed, fracture fragments re-reduced, and fixed with 2.0 mm modular hand plates applied through the previous volar approach

EPL tendon was incised longitudinally, and the EPL tendon was transposed radial to Lister's tubercle. We then dissected sharply through the floor of the third compartment such that we could elevate the fourth compartment subperiosteally. We now made a 3 cm incision over the long finger metacarpal and mobilized the extensor tendon ulnarly. A tunnel for the plate was now created by passing a blunt elevator under the extensor tendons but superficial to the dorsal wrist capsule and ulnar to Lister's tubercle. A third 3 cm incision was made approximately 4 cm proximal to the fracture dorsoradially. We identified the dorsal sensory branch of the radial nerve and protected it. Dissection was carried between the long thumb abductor muscles and the extensor carpi radialis longus/brevis muscles. A tunnel for the plate was now created by passing a blunt elevator under the APL/APB muscles distally and ulnar to Lister's tubercle creating a continuous path from the long finger metacarpal to the radial shaft.

We selected a low profile 2.4 mm DBP and passed it from distal to proximal ensuring passage under the extensor tendons. The plate was first secured with K-wires to the metacarpal and the radius (Fig. 9.7).

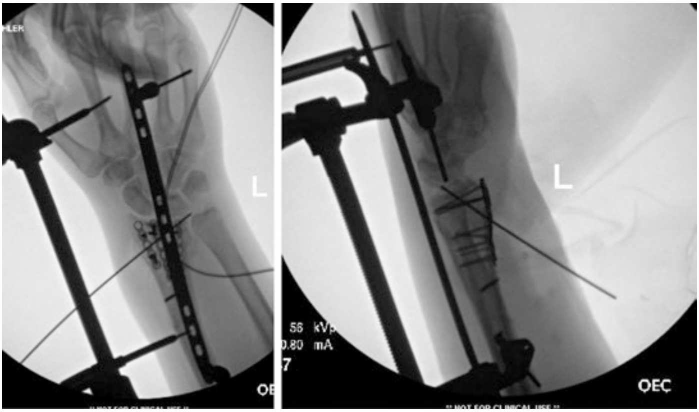

Fig. 9.7 Submuscular application of the DBP with provisional K-wire fixation

Fig. 9.8 Two-week postoperative PA and facet view lateral

Distraction was eased so as to maintain radial height but not distraction of the radiocarpal and intercarpal joints. The plate was then drawn down to the bone with cortical screws and then secured with locking screws with 6 cortices proximal and distal to the fracture. The distractor was removed and the wounds were closed with absorbable subcutaneous sutures and nylon in the skin. A volar resting splint was applied for soft tissue rest (Fig. 9.8).

Postoperative Protocol

The patient remained in the protective volar splint for 2 weeks. Sutures were removed at the 2-week visit, and he was transitioned to a removable splint. Finger ROM was initiated immediately postoperative and reviewed in the office. Weightbearing/lifting was restricted to 5Lbs.

Follow-Up with Radiographs

First postoperative visit 2 weeks after ORIF, DBP, and removal of hardware (see Fig. 9.8). Occupational therapy initiated within 1 week of surgery 2–3 times/week.

Second postoperative visit 6 weeks: Assess progress and wound healing. Advance weight bearing and strengthening.

Dorsal Bridge Plate Removal

Third postoperative 12 weeks: Assess progress and plan DBP removal.

The patient was returned to the operating room 12 weeks postoperative for the removal of the dorsal spanning plate (Fig. 9.9) [6].

Fig. 9.9 Healed fracture post DBP removal

Tips and Tricks

1. Dorsal bridge plate is helpful for highly comminuted intra-articular fractures where conventional forms of internal or external fixation are not likely to maintain reduction.
2. Combined volar fixation with a DBP is helpful in young patients where articular reduction will result in a congruent articulation between the distal radius, scaphoid, and lunate minimizing the risk of PTOA and a more durable result.
3. The compressor/distractor is a powerful tool in chronic cases to bring the radius out to proper length. Be sure to place the proximal pin while visualizing bone to avoid injury to the sensory branch of the radial nerve.
4. Use a volar locking plate or fragment specific plate as appropriate for articular fixation.
5. Apply the DBP to maintain length and alignment while neutralizing deforming forces at the articular fragments. Avoid over distraction of the radiocarpal and intercarpal joints.

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10 Dorsal Plating for Distal Radius Fractures

Catphuong L. Vu and Jerry I. Huang

Case Presentation/ History/Examination/Initial Management in ED/Office

A 45-year-old right-hand-dominant male presented following a fall from bike and sustained an isolated closed left intra-articular distal radius fracture. The patient has no significant past medical history but did have a remote left wrist fracture treated with closed reduction at age 12. The patient works as a computer programmer.

Physical Examination: Gross deformity of the left wrist with dorsal angulation and circumferential swelling. He had diminished sensation along the dorsal thumb and index finger. Motor exam was intact in radial, median, ulnar nerve distributions. Radial pulse was palpable and extremity well perfused.

The patient was evaluated in the emergency department and underwent close reduction of his left distal radius fracture with lido-

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https://doi.org/10.1007/978-3-030-74293-5_10

Fig. 10.1 PA and lateral radiographs of the left wrist the at time of injury and post reduction

caine hematoma block and placement in long arm plaster splint (Fig. 10.1). The patient was discharged home and planned for outpatient follow-up in 1 week for further evaluation and treatment.

Radiographs/CT

Radiographs and CT scan of the left wrist demonstrated intra-articular distal radius fracture with a coronal split with a dorsally displaced dorso-radial fragment (Fig. 10.2).

Fig. 10.2 CT scan of left wrist demonstrating intra-articular fracture line with coronal split with displaced dorsal radial fragment with gapping and articular step-off

Surgical Timing/Planning Including Equipment

The patient was evaluated in clinic 1 week after injury and surgery was discussed given the articular displacement and instability of his fracture pattern. As the CT demonstrated the fracture line going from dorsal proximal to volar distal with the majority of the articular fragment being dorsal, a dorsal plate was selected to buttress this fragment. A 2.4 mm locking plate with an L-shaped configuration was chosen to allow for dorso-radial buttressing of the distal articular fragment. Locking screws are used distally for better fixation in the distal fragment and placement of unicortical screws are intended to avoid flexor tendon irritation on the far cortex. The plate was over-contoured in a convex fashion so that it is low profile against the dorsal cortex to minimize extensor tendon irritation.

Surgical Tact: Position, Approach, Fixation Technique

- Positioning: The patient was placed supine on an operating table with an arm table.
- Approach: A dorso-radial approach was utilized between the first and second dorsal compartments. Incision with a 15 scalpel was taken down through skin and subcutaneous tissue followed by blunt dissection with tenotomy scissors. The radial sensory nerve and its branches were identified and protected. The extensor retinaculum was incised over the radial aspect of the second dorsal compartment. The extensor carpi radialis longus (ECRL) and extensor carpi radialis brevis (ECRB) tendons were subperiosteally elevated off the dorso-radial aspect of the distal radius. Transverse dorsal capsulotomy was performed to visualize the articular surface.
- Fixation: With direct visualization of the fracture line and the articular step-off, the fragment was reduced with a point-to-point clamp, followed by provisional fixation with a 0.054 K-wire from the radial styloid into the radial shaft proximally (Fig. 10.3). An oblique L-shaped 2.4 mm dorsal locking plate was then contoured to the dorsal cortex and affixed using 2.4 mm locking screws distally and 2.4 mm cortical screws proximally in the shaft. A 2.7 mm lag screw was also placed from radial to ulnar direction perpendicular to fracture line for supplemental fixation. The extensor retinaculum was reap-

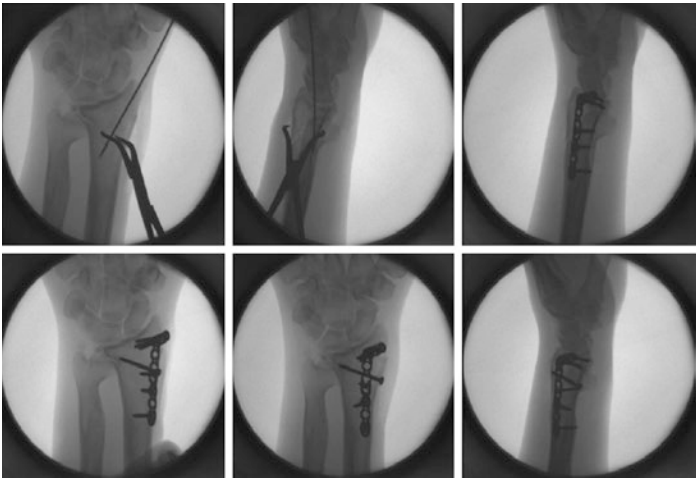

Fig. 10.3 Fluoroscopy images demonstrating reduction and provisional fixation with a 0.054 K-wire, followed by placement of a dorsal radial plate to buttress the fracture

proximated with 3–0 Vicryl absorbable sutures and skin closure with 4–0 Nylon sutures. The patient was placed into a short arm volar plaster splint.

Postoperative Protocol

The patient returned for re-evaluation 2 weeks post surgery for transition into short arm volar thermoplast splint and start active range of motion exercises for the forearm, wrist, and hand with hand therapy (Fig. 10.4). Weight bearing is limited to two pounds (coffee-cup weight bearing). At 6 weeks' follow-up, imaging is repeated, and the patient is transitioned out of wrist splint except for outdoor activities. Weight bearing limit is increased to ten pounds. Passive range of motion exercises are initiated at this time. Strengthening is not recommended until 3 months postoperatively. At 3 months, the patient is allowed to return to weight bearing and activities as tolerated.

Fig. 10.4 PA, oblique, and lateral X-rays of left wrist at 2 weeks, 6 weeks, and 3 months post surgery

Tips and Tricks

- Dorsal plating of distal radius fractures can be approached through a variety of approaches including dorso-radial (between first and second dorsal compartments), direct dorsal (between the second and fourth dorsal compartments), and dorso-ulnar (between the fourth and fifth dorsal compartments).

- Transverse dorsal capsulotomy allows for direct visualization of the articular surface.
- The dorsal plate should be contoured to fit the convex surface of the dorsal distal radius with selection of plates with a low profile smooth edge distally.
- Step-cut of the extensor retinaculum can be performed to allow easier closure of the retinaculum following plate placement.
- Recommend preoperative counseling about complications of dorsal plating includes extensor tenosynovitis, extensor tendon rupture, and wrist stiffness and the potential need for future hardware removal and extensor tenolysis.

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11 Extra-articular Malunions of the Distal Radius

Ji H. Son and Gregory H. Rafijah

Case Presentation/ History/Examination/Initial Management in ED/Office

On presentation, upper extremity is assessed for deformity, pain, wrist / forearm / digital range of motion, grip strength, distal radioulnar joint stability. Deformity by itself is not an indication for malunion correction.

A 72-year-old right-hand-dominant, active woman presents after nonoperative treatment of left Colles fracture with pain along the ulnocarpal joint and difficulty flexing her wrist.

Radiographs/CT

Standard imaging (anteroposteral, lateral, oblique) is obtained (Fig. 11.1). Although there are no fixed radiographic criteria for correction, the following is commonly used: radial inclination

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https://doi.org/10.1007/978-3-030-74293-5_11

Fig. 11.1 Left wrist AP, lateral, oblique views of a 72-year-old woman presenting with Colles fracture. Note thumb CMC joint replacement

<10 degrees, volar or dorsal tilt >20 degrees, ulnar variance > +2 mm, and articular incongruity >2 mm. Dorsally malunited radius can result in carpal instability.

Surgical Timing/Planning Including Equipment

Timing

The optimal time for malunion correction remains unclear. Osteotomy can be considered when no soft tissue trophic changes or swelling exist and digital motion is recovered. Jupiter and Ring retrospectively compared 10 malunited distal radius fractures that had been corrected early (6–14 weeks after injury or nascent) against 10 malunited distal radius fractures that were corrected late (30–48 weeks or considered mature) and found that the results were similar. However, they preferred an earlier correction because it was technically easier and reduced the overall period of disability. In older patients age >60, because functional outcomes are similar in those treated with surgical correction versus casting, corrective osteotomy can be performed late to allow for better bone stock after fracture healing and remodeling.

In this patient, corrective osteotomy was performed 31 weeks after the injury.

Planning

Shape of the malunion determines the approach used to correct the malunion. A volarly tilted malunion or incongruity of the volar cortex is treated through a volar approach. Dorsally tilted malunions are treated through either approach. Well-aligned distal radius without degenerative changes may only require an ulnar shortening osteotomy. Impacted malunions where more than 1 cm of radial lengthening is required will often need an ulnar shortening osteotomy. This can be performed simultaneously or delayed. Imaging from the time of injury can aid in operative planning as the osteotomy line is planned at the site of previous fracture. Contralateral, uninjured wrist imaging can provide preinjury anatomy. As the surgical complication rate is reported to be as high as 50% with corrective osteotomy, potential complications should be discussed with the patients. They include nonunion, loss of reduction, implant failure, nerve injury, tendon injury, and complex regional pain syndrome.

Surgical Tact: Position; Approach, Fixation Technique

Position

The patient is placed supine with the affected upper extremity on a hand table and tourniquet in place. Ipsilateral iliac crest is prepared in case autogenous bone graft is required.

Surgical Approaches

Volar approach is performed using a longitudinal incision between the radial artery and flexor carpi radialis (FCR). The FPL tendon is encountered and retracted ulnarly to expose the pronator quadratus muscle that is then incised in an L-shaped fashion. The insertion of brachioradialis tendon is released from the distal radius to reduce its deforming force.

Dorsal approach is performed using a longitudinal incision over the Lister's tubercle. The EPL tendon is mobilized from the third compartment and retracted radially. Subperiosteal dissection is performed between third, second, and fourth compartments to expose the malunion site. In the case a dorsal spanning plate is utilized, two additional incisions are made. A longitudinal incision is made over the shaft of second or third metacarpal. Extensor tendon and branches of sensory nerves are retracted. A separate longitudinal incision is made in the dorsal radial shaft. An interval is made between brachioradialis and ECRL or between ECRB and EDC.

Fixation

After exposing deformity, malunion site is identified and confirmed on fluoroscopy. An osteotomy is made at the site of prior fracture, parallel to the articular surface, with an oscillating saw from volar to dorsal direction. The osteotomy must not violate the sigmoid notch of the distal radial ulnar joint. An osteotome is used for the dorsal cortex to prevent iatrogenic injury to the extensor tendons. A lamina spreader may be used for impacted fractures. A volar locking plate is placed over the distal radius, with the plate rim parallel to the lunate facet to restore the radial inclination. Locking screws are used to secure the plate distally. The proximal portion of the plate is secured to the shaft using a bone clamp, and alignment is confirmed on fluoroscopy with the goal of neutral ulnar variance. The plate is secured using screws.

For sagittal plane malunion, an alternative method of fixation and osteotomy is to place the volar locking plate on distal radius before the osteotomy. The plate is provisionally secured using two Kirschner wires distally and drill the oblong hole of the proximal portion of the plate (Fig. 11.2). The most proximal aspect of the oblong hole is drilled in anticipation that the plate would sit more

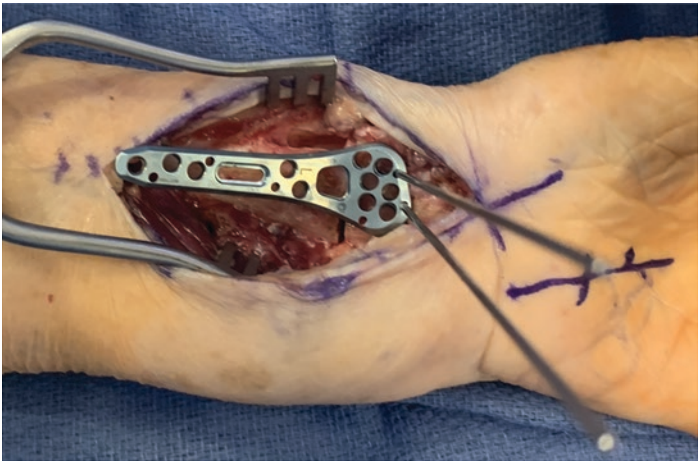

Fig. 11.2 Volar approach is shown in this image. The plate is provisionally secured using two Kirschner wires distally and drill the oblong hole of the proximal portion of the plate

proximally upon reduction of the distal radius after osteotomy. The plate is removed with pins still in place, and an osteotomy is made. The plate is replaced and secured proximally using a screw at the oblong hole. Locking screws are used to secure the plate distally, and remaining proximal holes of the plate are filled using screws to secure proximal portion of the plate.

In older patients with osteoporotic bone in which direct fracture fixation is likely to be poor, a dorsal spanning plate should be considered (Fig. 11.3). Osteotomy is performed using dorsal approach over the Lister's tubercle at the site of prior fracture. An osteotome can be used to distract the osteotomy site, and fixated in the corrected position using two Kirschner wires. The plate is inserted in a retrograde fashion from the area of the metacarpal, centralized over the metacarpal and aligned on the radial shaft. The second-to-last hole at the distal end of the plate is drilled, and a bicortical screw is placed in the metacarpal, allowing slight plate adjustment if necessary. The plate is clamped to the radial shaft with a bone reduction clamp. The remaining screws distally and proximally are placed.

Fig. 11.3 Left wrist AP, lateral, oblique views of a 68-year-old woman presenting with Colles fracture. Dorsal spanning plate was used in the patient with two Kirschner wires for radial styloid fracture. Kirschner wires were removed 4 weeks postoperative, and the dorsal spanning plate was removed 3 months postoperative. She went to achieve bony union after corrective osteotomy

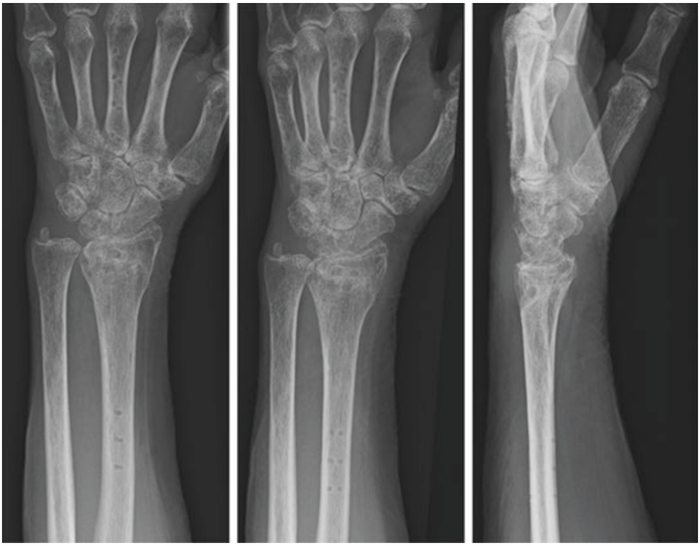

Fig. 11.3 (continued)

Cancellous autograft or allograft can be used to fill the osteotomy site, although not necessary.

Postoperative Protocol

Above the elbow, splint was applied intraoperatively. This splint is maintained for 2 weeks and transitioned to a removable wrist splint. Finger range of motion is encouraged immediately after surgery.

Follow-Up with Radiographs/Pictures if Any

The patient from Fig. 11.1 now 2 months after correction has X-rays demonstrating bridging bone across the osteotomy site (Fig. 11.4).

Fig. 11.4 AP, lateral, oblique views of the left wrist 2 months postoperative. Note restored distal radius length, volar tilt, and radial inclination

Tips and Tricks (5 Salient Points)

- Release brachioradialis for lengthening of the distal fragment.
- Complete the osteotomy with a thin osteotome to avoid risk for injury to the extensor tendons.
- Prophylactic carpal tunnel release should be performed routinely as length restoration may strain a scarred median nerve.
- Kirschner wires placed in the distal portion parallel to the articular surface can help confirm the direction of the osteotomy.
- Avoid osteotomy cut entering the sigmoid notch!

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12 Bridge Plating of Distal Radius Fractures

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and Douglas P. Hanel

Case History

Clinical History

A 46-year-old right-hand-dominant male laboratory technician and avid violinist sustained bilateral injuries to his wrists following a fall while riding his bicycle to work.

Examination

He presented to our emergency department shortly after his injury with bilateral wrist deformity associated with swelling, ecchymosis, and intact skin. He was able to range his shoulder and elbow without pain, and his neurologic status was intact. He denied any numbness or tingling in his extremities, and two-point discrimination was normal in all digits. Forearm compartments were soft and both radial and ulnar pulses 2+, with well-perfused fingers.

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https://doi.org/10.1007/978-3-030-74293-5_12

Initial ED Management

Following radiographic imaging, he was placed into bilateral long arm plaster splints with a gentle mold.

Imaging (Radiographs/CT)

Anteroposterior (AP), oblique, and lateral radiographs of bilateral wrists were obtained demonstrating volarly displaced, intra-articular distal radius fractures (Fig. 12.1). Both fractures had displaced volar ulnar fracture fragments ("critical corner") without evidence of injury to the carpus or distal radioulnar joint (DRUJ).

Fig. 12.1 Initial injury radiographs of the right and left wrists: (**a**) right wrist, (**b**) left wrist

A computed tomography (CT) scan was deferred given that the fracture could be well characterized on the injury radiographs and a CT scan was unlikely to significantly alter our management.

Surgical Timing/Preoperative Planning

Indications and Surgical Timing

The pros and cons of operative versus nonoperative treatment of his injuries were discussed with the patient, including the risk of malunion, stiffness, and post-traumatic arthritis. In addition, the patient's employment and hobbies required the use of bilateral wrists on a regular basis. Given that restoration of normal anatomy after distal radius fracture provides better function, he was indicated for surgical treatment to ensure correction of the displacement and maintenance of reduction. Given the bilateral nature of his injuries and the anticipated difficulty with self-care at home in bilateral long-arm splints, he was admitted to the hospital and taken to the operating room on the second day post-injury.

Preoperative Planning

Based on the imaging, both fractures involved a small, displaced volar ulnar corner which we planned to reduce and fix using fragment-specific fixation. Given the bilateral nature of his injuries, the increased fracture comminution of the left distal radius fracture, and the need for load-bearing through at least one wrist for activities of daily living, we planned to use a dorsal distraction bridge plate for the left wrist injury. Bridge plating provides strong fixation and allows for distraction of impacted articular segments, and it can be used in conjunction with fragment-specific fixation of intra-articular components, making it a particularly appropriate technique for the patient's left distal radius fracture [1–3]. For the right distal radius fracture (dominant side), we planned to use fragment-specific fixation alone if the construct was stable to allow for earlier wrist range of motion.

Equipment

Options for implants include 22-hole 2.4 mm titanium mandibular reconstruction plates or other titanium or stainless-steel plates specifically designed for use as a distal radius bridge plate. In this case, we used a TriMed bridge plate (TriMed, Inc.©; Santa Clarita, CA) constructed of stainless steel with tapered edges to facilitate sliding of the plate within the extensor compartment. Locking screw options were available both proximally and distally.

Surgical Tact

Positioning

The patient was placed in the supine position on the operating table and both extremities were draped free and centered on a radiolucent hand table, such that a C-arm could enter the field from either above or below the hand table.

Reduction

Under image intensification, the closed reduction maneuver as described by Agee was performed [4]. Finger traps were applied to the index and middle fingers and 10–15 lbs. of longitudinal traction was applied using a rope and pulley system to restore length and assess the benefit of ligamentotaxis for the restoration of articular step-off. Next, the hand was translated volarly to restore volar tilt and asses the integrity of the volar lip of the radius. Finally, the hand was pronated to correct any supination deformity. Following the initial reduction maneuver, the fracture was then re-assessed to determine the need for additional reduction or fixation prior to application of a dorsal bridge plate. Given persistent displaced volar ulnar fracture fragments, a separate volar incision was performed with fragment-specific fixation to provide appropriate buttress support.

For the right wrist, reduction was challenging, but after manipulation using the Agee maneuver and placement of fragment-specific fixation, the construct was felt to be quite stable to Agee reduction stress so a dorsal bridge plate was not applied (Fig. 12.2). For the left wrist, we reconstructed the intermediate column by using small implants for the volar ulnar column, and then proceeded to place a dorsal bridge plate based on our preoperative plan.

Approach

The dorsal bridge plate was superimposed on the skin of the radial diaphysis proximally and the metadiaphysis of the second metacarpal distally. We choose to place the plate in the second compartment as our experience has been that securing the plate in the second compartment nicely restores radial inclination, volar tilt, and radial length [3]. Plate positioning was verified with C-arm imaging, and 5 cm skin incisions were marked proximally and distally (Fig. 12.3). Subcutaneous tissues were infiltrated with 0.25% bupivacaine with epinephrine to promote hemostasis.

Distally, the incision was made over the second metatarsal base extending along the shaft, and tissues were dissected down to bone taking care to preserve nearby dorsal sensory nerves. A second incision was made over the radial diaphysis just proximal to the out-cropper muscle bellies (abductor pollicis longus and extensor pollicis brevis) in line with the extensor carpi radialis longus (ECRL) and brevis (ECRB) tendons. The interval between the ECRL and ECRB was bluntly dissected to expose the radial diaphysis.

Fixation Technique

The dorsal bridge plate was then introduced distally through the second extensor compartment of the wrist. After the plate was passed, it was secured to the second metacarpal by placing a non-

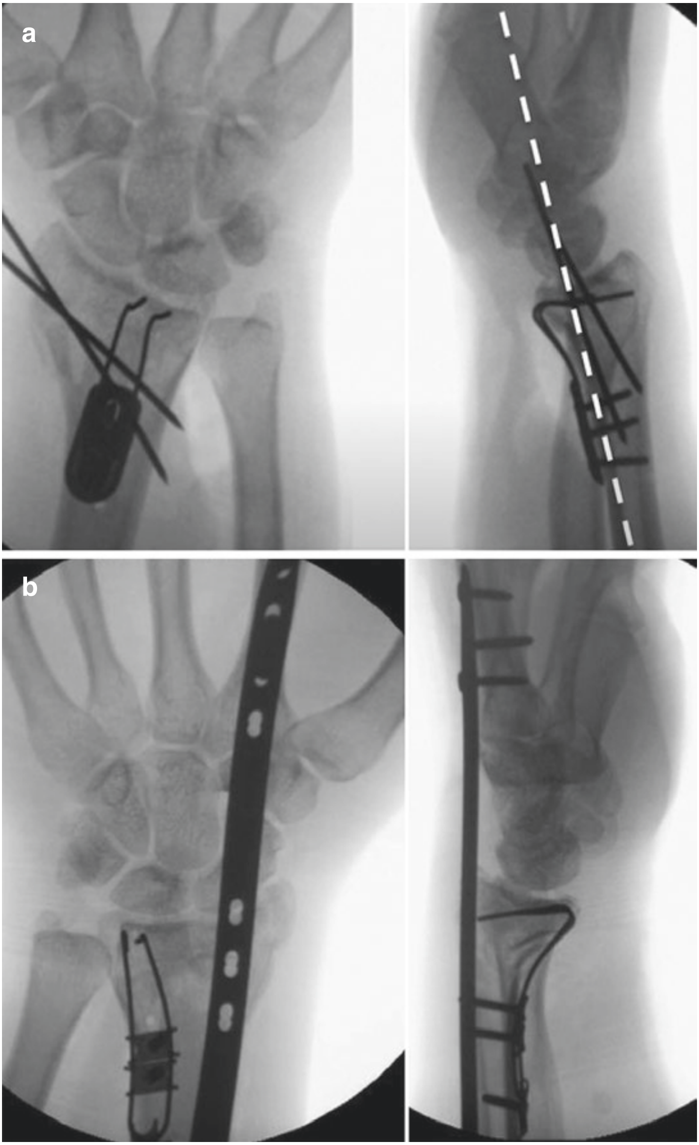

Fig. 12.2 Intraoperative radiographs of the right and left wrists: (**a**) right wrist, (**b**) left wrist

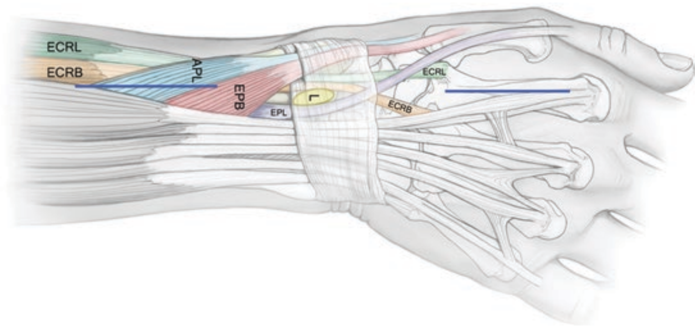

Fig. 12.3 Relevant anatomy to placement of dorsal bridge plate with proximal and distal incisions (blue)

locking fully threaded cortical screw through the most distal plate hole. The proximal end of the plate was then identified in the forearm and secured by placing a nonlocking fully threaded cortical screw in the most proximal screw hole. In this manner, the plate was secured along the longitudinal axis of the radius and the remaining holes were filled with 2 additional fully threaded screws proximally and distally (one nonlocking and one locking, Fig. 12.2).

Distal Radioulnar Joint Management

The DRUJ was tested after reconstruction of both wrists and found to be stable, so both limbs were immobilized in a long-arm splint with the forearm in supination for 10–14 days postoperatively. In settings where the DRUJ is unstable and there are no contraindications to prolonging the operation, we will typically repair or reconstruct the DRUJ and the triangular fibrocartilage complex. If there is a contraindication to further surgery, we manually reduce the ulnar head into the sigmoid notch and transfix the ulna to the radius with at least two 1.6-mm Kirschner wires placed proximal to the DRUJ.

Postoperative Protocol

Digit range-of-motion exercises were initiated within 24 hours of surgery. For the left wrist which was fixed with a dorsal bridge plate, load-bearing through the forearm and elbow was permitted immediately, but lifting and carrying was restricted to 10 lbs.

In our protocol for distal radius fractures fixed with a dorsal distraction bridge plate, at the 2-week postoperative visit, sutures are removed, and DRUJ stability and forearm motion are assessed. If the patient can supinate the forearm and the DRUJ is stable, splinting is discontinued and axial loading through the extremity is allowed. If the patient has difficulty maintaining supination or if the DRUJ was acutely reconstructed, a removable long-arm splint is fabricated for the patient's use. Kirschner wires used to transfix the DRUJ are removed in the third postoperative week and DRUJ stability is reassessed. Supplemental K-wires for articular fixation are removed 6 weeks postoperatively. The dorsal bridge plate and screws are removed no earlier than 12 weeks from injury. After plate removal, a removable short-arm splint is worn for 2–3 weeks, and hand therapy is directed at regaining motion and strength.

Patient Follow-Up

Two weeks postoperatively, sutures were removed, and range of motion was improving. The left DRUJ was stable and mobile, so his splint was removed. The right DRUJ was stiff, so he was referred to PT. By 4 weeks postoperatively, pain was decreased, range of motion continued to improve bilaterally, and he had returned to playing the violin and riding his bike.

However, at 6 weeks postoperatively, the patient noted a marked difference in the appearance of his right wrist and imaging confirmed failure of fixation. His lateral carpal line demonstrated that the fracture had shifted volarly and shortened. Further evaluation by CT scan demonstrated that this was a salvageable fracture (Fig. 12.4). For the revision operation, a carpal tunnel

Fig 12.4 Six-week postoperative visit: (**a**) right wrist with failed fixation, (**b**) left wrist with intact fixation and alignment, (**c**) CT scan of right wrist demonstrating salvageable fracture fragments, (**d**) revision fixation of right wrist

exposure was utilized to manage the "critical" volar ulnar corner. Prior fixation was removed, and the articular surface was reconstructed and held in place with a volar locking plate. Despite this being a strong construct, the decision was made to supplement the fixation by using a bridge plate, given that another common indication for use of a dorsal bridge plate is for augmented fixation for comminution, osteoporotic bone, or carpal instability in primary or revision cases.

Ultimately, the patient did well. After 16 weeks postoperatively, his fractures healed, and the distraction plates were removed. And after 40 weeks postoperatively, radiographs confirmed successful reconstruction of his articular surfaces (Fig. 12.5). Strength and range-of-motion recovery were greater on the dominant side compared to the nondominant side, which is typical of fractures treated with this technique (Fig. 12.5) [5]. Eight years postoperatively, he has returned to performing with his violin and rides his bike to work every day.

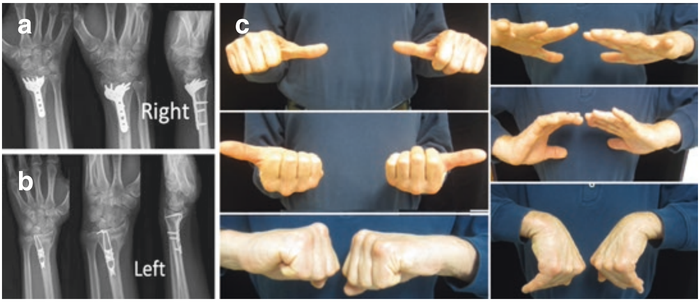

Fig. 12.5 Final follow-up: (**a**) healed right wrist fracture, (**b**) healed left wrist fracture, (**c**) final range of motion

Tips and Tricks

1. Consider the direction of carpal displacement before inserting the plate. This avoids catching the plate on or under fracture fragments as it is advanced. Occasionally the plate will not pass easily, in this case: first try passing a guidewire or stout suture retriever from distal to proximal and then deliver the plate using the guide from proximal to distal. If this technique fails, a third incision can be made directly over the metaphysis of the radius to expose the proximal half of the second compartment to pass the plate under direct vision. This third incision may also be used to assess the articular surface, reduce impacted or die-punch fragments, and place bone graft.
2. If radial length is not restored after securing the plate distally, push the plate distally using a distraction device in the proximal forearm incision until length is reestablished. Then, secure the proximal portion of the plate with a nonlocking screw.
3. Intra-articular reduction can be further adjusted using limited periarticular incisions to allow for direct manipulation of articular fragments, place of bone graft, repair of ligament injuries, or augmented fixation.

4. Displaced volar ulnar fracture fragments ("critical corner") that are not reduced with this technique require a separate volar incision and appropriate buttress support.
5. Dorsal bridge plating is useful as a salvage for prior failed treatment by offloading the forces on a distal radius fracture that is being treated for instability and comminution.

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13 Compartment Syndrome Forearm and Hand

Ali Azad and Nader Paksima

Case Presentation/History/Examination/Initial Management

We present the case of a 16-year-old right-hand-dominant male without significant medical history who sustained a left ulna fracture while playing soccer in school and subsequently, 3 months later, ipsilateral radius and ulna diaphyseal fractures. The initial ulna fracture was minimally displaced and treated nonoperatively with immobilization; however, the subsequent injury was treated with open reduction internal fixation of both the radius and ulna (Fig. 13.1). At the patient's 2-week postoperative visit, he reported severe pain during the first week requiring narcotic pain medications, however, felt "okay." He also noted progressive wrist and digit stiffness with intermittent numbness. At the 6-week

Supplementary Information The online version of this chapter (https://doi.org/10.1007/978-3-030-74293-5_13) contains supplementary material, which is available to authorized users.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_13

Fig. 13.1 Radiographs of the left forearm obtained during initial evaluation showing a radius and ulna fracture s/p ORIF with a plate/screw construct. (**a**) PA, (**b**) and lateral radiographs

postoperative visit, clinical examination revealed severe stiffness of all digits and significant global loss of sensation to the hand. At that point, he was referred to our office for further evaluation.

Our initial clinical examination revealed an intrinsic minus deformity secondary to extrinsic muscle contractures (Fig. 13.2). There was near complete loss of sensation with an associated muscle strength grade ≤2/5 in median, ulnar, and radial nerve distributions. A Tinel's sign of the median and ulnar nerves was present ~1 cm proximal the surgical scars. Relaxing the extrinsics

Fig. 13.2 Clawing of the digits demonstrated on profile (**a**) and volar (**b**) images of the hand

with passive flexion and extension of the wrist was able to produce full passive proximal interphalangeal (PIP) joint and distal interphalangeal (DIP) joint extension and flexion, respectively. The findings were consistent with a moderate Volkmann contracture based on the Tsuge Classification. Given the delayed nature of the presentation, compartment pressure measurement was not indicated. Radiographs of the affected extremity are imperative to characterize the extent of injury. Plain films of the left forearm showed well-reduced radius and ulna diaphyseal fractures with plate/screw constructs. An electrodiagnostic study was also performed and revealed severe acute median and ulnar neuropathy with acute denervation of all, respectively, innervated muscles. Of note, there was no evidence of radial neuropathy. The work-up was completed with laboratory analysis (CBC, PT/INR, and PTT) to rule out a bleeding disorder, which was negative.

Surgical Timing, Planning, Equipment

In the acute setting, devastating complications can be minimized with prompt intervention. Emergent surgical decompression is performed as soon as possible. However, in this instance, due to the delayed presentation and uncertainty of surgical outcomes, intervention was scheduled for several days later to allow the patient and family to consider his treatment options. The operative goal was to decompress the superficial and deep volar/flexor compartments, Z-lengthening of the flexor tendons, and neurolysis of the median and ulnar nerves. Clinical evaluation of the dorsal forearm and hand should be done following volar compartment release to determine whether additional releases are indicated. In this particular case, the extensor compartment/mobile wad and hand compartments were not released; however, we have included our preferred approaches.

Surgical Tact: Position, Approach, Fixation Technique

The procedure was performed in the supine position with general anesthesia. A high arm tourniquet was used to maintain a bloodless field. Our preferred surgical approach to release the volar forearm compartments is generally done through a long extensile incision aiming to minimize exposure of neurovascular structures in the event that the incisions are left open. The approach should also allow for extension distally into the carpal tunnel and proximally into the medial arm if needed.

Our preferred extensile approach for acute compartment syndrome involves an ulnarly based incision over the flexor carpi

Fig. 13.3 Post-operative images of volar forearm intra-operatively (**a**) and early during the post-operative (**b**) period

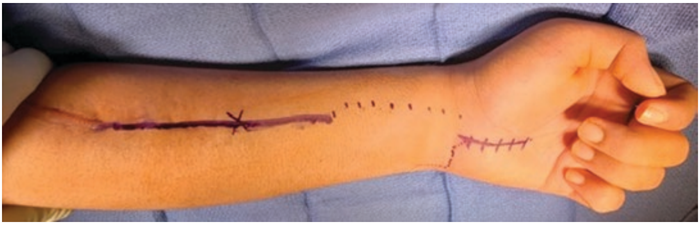

Fig. 13.4 Extensile approach to the volar forearm and carpal tunnel using previously made incisions for fracture fixation.

ulnaris (FCU) and a separate incision for the carpal tunnel release (Fig. 13.3). In this manner, the acute fasciotomy wound can be left open with no fear of covering the median nerve or ulnar neurovascular bundle. Delayed primary closure or skin grafting can easily be performed over the FCU muscle belly. In this particular case, our preferred approach was not possible due to the previously made incisions for fracture fixation. Therefore, the previously made volar approach to the radius was utilized (Fig. 13.4). The prior scar was excised and extended proximally and distally. The antebrachial fascia was incised longitudinally from the lacertus fibrosus to the wrist crease to expose and release the superficial flexor compartment. Thickened bands of fascia contributing to the contracture were excised. Muscles of the superficial flexor

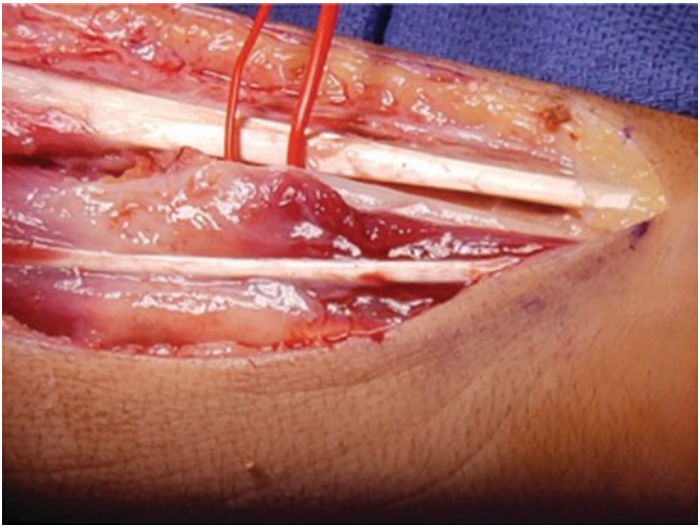

Fig. 13.5 Pale necrotic muscle within the superficial flexor compartment

compartment including flexor carpi radialis (FCR), palmaris longus (PL), and FCU were identified followed by tenolysis. Severely contracted muscle and pale necrotic muscle were excised (Fig. 13.5). The epimysium of the FCR, PL, FCU, and flexor digitorum superficialis (FDS) are released. Following decompression of the superficial flexor compartment, a neurolysis of the median and ulnar nerves is performed (Fig. 13.6). A separate carpal tunnel incision was used to decompress the median nerve within the carpal tunnel. Care must be taken to identify and protect the palmar cutaneous branch of the median nerve if the incision crosses the wrist crease. This is especially important if an extensile approach is utilized connecting the carpal tunnel incision to the forearm incision. In this instance, a standard carpal tunnel release was performed by dividing the palmar fascia and transverse carpal ligament. The median nerve was found to be encased in thick fibrotic scar in the mid forearm, however, appeared healthy with well-maintained structural integrity once a complete neurolysis

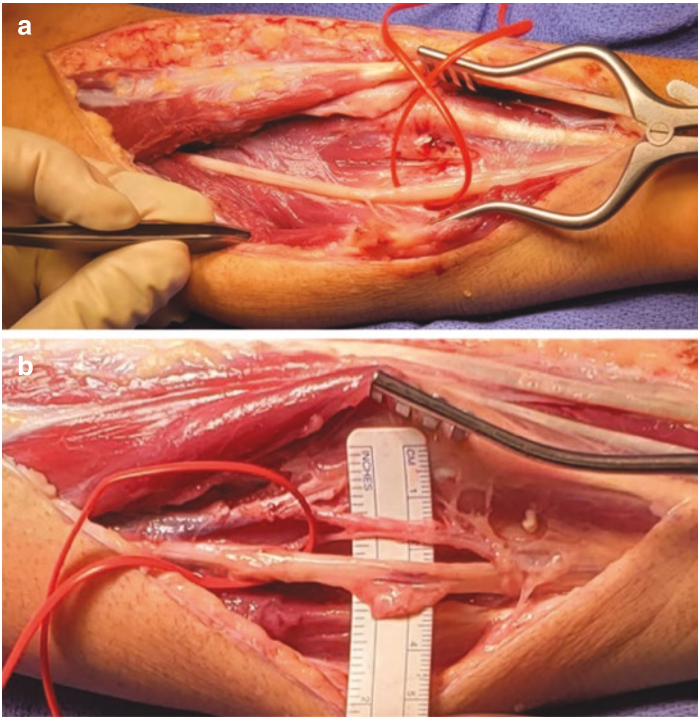

Fig. 13.6 Neurolysis of the (a) median and (b) ulnar nerves

was performed. The ulnar nerve was also intact, however, contused and narrowed deep to a fascial band, which was excised. An epineurial release was carried out to reveal fascicular continuity; therefore, excision and repair was not indicated. The radial artery was structurally intact. The ulnar artery was collapsed/thrombosed. The deep flexor compartment was accessed through the interval between the FDS and the FCU. The epimysium of the flexor digitorum profundus (FDP), flexor pollicis longus (FPL), and pronator quadratus (PQ) were released followed by a tenolysis. A portion of the FPL that was pale and necrotic was excised.

To address the intrinsic minus claw hand deformity secondary to extrinsic contractures, Z-lengthening of the flexor tendons

(FDS, FDP, and FPL) was performed. This was done by creating partial step cuts on opposing sides of each tendon with a 10 cm longitudinal limb. Tendon repair was performed with 3–0 FiberWire interrupted suture. Various tendon lengths were evaluated with provisional repair to ensure appropriate tension. The tendons were lengthened approximately 5 cm to restore a natural resting cascade and passive tenodesis. Following the lengthening, full passive digit flexion and extension was achieved with the wrist held in the neural position.

Fasciotomy of the dorsal forearm and hand was not performed for this patient. However, when indicated, our preferred approach to release the extensor compartment is a single midline longitudinal dorsal incision. Release of the compartments of the hand starts with a distal and radial extended carpal tunnel release through which the fascia of the adductor pollicis is also released. The thenar and hypothenar compartments are released through separate incisions along the border of glabrous skin. The dorsal and volar interosseous muscles are released through two longitudinal incisions centered between the second and third metacarpals and fourth and fifth metacarpals. The first dorsal interosseous muscle is released through an incision in the first web space. Finally, a midaxial dermotomy of all involved digits is performed, avoiding pinching surfaces.

Following a complete decompression, the tourniquet was let down and hemostasis was achieved. Due to the extensive dissection, the skin was closed over a drain, sterile dressings and a short arm resting splint were applied, and the patient was admitted for 24 hours of observation. The drain was removed on postoperative day 1 and the patient was discharge home. In the acute setting, our preference is to keep the incisions open to avoid undue tension, to account for interim muscle swelling as perfusion improves, and in anticipation of a second look at a later date. Dressing options include negative pressure wound dressing or moist gauze dressing. Closure is achieved with delayed primary closure, split thickness skin grafting, secondary intention, or a combination thereof.

Postoperative Protocol/Follow-Up Radiographs/ Pictures

Routine follow-up appointments were scheduled for 2 weeks, 6 weeks, 3 months, 6 months, 9 months, and 1 year. At 2 weeks, once the incision was well healed, occupational therapy was initiated with the use of lumbrical bar and thumb opposition splints. The goal of early occupational therapy was to maintain full passive range of motion (ROM) while awaiting clinical improvement/return of active ROM. At 6 weeks, the patient noted subjective improvement in sensation without any appreciable change in motor function. At 3 months, there was a notable improvement in motor and sensory function. Active wrist flexion and extension was 70° and 30°, respectively. FDS, FDP, FPL, and APB muscle strength improved to 4/5. Adductor pollicis strength remained 1/5. An advancing Tinel's sign was noted approximately 7–8 cm proximal to the wrist crease. At 9 months, the patient was noted to have near full flexion and extension of the wrist and digits (Fig. 13.7 and Video 13.1). Motor evaluation revealed 5/5 muscle strength in medial and ulnar innervated muscles. Grip strength of the right and left upper extremity was 110 lbs. and 30 lbs.,

Fig. 13.7 Postoperative functional outcomes at 9 months

respectively. Two-point discrimination was 4 mm in all digits and protective sensation was intact when evaluated with a Semmes-Weinstein 2.83 monofilament test.

Tips and Tricks

1. Early diagnosis and emergent surgical intervention are imperative to decrease the risk of permanent disability.
2. Appropriate surgical intervention involves an extensile approach with incisions planned to provide coverage of neurovascular structures, debridement of necrotic muscle, and release of all compartments and the epimysium of individual muscles.
3. The deep flexor compartment (FDP, FPL, and PQ) is exposed and released through an interval between the FCU and FDS.
4. Following volar compartment release, repeat examination of the dorsal forearm and hand should dictate if release is indicated.
5. Therapy is initiated immediately following surgery to achieve maximum active and passive range of motion.

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14 Arthroscopic-Assisted Fracture Fixation: Distal Radius

Omri Ayalon

Case Presentation/History/ Examination/Initial Management in ED/Office

This is a 71-year-old right-hand-dominant woman who fell from standing height onto her right outstretched hand sustaining a closed intraarticular and displaced fracture of the right distal radius (Fig. 14.1). She was seen in the emergency room and underwent attempted closed reduction and splinting with suboptimal alignment of the fracture with radial translation, loss of height, and displacement of an intraarticular dorsal coronal shear fragment. (Fig. 14.2). These were compared to images of the contralateral side (Fig. 14.3). Finger motion and neurovascular examination at follow-up in the office were benign, and the decision was made to plan for operative fixation with a volar plate and arthroscopy for assistance with the intraarticular reduction and examination of soft tissue structures.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_14

Fig. 14.1 Injury AP, lateral, and oblique. Please note the dorsal rim involvement

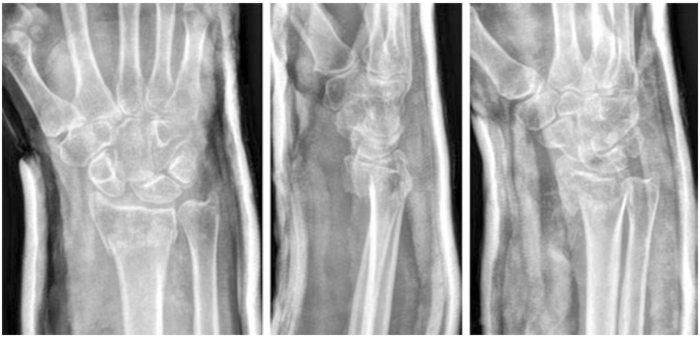

Fig. 14.2 Images after attempted closed reduction. Evident is loss of height, cortical collapse with central impaction, DRUJ malalignment, and rotation of the distal fragment with further intraarticular displacement of the dorsal rim fracture

Fig. 14.3 Contralateral comparison films to establish normal parameters for the patient with evidence of mild resting widened scapholunate gap on asymptomatic side

Surgical Timing/Planning Including Equipment

Surgical timing: For displaced, intraarticular fractures and anticipated difficulty of reduction, it is optimal to operate expeditiously to prevent nascent callus which may block reduction. Ideal operative timing is within 7–10 days of injury. In the interim, it is strongly recommended to focus on strict hand elevation to lessen swelling before surgery.

Equipment planning: For arthroscopic-assisted cases, plan implants as one would for a typical distal radius fracture with a volar or dorsal plate depending on the preoperative plan with appropriate reduction clamps and aids. Make sure to have ample K-wires for provisional fixation. In addition, book the case with

2.7 mm wrist arthroscope and traction tower, preferably one with an adjustable arm to get out of the way of the volar and dorsal aspect of the wrist so as not to block access to the patient's wrist. Equipment for possible soft tissue repairs such as suture anchors is prudent to include on the booking as well.

Surgical Tact: Position, Approach, Fixation Technique

Regional anesthesia is recommended for this procedure. The patient is placed supine with the arm on a radiolucent hand table. Tourniquet is used for a bloodless field for both the open and arthroscopic portions of the procedure. Ensure the arthroscopy tower is easily assembled and the traction arm is out of the way of the mini-fluoroscopy machine which should be brought in parallel to the floor (Fig. 14.4) to accommodate the traction tower. The typical open approach should be used first, in this case the extended FCR approach was used to provide adequate distal exposure along with release of the brachioradialis insertion (Fig. 14.5). The shaft of the radius is pronated out of the wound to release dorsal callus and periosteum to assist in achieving reduction parameters, especially height and volar tilt (Fig. 14.6). After the reduction is achieved, the plate is applied and held in place only with provisional fixation including K-wires and clamps (Fig. 14.7). This is done to ease adjustment of the intraarticular reduction during the arthroscopic portion. Next, the intraarticular reduction is checked with arthroscopy. The traction tower is set up in standard fashion with 10–15 lbs. of traction placed through the index and middle fingers (Fig. 14.8). The 3–4, 4–5, midcarpal, 6R, and 6 U portals are identified on the skin. It is important to make these skin markings for the portals after traction is applied, as the skin markings will shift after the traction is applied. With the arthroscope in the 3–4 portal, a dry scope is recommended to prevent fluid egress into the soft tissues and causing significant swelling. The reduction in the radiocarpal joint and sigmoid notch are then inspected (Fig. 14.9). In addi-

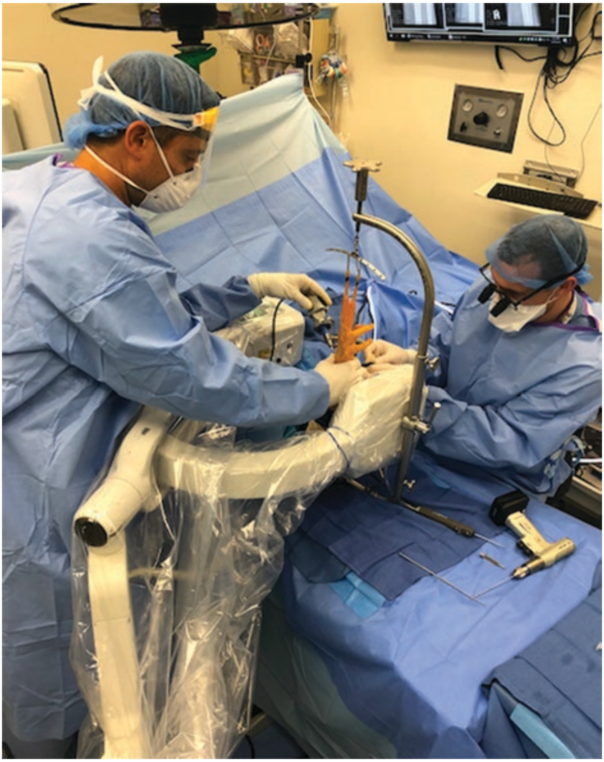

Fig. 14.4 Room set up with mini-fluoroscopy machine in place to allow access to the dorsum of the wrist. Note the traction tower used here has adjustable arm position which does not interfere with imaging. The assistant on the volar side of the wrist can adjust temporary fixation, while the primary surgeon performs the arthroscopic portion of the procedure and adjusts the intraarticular reduction as necessary

tion, a normal diagnostic arthroscopic examination should be performed, inspecting the volar radiocarpal ligaments, quality of the articular cartilage, the triangular fibrocartilage (Fig. 14.10) integrity, and scapholunate ligament (Fig. 14.11). At this point, any fracture displacement can be palpated with a probe and debrided with a shaver (Fig. 14.12) in order to mobilize the frag-

Fig. 14.5 Skin marking for the extended FCR approach used for the more distal fracture patterns

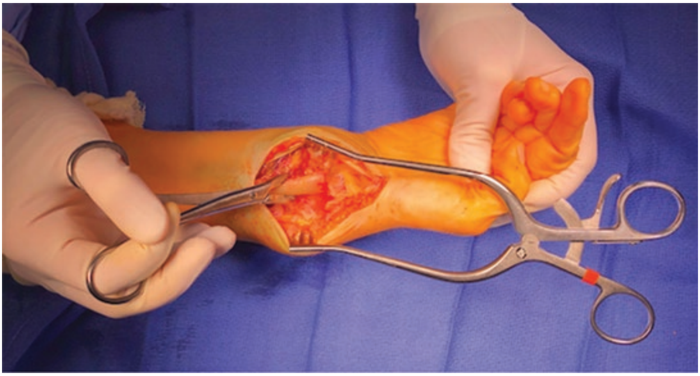

Fig. 14.6 Pronation of the radial shaft to allow excision of dorsal callus to allow reduction for recreation of volar tilt parameter

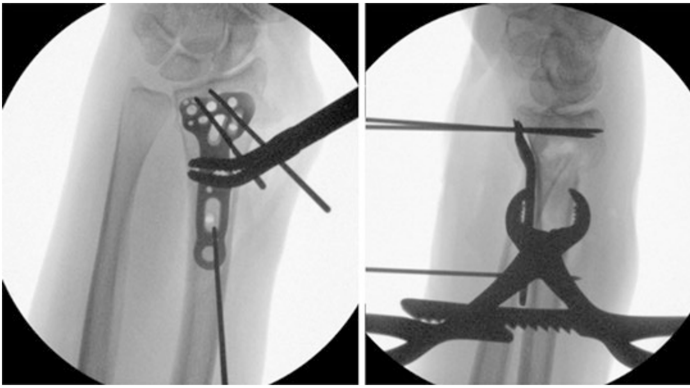

Fig. 14.7 Provisional reduction is achieved with all temporary fixation including reduction clamp and Kirschner wires through the plate. Lateral image below shows suboptimal recreation of intraarticular alignment. At this point, the arthroscope is brought in to improve the reduction of the joint surface

Fig. 14.8 Patient is placed in finger traps and traction is applied. Then skin markings are made showing standard wrist arthroscopy portals in relation to Lister's tubercle and the FCU tendon

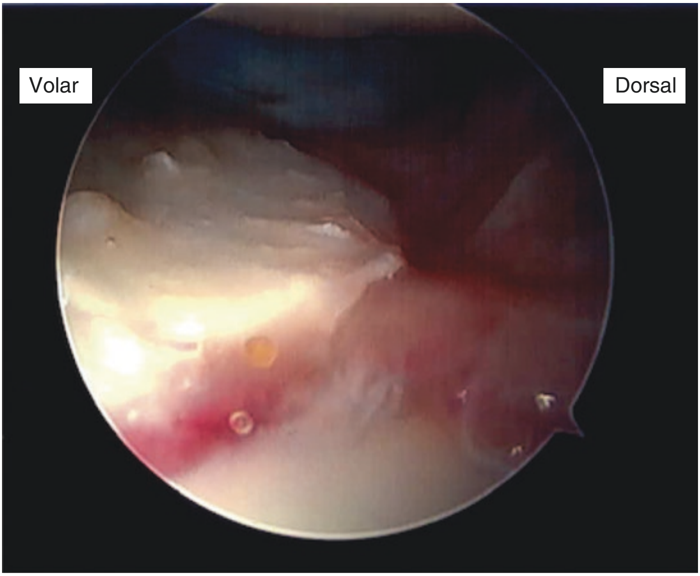

Fig. 14.9 Vantage from the arthroscope showing 3 mm step off at the dorsal rim of the radiocarpal joint with early callus in the fracture site

ments. Now, any temporary fixation can be sequentially removed to allow fracture adjustment. In this case, a dorsal intrafocal K-wire was inserted into the fracture fragment and levered to restore the volar tilt and reduce the intraarticular step off (Fig. 14.13). This was held temporarily with a purposefully long, bi-cortical nonlocking screw to compress the joint surface and is later exchanged out for a locking screw of the appropriate length. With the arthroscope still inserted, the joint reduction is examined closely again and is seen to be much improved with no articular step-off (Fig. 14.14). Next, the plate is filled with appropriate screw lengths for final fixation construct with care taken to avoid joint penetration (Fig. 14.15). Make sure to check the DRUJ stability at this point. After plate fixation is complete, focus should be shifted to systematic examination of the soft tissue stabilizers

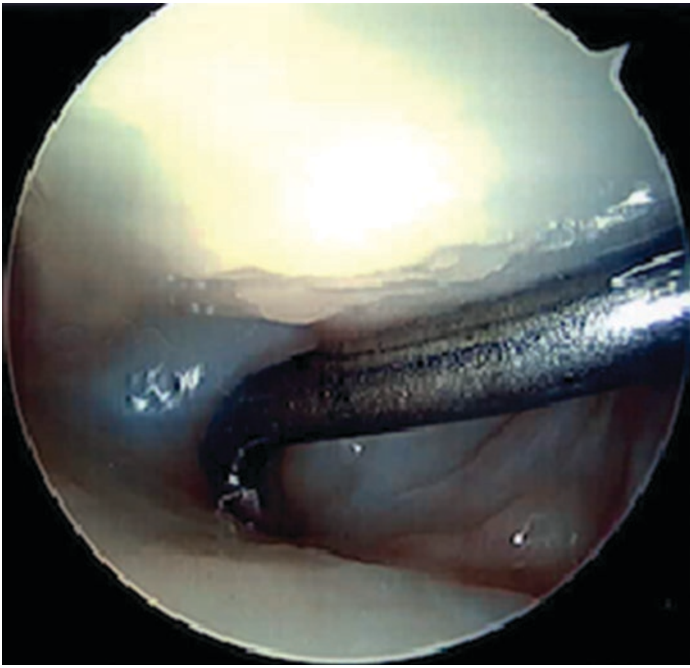

Fig. 14.10 Arthroscopic examination of the triangular fibrocartilage complex and disc showing no injury and good trampoline effect

for potential management. In our case, concern for scapholunate ligament incompetence was examined and found to be nearly symmetric to the contralateral side with no drive through of the arthroscope, and thus the decision was made not to perform a repair or other stabilizing procedure. Similarly, the articular disc of the TFC was seen to be intact. Final X-rays are taken to show the final construct including a 15° elevated joint-line lateral view to see the radiolunate joint appropriately (Fig. 14.15). The tourniquet is released, hemostasis is achieved, pronator quadratus is repaired over the plate, and the skin and subcutaneous tissues are closed with absorbable sutures.

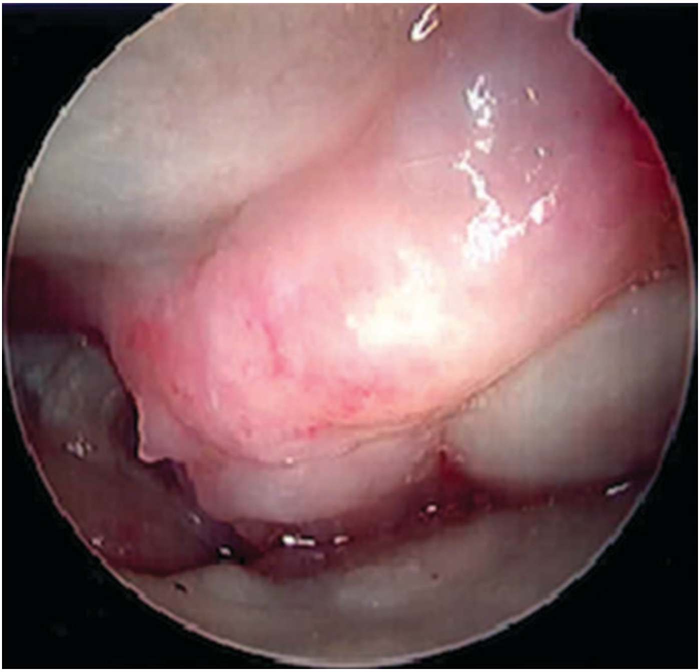

Fig. 14.11 Arthroscopic examination of the scapholunate ligaments revealed Geissler grade II injury

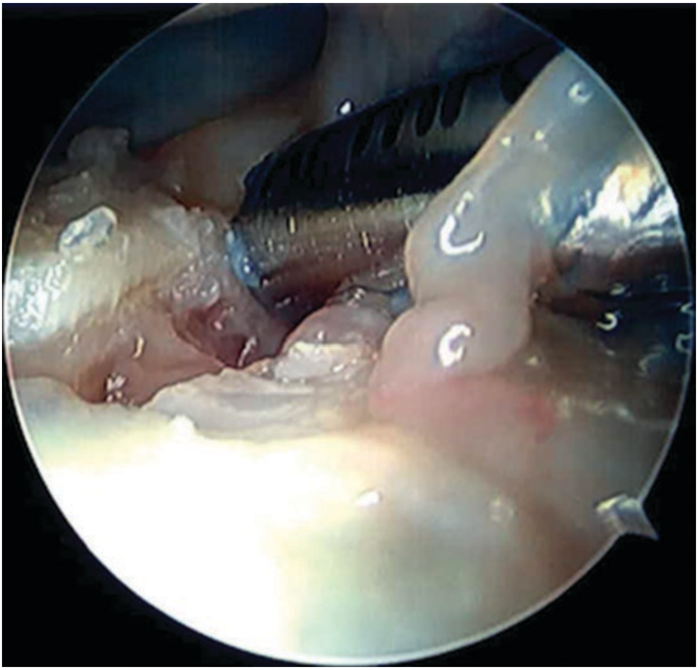

Fig. 14.12 Debridement of the fracture site using a shaver

Fig. 14.13 With the arthroscope inserted in the 3–4 portal, an intrafocal Kapandji-style dorsal wire is inserted percutaneously and flipped to elevate the dorsal fragments and held in place with a temporary cortical screw placed purposefully long to compress the fracture and help maintain the volar tilt

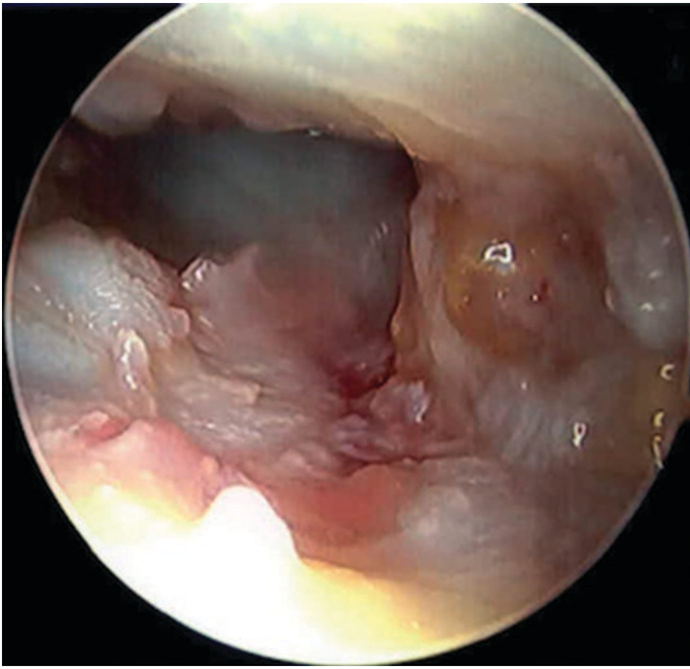

Fig. 14.14 After reduction of the joint and correction of step-off to restore articular congruity

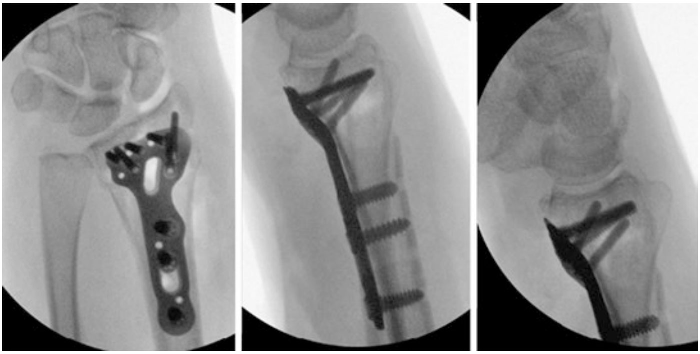

Fig. 14.15 The cortical screw is exchanged for a locking screw of appropriate length, and the remaining proximal and distal screws are placed to achieve final fixation with good restoration of reduction parameters. First lateral is taken with arm resting flat on the table, showing screw lengths and superimposed scaphoid and lunate facets. Final lateral is taken in 15° of elevation to accurately examine the lunate facet, showing restoration of joint congruity, with placement of the plate proximal to the watershed line. Note mild SL gapping which is equal to contralateral side

Postoperative Protocol

A well-padded volar slab of plaster splint is placed in the operating room for the first 10–14 days. Instructions are given for strict elevation and finger motion for the first 48 hours postoperatively. At this first postoperative visit, 10–14 days after surgery, the splint is discontinued and a removable wrist cock-up brace is given to be worn when outside for another 2 weeks. Exercises for wrist and finger motion are given at this visit, to be completed 3 times a day. In addition, occupational therapy begins at this time for wrist and finger mobilization, as well as edema management. The next appointment at 6 weeks after surgery is meant for follow-up X-rays if there is any clinical concern and a return to activity in a gradual manner, based on patient demands.

Follow-Up with Radiographs/Pictures if Any

These clinical images show excellent return to function at 6 weeks with some mild residual stiffness as compared to the contralateral uninjured side. It is important to examine wrist flexion, extension, supination, pronation, and radial and ulnar deviation (Fig. 14.16).

Fig. 14.16 Clinical follow-up showing flexion, extension, pronation, and supination

Tips and Tricks (5 Salient Points)

1. An assistant who is facile at placing and removing K-wires and screws will help with ease of transitioning between the arthroscope and the open portion of the procedure.
2. Perform the arthroscopy dry, as this will prevent over insufflation of the joint with egress of the fluid into the soft tissues. If visualization is difficult, a simple syringe with small (1 cc) amounts of saline instilled intermittently through the arthroscope will improve this.
3. Use provisional fixation prior to arthroscope insertion, as this will allow more facile adjustment of the fracture reduction.
4. Examining the soft tissues (SL, TFC, LT, articular cartilage damage) after fixation is complete and be prepared with implants for potential management at the time of the distal radius fixation.
5. Taking meticulous X-ray images intraoperatively, including an elevated joint line lateral view, is paramount to obtaining good reduction.

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15

Arthroscopic-Assisted Operative Fixation of Scaphoid Fracture

Adam Jacoby
and Jacques Henri Hacquebord

Case Presentation

The patient is a 25-year-old male who sustained a fall while skateboarding and went to the emergency room the day of the injury. He was diagnosed with a scaphoid waist fracture, placed into a thumb spica splint, and instructed to follow-up with a hand surgeon. Seven days later, he was seen and evaluated in the hand surgery clinic. Radiographs were obtained that confirmed the patient did have a scaphoid waist fracture. The injury was to the patient's dominant hand and his occupation is that of a computer programmer.

The fracture on radiographs did not appear to be displaced. At this point, the patient was counseled that, based on the literature,

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_15

a non-displaced scaphoid waist fracture can be treated with either non-operative intervention and cast immobilization or with operative intervention most commonly in the form of a percutaneous headless compression screw insertion. Very importantly, the patient was informed that in the setting of a minimally displaced fracture (<2 mm), the benefit of operative treatment is a quicker healing time, and the benefit of non-operative treatment is avoidance of surgery. The patient decided to proceed with non-operative treatment. Especially if non-operative treatment will be pursued, it is important to confirm that the fracture is not displaced >2 mm. Therefore, a CT scan in the axis of the scaphoid is necessary. A CT scan was obtained for the patient. But during this time, the patient realized the impediment that prolonged cast immobilization would cause and decided to proceed with operative intervention.

Preoperative Imaging

Surgical Plan

- Supra-clavicular nerve block with monitored anesthesia care (MAC)
- Tourniquet
- Supine position with hand table
- Fluoroscopy
- 2.0–3.5 mm headless compress screw (HCS) system with length of 18–30 mm depending on patient size

Surgical Procedure

The patient is placed supine on a standard operating table with the operative arm on a radiolucent hand table. Non-sterile tourniquet is placed around the upper arm. Depending on the arthroscopic traction tower set-up used, it can be beneficial to wrap coban around the upper arm and the hand table before prepping and draping to provide counter resistance to the traction from the finger traps. If this is done, it is very important to avoid overtightening the coban for two reasons: (1) the coban can inadvertently function as a tourniquet and (2) if overtightened, it impedes draping and placement of traction tower base under the upper arm. A mini C-arm is strongly recommended over a large C-arm. We have only used a mini C-arm for this procedure as obtaining appropriate images with a large C-arm while the wrist is in a traction tower would be exceedingly difficult. It is very important that the mini C-arm is placed at the foot of the bed to the side of the operative arm (Fig. 15.1). This allows for the C-arm to be moved parallel to the bed. The arthroscopy screen is placed next to the C-arm machine near the foot of the bed. The overall diagram of the operating room set-up is shown in Fig. 15.2.

Once the patient is prepped and draped, place the effected arm in the arthroscopic tower with 10–15 lbs of skeletal traction. Place

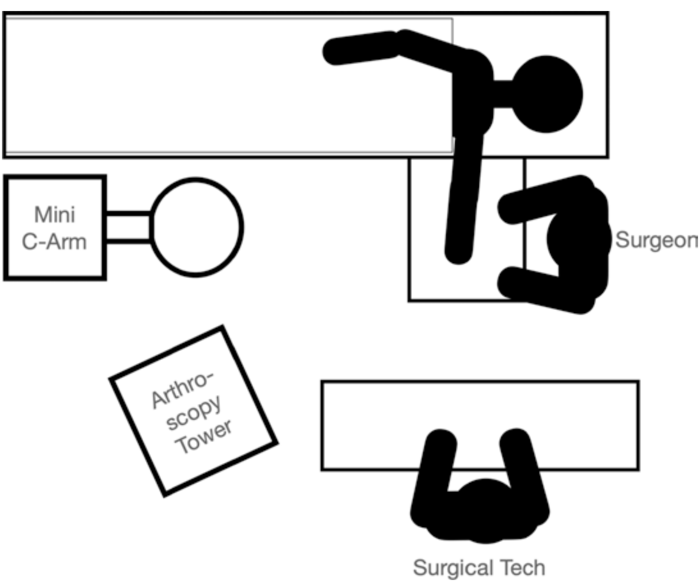

Fig. 15.1 Operating room arrangement for an arthroscopic-assisted scaphoid fracture fixation procedure

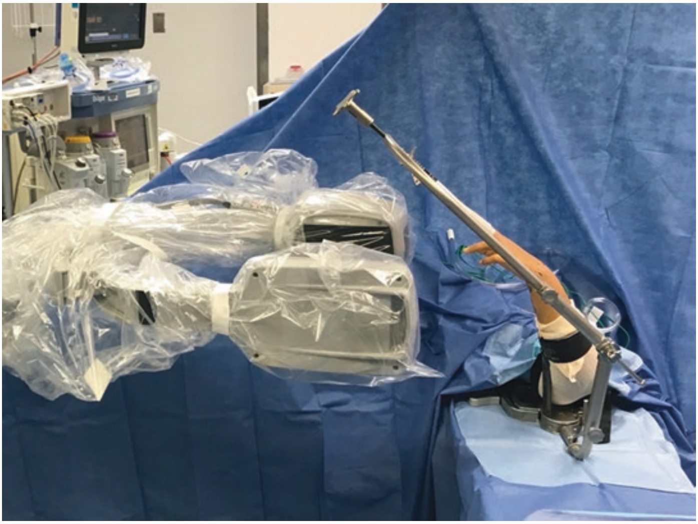

Fig. 15.2 Wrist in arthroscopic tower with wrist flexed to roughly 45 degrees. C-arm fluoroscope is coming from the foot of the bed

the wrist in 45 degrees of flexion while maintaining appropriate tractional force (Fig. 15.2).

The arthroscopic tower that is used is very important. It is essential to use one with an articulating arm that allows to hold the wrist in flexion since this will be the position of the wrist for the majority of the procedure, e.g., placement of headless compression screw(s), obtaining the majority of fluoroscopy images, and the arthroscopic portion. The primary working incision is 15 mm in length just distal to Lister's tubercle. Our recommendation is to make the incision large enough so that the proximal pole of scaphoid is easily visualized with no soft tissue interposed that can interfere with drilling and placement of a headless compression screw. Some surgeons advocate for a smaller incision and to visualize placement of K-wire as a guide wire with the arthroscope through a 4/5 portal. We do not believe that this is necessary or that it minimizes any meaningful morbidity to the patient. However, it is important that the reader knows using a 4/5 portal to visualize the starting point is an option. Next, select a guide wire from the HCS system of your choosing with typical screw diameter used ranging from 2.0 to 3.5 mm. The size of the screw selected varies on two factors: (1) the size of the patient's scaphoid and (2) if it is believed a second HCS will be needed. With the wrist flexed at 45 degrees, the proximal pole of scaphoid will now be the most dorsal aspect of scaphoid seen through the 3/4 interval incision; it will not be the most proximal portion. Aim the guidewire toward the first carpometacarpal (CMC) joint, in line with the long axis of the thumb, and advance ~5 mm such that the guidewire is sufficiently enough in bone. Move the C-arm in from the base of bed and obtain first an AP image and then a lateral (by rotating the arm 90 degrees). Note: it is important that the articulating arm of the C-arm be fully utilized to obtain the appropriate views so that the wrist in the traction tower is not needed to be manipulated. Once appropriate trajectory of the guidewire is confirmed, advance the wire across the fracture and to the far cortex of the scaphoid.

Note: It is important that the guidewire cross the fracture at as close of a perpendicular angle as possible and that the guidewire is in the central portion of the scaphoid. Deviation from this will cause for translation and/or asymmetric compression of the distal fragment relative to the proximal fragment.

MidcCarpal Arthroscopy

Once the guide wire is in and across the fracture, establish a radial midcarpal portal. This will be about ~7 mm distal to the working incision. Confirm the anatomy and determine if in the appropriate interval (scapho-capitate joint) or too distal (STT or trapezoid-capitate joints). Through the radial midcarpal portal you can view the scaphoid waist and determine the degree of fracture displacement. When there exists only a small gap, the guidewire should then be advanced (Fig. 15.3).

A de-rotational wire that crosses the fracture should be advanced as well. If the fracture gap is greater than a few millimeters and/or there is translation of the fracture, place a 0.064″/1.6 mm K-wire percutaneously both into the proximal

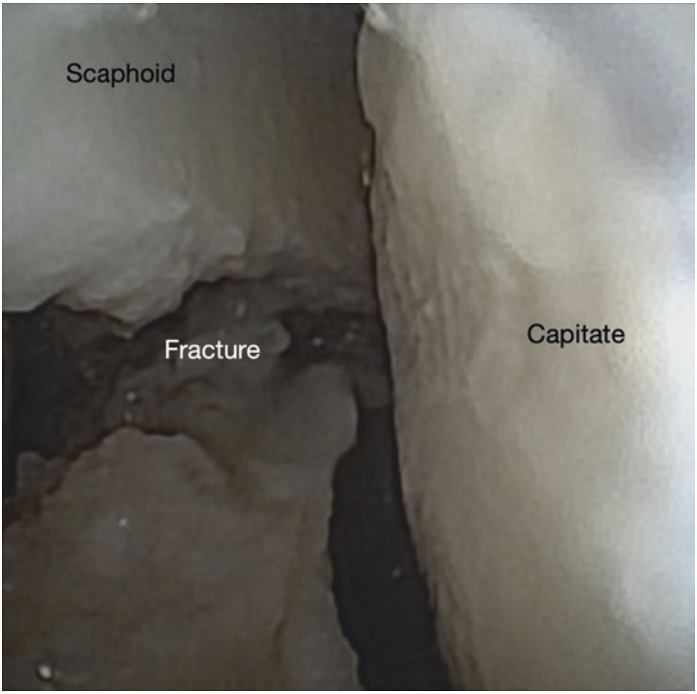

Fig. 15.3 Displaced scaphoid waist fracture before reduction and compression viewed through radial midcarpal portal

and distal fragments. Use these as joysticks to manipulate and reduce the distal fragment to the proximal fragment. This reduction can then be confirmed by the arthroscopy. Once translation, rotation, and length of scaphoid corrected, advance guidewire and de-rotational wire across the fracture to far cortex of the scaphoid. Confirm with fluoroscopy, measure, and advance the guidewire through the distal pole into the trapezium to prevent unintentional removal of the guidewire. Next, use the drill from the selected HCS system and drill through the proximal fragment into the distal fragment. Place the appropriate length screw into the scaphoid and watch the fracture through the radial midcarpal portal. If the fracture is gapping

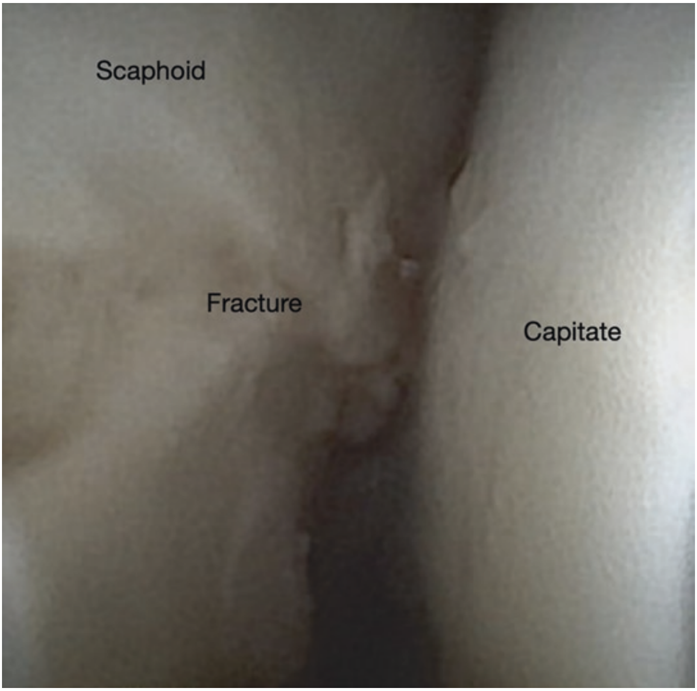

Fig. 15.4 Reduced scaphoid fracture with good compression viewed through radial midcarpal portal

with placement of the screw, there are one of two explanations for this: (1) HCS is not engaging into the distal fragment likely because of inadequate drilling or (2) the guidewire is not crossing the fracture in a perpendicular orientation at the center point of the scaphoid and thus introducing a deforming force. If the HCS is in the correct plane and appropriately engaging the distal fragment, you will be able to see excellent compression of the fracture (Figs. 15.4 and 15.5). Once the scaphoid is appropriately reduced and compression screw placed, obtain final C-arm imaging. Remove the guidewire and de-rotational wire. Irrigate the incisions. Close the working incision with 4–0 vicryl suture for the deep dermal layer and then a running 4–0

Fig. 15.5 Excellent compression and screw placement viewed via fluoroscopy

monocryl for the subcuticular layer. Remove from the traction tower and place into a small thumb spica splint.

Postoperative Protocol

The patient is to follow-up for a 2-week postoperative visit. For minimally displaced scaphoid waist fractures, if the patient is reliable one can place into a removable thumb spica splint at the first follow-up which can be removed for hygiene. For patients that are less reliable, place into a cast for a period of 4 additional weeks.

Tips and Tricks

- Confirm correct room and C-arm set-up (Fig. 15.1).
- Use a wrist arthroscopy traction tower that allows for maintenance of the wrist in 45 degrees of flexion is essential.
- Establish a radial midcarpal portal by confirming that you are viewing the capitate on the right of the screen and the scaphoid on the left.
- Make sure that your guidewire is perpendicular to the fracture plane and that it is in the center of the scaphoid.
- The use of percutaneous 1.6 mm K-wires used as joysticks is an effective means to reduce the scaphoid fracture if there is any translation or gapping >2 mm.

- Finally, when placing the HCS, watch the fracture reduction through the radial midcarpal portal to confirm appropriate compression.

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16 Capsulorrhaphy Reconstruction Technique for the Treatment of Chronic Distal Radioulnar Joint Instability

O. Alton Barron

Case Presentation of Chronic Dorsal DRUJ Instability: A 48-year-old male tripped and fell hard onto his dominant right wrist. Initial pain and swelling were moderate, leading him to present to an urgent care facility. He was told there was no fracture on X-rays and was placed into a removable wrist immobilizer. He sought no additional acute care, but he wore the splint for 4 weeks before attempting to return to normal activities and workouts. Six months post-injury, he presented with complaints of persistent pain, clicking, and a feeling of "something moving unnaturally" in his wrist. He could not lift weights or do pushups and combined gripping/twisting movements were painful.

Examination revealed no swelling on inspection, but there was a mildly asymmetric dorsal prominence of the distal ulna with the forearm pronated. There was full pronosupination with mild end-

Supplementary Information The online version of this chapter (https://doi.org/10.1007/978-3-030-74293-5_16) contains supplementary material, which is available to authorized users.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_16

range pain, normal wrist flexion, and slightly diminished wrist extension due to guarding. As is typical for cases of chronic DRUJ instability, with the elbow flexed 90 degrees and the forearm in neutral rotation, there was notably increased DRUJ translation (approximately 1.5 cm more than the normal contralateral wrist) with a load-shift maneuver. There was mild DRUJ crepitus with translation. There was pain with a dorsally directed force on the distal ulna, especially while pronated and pain with resisted pronation. These latter two findings are generally required for the author to diagnose symptomatic DRUJ instability.

Radiologic Evaluation: Plain radiographs were normal without evidence of DRUJ widening or arthritis. As is frequently the case with chronic DRUJ instability, the MRI revealed no evidence of tearing or attenuation of the dorsal or volar radioulnar ligaments, but there was partial tearing of the triangular fibrocartilage (TFC).

Surgical Timing and Equipment: Given the persistent symptoms and clinical findings consistent with DRUJ instability, the patient was eager to proceed with definitive surgical treatment. For this relatively simple soft-tissue procedure, 3–0 braided polyester or 4–0 reinforced polyester with a small tapered needle is one of the few supplies needed for fixation. In case there is an undetected avulsion of the radioulnar ligaments, it is important to have some variety of a small 2 or 2.5 mm anchor available, though this is rarely needed. A simple Freer elevator (small, flattened, and slightly curved spatula) is also needed as this allows for (1) assessment of the DRUJ cartilage integrity and (2) is placed deep to the TFC for safe placement of the TFCC mattress stich (see below). Fluoroscopy should be in the room in the unlikely event that the DRUJ needs to be pinned postoperative.

Patient Positioning and Surgical Technique: Note that if the surgeon prefers to perform adjunctive wrist arthroscopy for TFC assessment, synovectomy, etc., this is performed first before the capsulorrhaphy. If TFC repair or re-tensioning is indicated, this suture placement may be performed arthroscopically or open as described below. The capsulorrhaphy is performed with the patient supine with their arm on a hand table. A nonsterile proximal humeral tourniquet is placed after placement of a regional anesthetic block or general anesthesia. An examination under anesthesia is always performed to confirm the position of maxi-

Fig. 16.1 Curvilinear incision directly over DRUJ

mum DRUJ instability (usually neutral forearm rotation with the elbow flexed 90 degrees) and for any desired video documentation (Video 16.1).

N.B. This technique can be performed in a similar fashion for volar DRUJ instability as well. Fluoroscopy is not needed intra- or postoperatively.

A curvilinear incision is marked out directly following the underlying DRUJ curvature and centered over the fifth extensor compartment/extensor digiti quinti (EDQ) tendon sheath (Fig. 16.1). After exsanguination, and tourniquet inflation, the incision is made with a 15-blade only through the skin. A Littler or similar dissection scissor is used to clear the dorsal wrist retinacular tissue of any small vessels or sensory nerve branches. The retinaculum is carefully incised in the exact line of the skin incision and is protected for the final layered closure (Fig. 16.2). The fifth compartment is entered and opened along the length of the DRUJ up to the TFC. The EDQ tendon is protected and retracted out of harm's way. The floor of the sheath is sharply incised leaving a 2–3 mm cuff of strong insertional sheath attachment at the dorsal sigmoid notch (Fig. 16.3). Usually, there is a distinct underlying and thinner but clear capsular layer. Except in

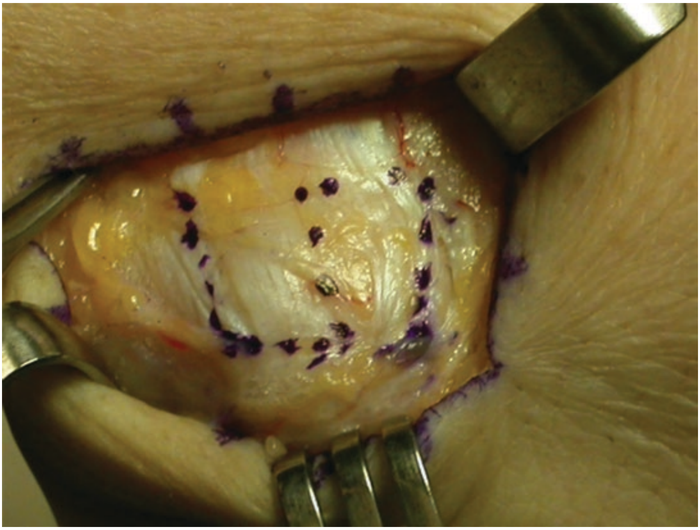

Fig. 16.2 Extensor retinaculum incisions

Fig. 16.3 Capsular incision

an acute traumatic setting, the capsule is always intact but is capacious. The excess capsular volume is assessed after reducing the ulnar head into the sigmoid notch.

The capsule is incised following the same shallow arc of the DRUJ and skin incision, leaving a cuff of capsule at the radial insertion. Care is taken to avoid damaging the cartilage of the ulnar head by inserting a Freer elevator through a small window and incising along the spatula. The joint is inspected for synovitis and loose bodies which are removed with a small rongeur. The Freer elevator is passed distally over the ulnar head but deep to the TFC. This serves as a needle backstop for outside-inside-outside TFC re-tensioning/repair mattress suture (either a 3–0 braided polyester or 4–0 reinforced polyester suture). This is not tied as yet.

Visual assessment of the capaciousness of the capsule determines whether a simple capsular imbrication which gathers approximately 3 mm of capsule when tied is sufficient. In cases of greater DRUJ laxity and abnormal translation, a narrow crescent of capsule is excised to allow additional tightening without excessive bunching of tissue. Next, a series of 3–4 mattress sutures are placed perpendicular to and spanning the DRUJ passing ulnar to radial through the capsular flap, into the flange of capsular origin at the sigmoid notch and then back ulnarward through the capsular flap. These are left untied on a small clamp (Fig. 16.4).

With the elbow flexed and the wrist in neutral rotation, the series of mattress sutures are tied from distal to proximal. Gentle pronation and supination are then performed to ensure that the capsular imbrication is not too tight. The EDQ tendon is left out of its sheath and the extensor retinaculum is closed with interrupted figure of 8 sutures, ensuring that the EDQ tendon is not pinched proximally by the closure by observing during wrist flexion and extension. After this secondarily stabilizing retinacular closure, DRUJ translation is tested with the wrist in neutral and the elbow flexed. Notable reduction in translation from preoperative is readily apparent.

The skin and the subcutaneous tissue are then closed in layers.

A sterile gauze dressing is followed by tourniquet deflation and placement of a short arm plaster cast that is as long as possible

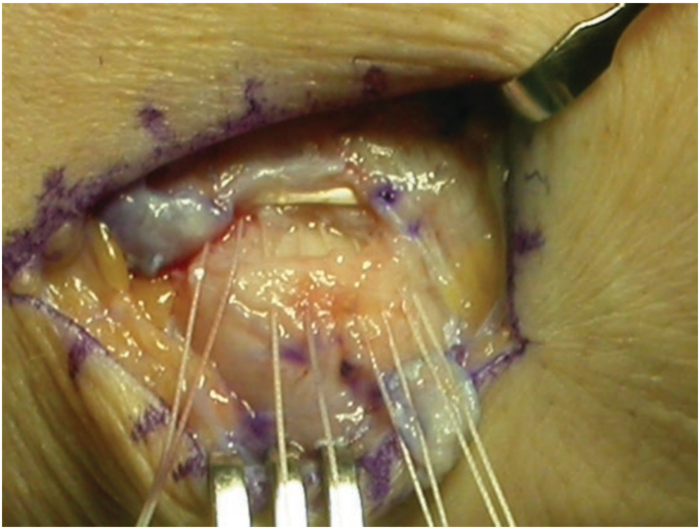

Fig. 16.4 Mattress sutures in place

proximally without compromising elbow flexion. Care is taken to achieve a good interosseous forearm mold of the cast. This allows for only about 20 degrees each of pronation and supination, well within the motion arc that the new capsulorrhaphy can tolerate without untoward effects (Video 16.2).

Postoperative Protocol: Patients are instructed to avoid trying to force pronation or supination with the short arm cast in place. The first office follow-up is at 3 weeks at which time the cast is removed, the wound inspected, the stability of the DRUJ confirmed with gentle translation, and a new also well-molded fiberglass cast is placed for an additional 2–3 weeks.

Rehabilitation begins at 6 weeks with grip strengthening and passive and active wrist motion. Forceful use such as lifting or arm-based sports are *not* allowed for an additional 4–6 weeks, at which time (3 months) progressive unlimited use is allowed.

Tips and Tricks

1. DRUJ instability is relatively common, especially following displaced distal radius fractures, and is often only identified as a late sequela.
2. Many patients with DRUJ instability can be treated with education and activity modifications, rather than surgery.
3. Careful physical exam with the elbow flexed and the wrist in neutral rotation will readily identify the excess dorsal and/or volar translation and confirm the diagnosis.
4. The simple technique can be coupled with arthroscopic synovectomy and TFCC repair, but this is surgeon's choice.
5. DRUJ capsulorrhaphy is a simple, anatomic reconstruction with straightforward postoperative rehabilitation and high patient satisfaction.

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17 Fractures of the Wrist – Scaphoid Fracture: Waist

David W. Zeltser and Lauren Shapiro

Case Presentation

Dorsal Approach Case

A 25-year-old right-handed retail salesman fell while riding a mountain bike, landing on his outstretched hand. X-rays revealed a scaphoid waist fracture when he presented to the emergency department (ED) 4 days later. He was immobilized in a thumb spica splint. A CT scan showed a minimally displaced scaphoid waist fracture (Fig. 17.1). After a discussion of the risks and benefits of operative and nonoperative management, he chose nonsurgical treatment with a short arm thumb spica cast. However, after 2 weeks, he requested surgical treatment.

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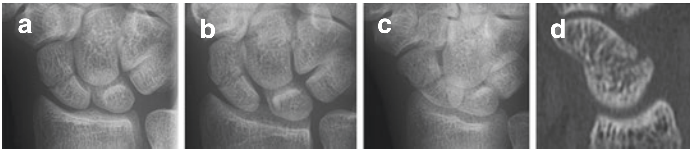

Fig. 17.1 Preoperative imaging demonstrates a minimally displaced scaphoid waist fracture. PA, scaphoid view, and oblique X-rays (**a**–**c**) and a sagittal CT scan (**d**)

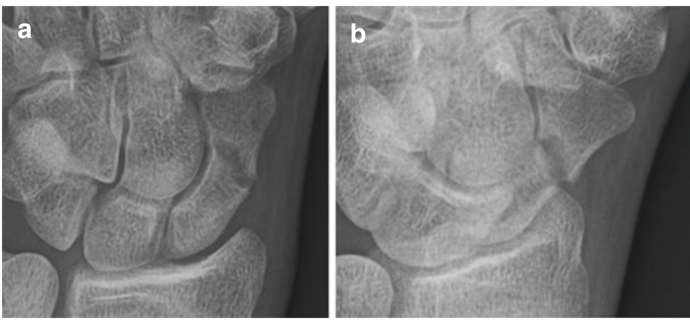

Fig. 17.2 Preoperative imaging demonstrates a minimally displaced scaphoid waist fracture. Scaphoid view (**a**) and oblique X-rays (**b**)

Volar Approach Case

A 20-year-old right-handed male college student fell onto an outstretched hand while playing football but did not seek medical attention. Due to persistent wrist pain for 6 weeks, he presented to his primary care provider who obtained X-rays showing a scaphoid waist fracture (Fig. 17.2). A CT scan (not shown) confirmed mild displacement. He was a nonsmoker and active in swimming and water polo. He elected for surgical treatment.

History, Examination, Initial Management

The mechanism of injury may inform the surgeon as to the degree of energy imparted to the wrist. A high-energy injury may suggest a more unstable scaphoid fracture or a more complex injury, such as a perilunate fracture-dislocation. Up to 16% of patients with a scaphoid fracture will have negative initial X-rays [1]. Therefore, patients who present with scaphoid tenderness after an appropriate injury mechanism but have normal radiographs should be managed as having an occult nondisplaced scaphoid fracture. The wrist is immobilized (with or without the thumb spica component) and the patient is re-examined clinically and radiographically after 2–3 weeks.

Radiographs/CT

In addition to PA, lateral, and oblique radiographs of the wrist, a scaphoid view (wrist ulnar deviation and extension) is helpful. If X-rays are negative, but a nondisplaced fracture is suspected, MRI is an option due to its high sensitivity and specificity for the detection of an occult fracture [2].

Compared to plain radiographs, CT provides a more reliable assessment of displacement. Additionally, CT is useful for preoperative planning as it imparts valuable information about fracture morphology, especially when obtained in the plane of the scaphoid. Sagittal plane reformats show the degree of scaphoid waist flexion (humpback deformity). The lunate may assume an extended posture (dorsal intercalated segment instability) in association with a displaced scaphoid fracture.

Surgical Timing/Planning Including Equipment

Surgical fixation of most isolated scaphoid fractures can be performed days or even several weeks after injury if properly immobilized. Preoperative planning requires careful evaluation of the fracture line's orientation [3, 4] and relative position, proximal or distal. Technical goals of screw placement include central placement, placement perpendicular to the fracture plane, adequate screw fixation proximal and distal to the fracture, and maximal screw length [3]. When the fracture line is oblique to the longitudinal axis of the scaphoid, there will be a conflict between the goals of maximizing screw length and maximizing perpendicularity to the fracture plane. In these situations, one may choose a shorter screw perpendicular to the fracture or compromise between these two extremes and still achieve good compression [3].

For proximal-waist fractures, antegrade (dorsal approach) screw placement facilitates adequate fixation of the proximal fragment. For distal-waist fractures, a retrograde (volar approach) screw may be preferable [4]. The dorsal approach more reliably allows one to place a screw in the central axis and thus a longer screw.

The volar approach requires one to choose a starting point volar and radial to the ideal starting point, remove the volar lip of the trapezium, or use a trans-trapezial approach. The volar approach has the advantage of positioning the wrist in extension which helps to reduce the typical flexion deformity of the scaphoid.

When a fracture is comminuted, displaced, subacute, or relatively distal, we are more likely to choose a volar approach.

What you need in the OR:

- Implant set: cannulated, headless compression screws (2.5–4 mm diameter). Screw design can be fully threaded or centrally smooth. Generally, the authors use a screw diameter of approximately 3.5 mm.
- Multiple screw lengths available, ranging from 16 to 26 mm.
- K-wires (0.35, 0.45, 0.62 in) and power drill.
- Basic hand set.
- Small bone reduction clamps.
- Small towel bump for wrist positioning.
- Mini C-arm.

Surgical Tact: Positioning, Approach, Fixation Technique

Regional anesthesia with variable degrees of sedation are used. The patient is positioned supine with the extremity on a hand table and a nonsterile tourniquet on the arm.

Dorsal Approach Case

The forearm is pronated and the wrist is positioned in flexion over a small towel bump. A 1–2 cm longitudinal incision is made just ulnar to the Lister tubercle at the level of the proximal carpal row. We partially release the extensor pollicis longus (EPL) tendon from its distal sheath and retract it radially. The dorsal wrist capsule is palpated and a longitudinal capsulotomy is made in line with the incision taking care to avoid injury to articular cartilage and the dorsal band of the SLIL. Maximal wrist flexion exposes the proximal pole and the proper starting point which is just radial to the SLIL.

If the reduction is unacceptable, joystick K-wires can be placed in the proximal and distal poles percutaneously or through the dorsal exposure. Alternatively, a bone reduction clamp can be applied strategically while avoiding the starting point. If needed, the dorsal approach can be extended distally in a straight longitudinal fashion or curved radially to better expose the scaphoid. Care should be taken to avoid damage to the scaphoid's arterial supply at the dorsal ridge.

The guide wire is advanced on power down the center of the scaphoid, using the palpable thumb CMC joint to estimate the proper trajectory. Guide wire position is checked with mini C-arm. If the first wire is not ideally positioned, we will reinsert it or place a second wire, using the first wire as a reference. To prevent malrotation of the fracture during drilling and screw insertion, we often use a temporary anti-rotation wire which can either be an errant guide wire or a second wire placed across the fracture or the scaphocapitate joint.

Because guide wire (and screw) position is one of the most important technical aspects of the procedure, we perform a thorough fluoroscopic assessment at each step. We find that multiple views are necessary and useful: (1) the pronated lateral (pronated oblique) profiles the proximal pole at the radiocarpal joint; (2) the hypersupinated AP shows the ulnar aspect of the scaphoid at the scaphocapitate articulation; and (3) the supinated lateral demonstrates overall fracture alignment and screw position within the longitudinal axis of the scaphoid [1].

Once the guide wire is properly positioned, it is advanced to the level of the distal pole cortex. To measure screw length, we either use the screw system's measuring device or we subtract the exposed guide wire length from a free guide wire. Then, we subtract 4–6 mm from the measured length in order to avoid hardware prominence.

Prior to drilling, the guide wire can be advanced into the trapezium or out the volar skin and clamped with a hemostat to avoid dislodgement during drilling. We monitor drill depth with the mini C-arm. The chosen screw is manually inserted over the guide wire until the trailing threads are fully seated beneath subchondral bone. Depending on the thickness of proximal pole cartilage, the screw may appear slightly prominent on fluoroscopy.

Volar Approach Case

For the volar approach, the forearm is supinated and the wrist is extended over a towel bump. We identify the starting point using fluoroscopy. Wrist extension helps to expose the distal pole of the scaphoid by sliding the trapezium dorsally. The starting point is as far dorsal as possible (immediately volar to the trapezium) and just radial to the center of the scaphoid tubercle. After making a 1 cm oblique (along scaphoid axis) incision, we spread bluntly and make a scaphotrapezial capsulotomy.

For an acute, mildly displaced fracture, reduction may be obtained with wrist extension alone. The subsequent steps are similar to the dorsal approach. In this instance, the guide wire can be driven into the distal radius to avoid dislodgement, but care should be taken to avoid wrist motion and wire breakage.

If reduction is not acceptable, similar techniques as described before are used. We extend the incision proximally along the flexor carpi radialis (FCR) tendon sheath, incise the sheath, and retract the tendon ulnarly. The volar branch of the radial artery can be either preserved or coagulated and divided. The important radioscaphocapitate ligament is incised longitudinally to gain access to the scaphoid and must be repaired at the conclusion.

During the capsulotomy, care is taken to avoid injury to the articular cartilage. Although this approach is more often used for scaphoid nonunions with humpback deformity, it can be used in select acute or subacute fractures. The volar approach requires wrist extension which is helpful to resist the typical flexion deformity. Additionally, the dorsal blood supply is relatively protected during dissection.

Postoperative Protocol

We place a short arm thumb spica splint initially and convert to a removable wrist brace after 2 weeks. We allow brace removal for hygiene and gentle range of motion exercises. We refer to hand therapy on an individual basis.

Weightbearing is avoided for at least 8 weeks based on healing. Follow-up wrist X-rays are obtained at 2 weeks, 6 weeks, 3 months, and 6 months postoperatively. If there is radiographic healing and no tenderness at the snuffbox 6 weeks postoperatively, the authors gradually increase activity.

If there is concern about healing, the authors consider a CT scan at about 10–12 weeks and allow increased activity if we see bridging trabecular bone crossing 50% or more of the fracture site.

Follow-Up with Radiographs

Dorsal Approach Case

The patient proceeded to heal his fracture uneventfully. X-rays taken 4 months postoperatively are displayed in Fig. 17.3.

Volar Approach Case

The patient similarly went on to heal his fracture uneventfully. X-rays taken 6 months postoperatively are displayed in Fig. 17.4.

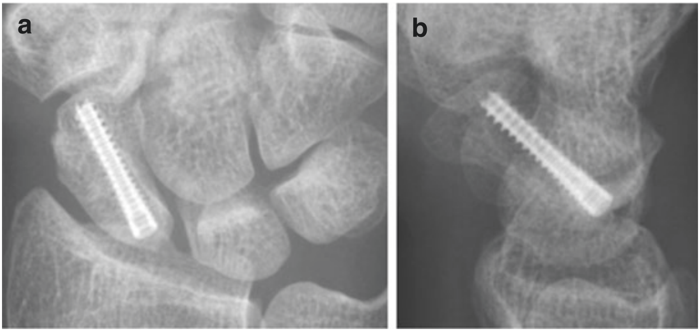

Fig. 17.3 PA (**a**) and lateral (**b**) X-rays taken 4 months postoperatively demonstrate bony union

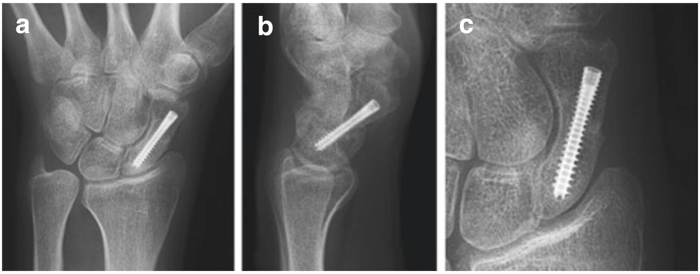

Fig. 17.4 PA (**a**), lateral (**b**), and scaphoid (**c**) view X-rays demonstrate bony union 6 months postoperatively

Tips and Tricks

1. A CT scan is helpful in characterizing fracture displacement and obliquity.
2. An anti-rotation K-wire or joystick technique resists malrotation during screw placement.
3. Avoid a long, prominent screw by subtracting 4–6 mm from the measured length. Fracture site compression, the curvature of the proximal pole, and cartilage thickness may result in a screw that is too long.

4. Most scaphoid waist fractures can be treated with a volar or dorsal approach. The dorsal approach allows for more central screw placement but requires wrist flexion (which may displace an unstable fracture) and protection of the extensor tendons. The volar approach is performed with the wrist extended and without significant risk to tendons, but screw placement in the central axis is limited by the trapezium.
5. The scaphoid is shaped like a twisted peanut. It is important to understand and use multiple fluoroscopic views to ensure safe positioning of the guide wire and screw. Limit the number of guide wire attempts to avoid falling into old paths and resultant frustration.

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18 Surgical Treatment of Scaphoid Non-Union

Ajul Shah and James E. Clune

History

An 18-year-old healthy right-hand-dominant male presented for evaluation of chronic right wrist pain. The patient sustained a right wrist injury when playing sports 18 months prior to presentation. The patient noted that he was diagnosed with a wrist "strain" at the time of the accident at an outside hospital, and initial X-rays were negative. He was immobilized in a removable brace, which he used for approximately 2 weeks, and did not seek follow-up. The pain returned and he presented for further evaluation. He stated that his ability to participate in work and sports were limited due to pain and discomfort, worsening over the past few months.

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https://doi.org/10.1007/978-3-030-74293-5_18

Exam

On exam there was pain with radial deviation of the wrist, and he had pain with palpation of the snuffbox. He did not have pain with passive wrist extension and flexion but noted pain with pressure applied to the wrist in extension. The wrist was stable on a shuck test and he had no DRUJ instability. On examination maneuvers that required grip or lifting, the patient described consistent pain in the area of the snuffbox.

Preoperative Imaging

On X-ray, he had a fracture of the proximal pole of the scaphoid without a humpback deformity (Fig. 18.1). MRI further demonstrated avascular necrosis of the proximal pole (Fig. 18.2).

Fig. 18.1 Scaphoid fracture 18 months after injury

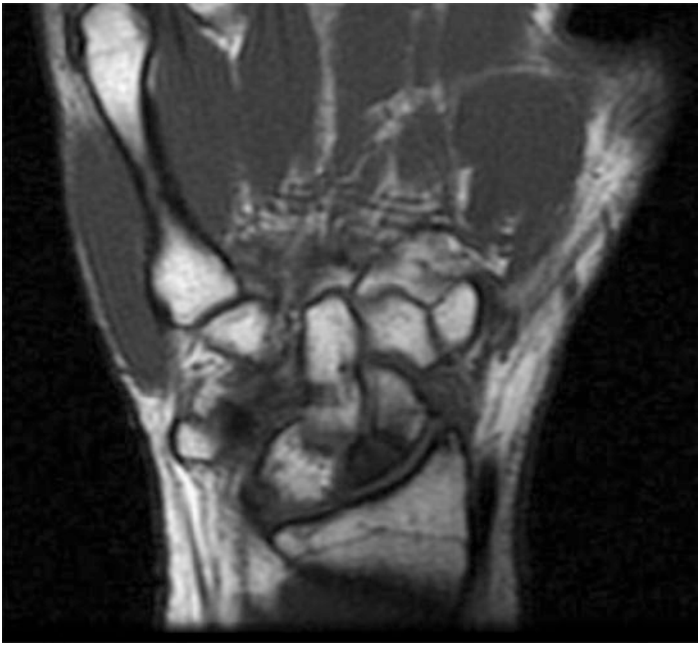

Fig. 18.2 MRI with avascular necrosis of proximal pole

Indications

The patient was diagnosed with a painful proximal pole non-union of the scaphoid. At this point, operative intervention with a vascularized graft was indicated given the potential non-viability of the proximal pole.

Surgical Approach

The approach utilized is similar to those previously described [1, 2]. Under a peripheral nerve block, the scaphoid and radius are exposed with a single dorsal incision. The incision is carried out ulnar to Lister's tubercle at the wrist and following the proposed pathway of the scaphoid. Careful dissection was used to expose the first, second, and third extensor compartments. The interval between the first and second extensor compartments was developed and the pedicle to the bone flap was identified. Prior to harvest of the bone flap, capsular incision was made and the scaphoid non-union was identified. The fibrous tissue is aggressively debrided at the fracture site. To assess the viability of the proximal pole, the tourniquet was released and some punctate bleeding was identified. Laminar spreader was used to further expose the fracture site. Once the scaphoid fracture was adequately exposed and debrided, a K-wire was used to maintain the fracture gap with the distal pole of scaphoid pinned to the capitate. The resultant space created by the removal of non-viable tissue is measured and will be used to ensure appropriate graft measurements.

Attention was then paid to the bone flap harvest. Markings were made on the proposed bone flap harvest site to match the defect. K-wires were then used to gently perforate the cortex in the area of the harvest. The proximal portion of the pedicle was identified and ligated. Small osteotome was then used to harvest the graft, protecting both the pedicle and the articular surface of the radius. The graft is then carefully elevated from its origin en bloc with the overlying periosteum and pedicle.

A long pedicle can be attained from this flap allowing for a tension-free placement of the graft. The graft is then placed into the defect and secured using a center-center guide wire. The previously placed stabilizing wire is removed and a cannulated screw is used to secure the graft and compress the scaphoid to the graft. Anterograde placement is preferred as the dorsal exposure has already been performed and allows access to the starting point at the proximal pole. Additional non-vascularized cancellous graft is then harvested to augment the reconstruction. After the flap is fixated, care is taken to tightly close the capsule.

Postoperative Protocol

The incision is closed with resorbable sutures (Monocryl 4–0) and skin glue covered with Telfa™ and a light wrap and volar splint in slight extension. Finger range of motion exercises commence immediately. The wrist is immobilized for 2 months and if appropriate healing is noted on subsequent imaging, then wrist range of motion commences. If there is any concern for delayed healing, a CT scan is obtained.

Postoperative Imaging

One month after surgery, the radiograph demonstrates a centrally located anterograde screw. The graft is seen bridging the gap between the two segments though not yet mineralized (Fig. 18.3). Images 6 months after surgery demonstrate a healing graft that has maintained the length of the scaphoid without evidence of collapse (Fig. 18.4). At 1 year, the graft remains viable and incorporated into the scaphoid with some sclerosis still visible (Fig. 18.5).

Fig. 18.3 One month postoperative

Fig. 18.4 Six months postoperative

Tips and Tricks [3–5]

- Care should be taken when performing the initial approach to the pedicle in order to protect the radial sensory nerves – the 1,2 ICSRA may send small perforating vessels to the skin and nerve branches and should be gently coagulated.
- A narrow strip of extensor retinaculum on either side of the pedicle should be preserved in order to protect the pedicle from injury.
- A radial styloidectomy can be performed in order assist in preparing the non-union site, but it is not needed in every case.
- The scaphoid must be aggressively prepared and free of any non-viable bone in order for the flap to heal appropriately – a combination of rongeurs, curettes, burrs, osteotomes, and laminar spreaders are used to achieve this purpose.

Fig. 18.5 One year postoperative

- Scaphoid waist non-unions often assume a flexed "hump back" position – the initial reduction must correct this deformity. Once the distal pole of the scaphoid is taken out of flexion, it can be temporarily fixated with a K-wire from the distal pole of the scaphoid to the capitate.
- The vascularity of the proximal pole cannot be definitely assessed with preoperative imaging; intraoperative assessment of bleeding bone is paramount
- Flap harvest through perforation of the cortex with K-wires and subsequent gentle osteotomes may be safer than the use of a high-speed saw.
- The use of a compression screw provides greater stability than the use of K-wires alone; however, meticulous technique

during placement of this screw is necessary to prevent "blowout" of the bone flap.

- The flap must be fully seated and temporarily fixated with the center-center guidewire.
- Hand drill is preferred to power drill during initial drilling and gentle application of the screw is needed to prevent destruction of the flap.

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19 Scaphoid *Chronic* Non-Union: Vascularized Bone Grafting

Patrick L. Reavey
and Jacques Henri Hacquebord

Case Presentation/History/Examination/Initial Management in ED/Office

A 20 year-old-male sustained a wrist injury while snowboarding 6 months before. He had continued radial wrist pain and presented for evaluation. On plain radiograph imaging, he was found to have a waist scaphoid fracture non-union with a humpback deformity. A CT was obtained to determine the amount of bone loss and assist with preoperative planning (Fig. 19.1).

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_19

Fig. 19.1 Sagittal cut of CT scan showing scaphoid non-union with collapse and humpback deformity

Radiographs/CT

In addition to standard radiographs of the wrist, CT and/or MRI can be useful for evaluation of scaphoid non-unions. MRI is better for determining the vascularity of the proximal pole; however, CT scan is more useful for evaluating the cortical deformity of the scaphoid and estimating the size of the required bone graft. In recalcitrant non-unions (or primary non-unions with evidence of poor proximal sclerosis), the author's preference is to plan on using a vascularized bone graft and limit advanced imaging to a CT scan.

Surgical Timing/Planning Including Equipment

Surgery can proceed at any time after the diagnosis. Other than the scaphoid fixation hardware of the surgeon's choice, minimal additional equipment is required. A sagittal saw with a 5 mm blade and 5 mm curved osteotome facilitate harvesting of the bone graft. The single-site incision allows for coordination of regional anesthesia for the surgery.

Surgical Tact: Position, Approach, Fixation Technique

The patient is left supine with the operative hand placed onto a hand table. A pneumatic tourniquet is placed on the upper arm, and the arm is sterilely prepped and draped to the elbow.

The arm is elevated for minimal exsanguination, which aids in the identification and dissection of the volar carpal artery, and the tourniquet is inflated. An extended volar approach to the scaphoid is made over the FCR tendon with radial extension toward the trapezium at the wrist flexion crease. Dissection to the scaphoid proceeds as usual on the radial side of the FCR tendon, making sure to stay distal to the volar rim of the distal radius. Proximal to the volar rim of the radius, the dissection proceeds on the ulnar side of the FCR to avoid injury to the volar carpal artery. The wrist capsule, distal radius, and pronator quadratus are then identified. The volar carpal artery can be identified on the periosteum of radius just distal to the pronator quadratus [3–5].

A radially based triangular flap is then made in the volar capsule to expose the scaphoid, making sure to protect the volar carpal artery as the capsulotomy is extended proximally.

The scaphoid non-union is then debrided, and 0.045″ K-wires are placed into the proximal and distal poles as joy-sticks. The humpback deformity is corrected and the size of the necessary bone graft is determined (Fig. 19.2). The bone graft is then planned from the ulnar epiphysis of the distal radius at the end of

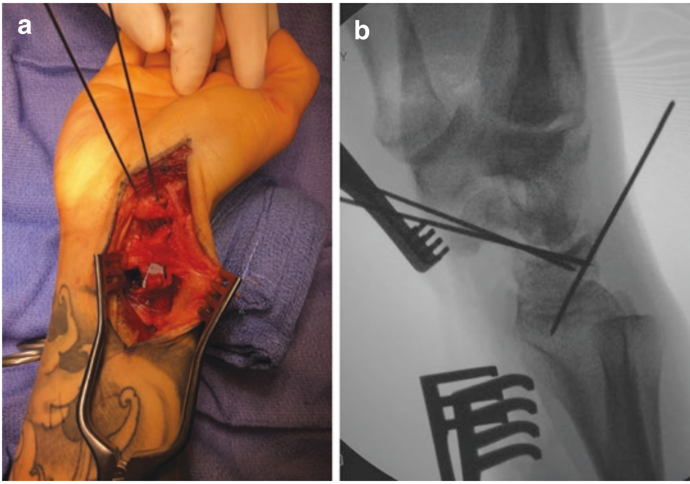

Fig. 19.2 (**a**) Intraoperative picture showing: (1) the defect in the scaphoid waist and (2) bone flap harvested from the distal ulnar corner of volar radius as indicated by the blue background. (**b**) Fluoroscopy image showing the defect in the scaphoid waist. Note the K-wire dorsally through the lunate into the dorsal distal radius to maintain proper carpal alignment and the two K-wires through the scaphoid to correct the scaphoid humpback deformity

the volar carpal artery. The proximal-distal and radio-ulnar dimensions of the graft will be the same as the defect in the scaphoid. The periosteum is then incised along either side of the volar carpal artery, leaving a 1 cm wide cuff. The periosteum under the pedicle is then gently elevated up to the radial border of the graft. A sagittal saw is then used to cut the distal radius cortex on the ulnar, proximal, and distal borders of the graft. An osteotome is used to make the radial osteotomy. A curved osteotomy is then used with the tip curving away from the graft to harvest a cortico-cancellous graft. Once the graft is free, the pedicle can be additionally dissected toward the radial artery until it will adequately reach the scaphoid.

The graft is then placed into the scaphoid (Fig. 19.3). Any fixation can be selected. If placing cannulated headless compression

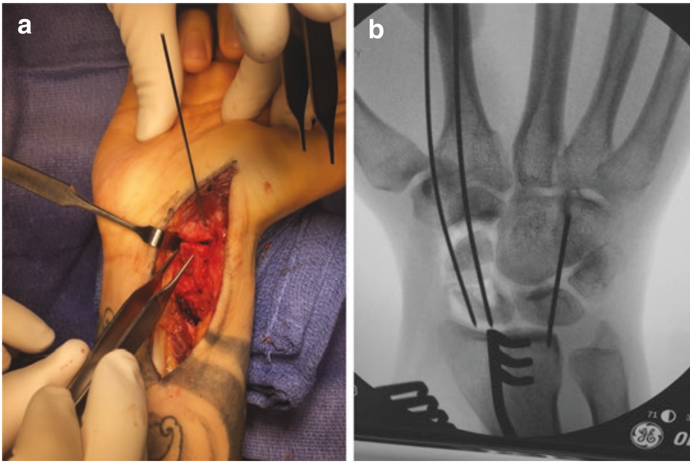

Fig. 19.3 (**a**) Intraoperative picture showing the bone flap inserted loosely into the defect of the scaphoid waist defect. (**b**) Fluoroscopy image showing the inserted bone flap into scaphoid waist defect

screws, it is recommended to place two K-wires across the fracture and graft – one down the central axis of the scaphoid and an additional off axis K-wire to help hold the graft in place during screw placement. If there is concern about adequate capture of the graft with the screw, then the additional pin can be left in place to be removed at 1 month.

A volar scaphoid locking plate, as used in this case, offers the advantage of buttressing the graft in place without having to capture it directly with a screw (Fig. 19.4). Additionally, the plate obviates the need to place a central axis screw, which can be difficult in secondary non-unions.

After fixation of the scaphoid, the volar capsule is closed with 4-O absorbable sutures. The triangular capsular flap can be slid in a V-Y fashion as needed to lengthen the capsular closure and avoid tight closure over the pedicle.

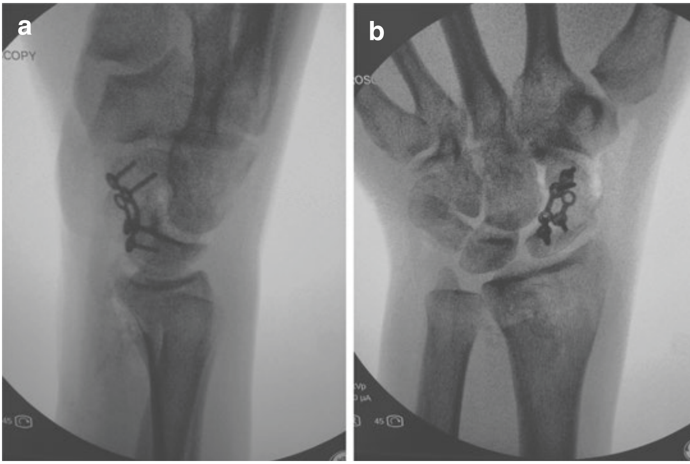

Fig. 19.4 (**a**, **b**) Intraoperative fluoroscopy images showing placement of the volar scaphoid plate maintaining reduction of the scaphoid and bone flap insertion

Postoperative Protocol

Patients are placed into a short arm splint at the end of the case. They are seen back in the office at 2 weeks and changed to a short arm cast. This is changed for hygiene every 4–6 weeks. A CT scan of the wrist is obtained by 3 months to assess for healing (Fig. 19.5). If there is evidence of bridging bone, the patient is changed to a removable brace. If there is not, then the patient is placed back in to a cast with repeat imaging obtained at 4.5 months.

Follow-Up with Radiographs/ Pictures if Any

Follow-up radiographs of the case demonstrate a healed fracture at 3 months.

Fig. 19.5 Sagittal cut of CT scan 6 weeks postoperative showing well-healed and incorporated bone flap into the previous non-union site

Tips and Tricks (5 Salient Points)

1. Keep distal dissection on the scaphoid radial to FCR tendon and distal to the volar rim of the radius. Proximal dissection for the bone graft then shifts to the ulnar aspect of the FCR tendon to safely identify the distal portion of the pedicle.
2. Pulling the contents of the carpal tunnel radially can make the ulnar osteotomy easier. Using a curved osteotome can make harvesting a good cortico-cancelous graft easier.

3. Take a wide swath of periosteum and tissue around the pedicle.
4. Avoid a tight closure of the volar capsule over the pedicle – this is aided by planning the triangular capsular flap as opposed to a straight-line incision.
5. Any fixation technique can be used. If any concern about capture of the graft, additional K-wires can be left in place to be removed at 1 month.

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20 Scapholunate Dissociation: Dorsal Capsulodesis/ Primary Repair

Natalie Hibshman and J. Bradford Hill

Case Presentation: History, Examination, and Initial Management

This patient was a healthy, 25-year-old male athlete without significant past medical history who sustained injury to the left wrist during his football season. The patient was casted initially for 12 weeks and he continued play during this time. He presented for evaluation after 4 months of persistent wrist discomfort and limited motion.

On physical exam, he endorsed mild tenderness over the anatomical snuff box. On scaphoid shift maneuver, there was crepitus and tenderness [1]. Palpation at the ulnar fovea also elicited tenderness. His range of motion was 50 degrees of flexion and 60 degrees of extension. There was no instability of his distal radial ulnar joint (DRUJ) noted.

Imaging

Radiographic anterior-posterior and lateral images were obtained (Fig. 20.1). Subsequent MRI evaluation showed a central triangular fibrocartilage complex (TFCC) tear with possible scapholu-

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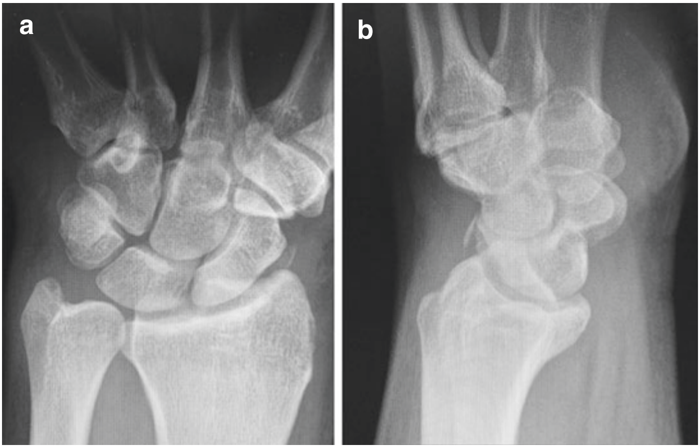

Fig. 20.1 Preoperative radiographic imaging of patient's left wrist; anterior-posterior (**a**) and lateral (**b**) views

nate ligament tear. Arthroscopy was planned to confirm the diagnosis [1].

Surgical Planning

Operative evaluation was deemed necessary, and the patient was scheduled for the procedure as an outpatient. Equipment—including small joint arthroscopy with appropriate camera and lighting equipment, mini C-arm, suture anchors, nitinol staples, and hand/wrist instrument trays—were requested.

Surgical Tact

The patient underwent general anesthesia before being positioned supine with his left upper extremity abducted to rest on a hand table. The patient was prepped and draped accordingly with a tourniquet in place.

On arthroscopy, we established standard 3–4, 4–5, and 6 U portals. The 2.7 mm arthroscope was easily driven into the membranous, central portion of the scapholunate interval, consistent with a Geissler stage IV complete SLIL tear [2]. Significant synovitis was noted and loose bodies were observed in the radiocarpal joint. Intraoperative fluoroscopy revealed dorsal intercalated segment instability (DISI) of the lunate as well. We proceeded with open exploration and reconstruction for the TFCC and SLIL tears.

There were traumatic osteochondral defects noted in the proximal surface of the lunate. The lunate facet of the radius and the midcarpal articular surfaces appeared healthy. There was a small central perforation of the TFCC and surrounding synovitis was debrided.

The wrist was opened in a dorsal approach and the capsule exposed with a radially based capsular sparing fashion, splitting the DIC ligament (Fig. 20.2a). A one-centimeter portion of the posterior interosseus nerve was removed at the floor of the fourth extensor compartment to aid with pain relief and recovery.

Kirshner wires were placed as joysticks to reduce the scapholunate interval (Fig. 20.2b) [1]. The region between the scaphoid and the lunate was gently decorticated with a curette to facilitate fibrous union. The scaphoid and the lunate were then held in association with a nitinol staple (Fig. 20.2c). Note the maintained crossing of the reduction wires after staple placement, demonstrating tight reduction and association without assistance of a clamp. A suture anchor was placed in the lunate and used to repair the avulsed SLIL remnant which maintained its scaphoid attachment (Fig. 20.3a).

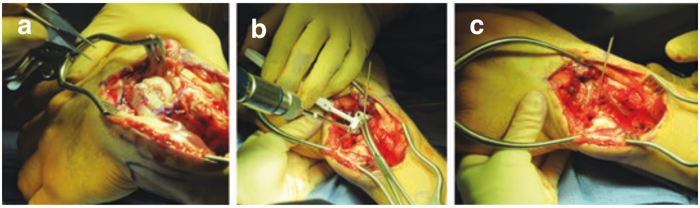

Fig. 20.2 Intraoperative photographs depicting dorsal approach (**a**), Kirshner wire placement (**b**), and nitinol staple association (**c**)

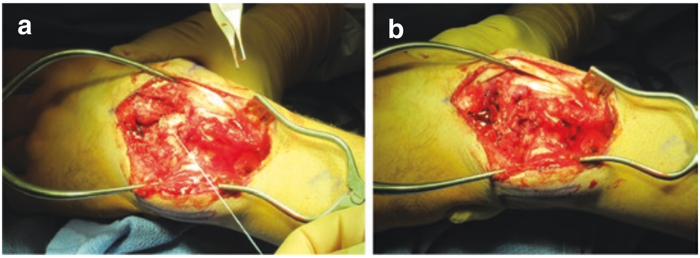

Fig. 20.3 Intraoperative photographs depicting suture anchor placement (**a**) and DIC capsulodesis (**b**)

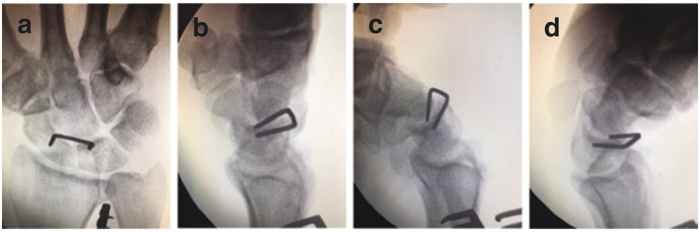

Fig. 20.4 Intraoperative fluoroscopy posterior-anterior (**a**) and lateral (**b**) views depicting maintained association in flexion (**c**) and extension (**d**)

The ends of the anchor were tied over the capsule for a DIC capsulodesis (Fig. 20.3b) [1, 3, 4]. A nylon suture was secured to the staple and long tail buried, through the capsule into the subcutaneous plane to aid future limited exposure and retrieval.

Intraoperative fluoroscopy showed reduction and association were maintained and persisted through passive motion (Fig. 20.4). Importantly, the staple was confirmed to not abut the dorsal lip of the radius in wrist extension.

Postoperative Protocol

Postoperatively, the extremity was dressed and placed in a resting volar splint. He was scheduled for follow-up in 1 week. He underwent 3 weeks full-time splinting in a Muenster splint, followed by an additional 3 weeks in a short arm cast. Gentle active motion was permitted from 6 to 12 weeks, and at 12 weeks he underwent hardware removal with subsequent release to activity without precautions.

Follow-Up with Imaging

Postoperative radiography showed maintained scapholunate association (Fig. 20.5). The patient reported improved subjective pain level and had made progress with physical therapy. At his 3-month follow-up, he underwent manipulation under anesthesia and staple removal. At his 6-month follow-up, while he had not returned to play due to knee injury, he endorsed low-grade dorsal radial wrist pain with heavy use in practice. Imaging continued to demonstrate maintained scapholunate association. He was given a steroid Injection into the radiocarpal joint. His active wrist motion was 45 degrees of flexion and 55 degrees of extension. He maintained full, painless forearm rotation.

Fig. 20.5 Postoperative imaging of patient's left wrist; anterior-posterior (**a**) and lateral (**b**) views

Tips and Tricks

1. Arthroscopy is a helpful modality for the evaluation and confirmation of SLIL injury.
2. Consider augmenting scapholunate association with a headless screw or nitinol staple across the scapholunate interval rather than buried K-wires. These can be removed in a delayed fashion.
3. A dorsal capsulodesis aids in controlling the unopposed flexion of the scaphoid in SLIL disruption, often used when primary repair is unachievable, but a DIC capsulodesis may be helpful to augment stability even after ligament repair [1].
4. Patients should be counseled of risk for loss of motion, persistence of pain, and long-term degenerative arthritis, following any repair or reconstructive modality [1, 3, 4].
5. Clinical judgment: while there is no consensus single procedure to restore scapholunate association after injury, multiple techniques can be combined synergistically [3, 4]. The goal is to approximate the function of the SL ligament by achieving coordinated motion and association between the scaphoid and the lunate.

Acknowledgment Dr. Kenneth Means of the Curtis National Hand Center (Baltimore, MD) for permission to use the case and photographs

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21 Radiocarpal Dislocation: ORIF

Christopher J. Dy and Andrew J. Landau

Case Presentation

History A 32-year-old woman fell off a running horse. She complains of severe pain in her right wrist as well as tingling and shooting pain in her thumb, index, and middle finger.

Physical Exam The patient's right wrist is swollen and ecchymotic with obvious deformity. She has a small poke hole wound along the volar/ulnar aspect of the distal forearm. The skin is otherwise intact. Her forearm compartments are soft. There is a step-off deformity of the distal forearm just proximal to the wrist dorsally, with edema and exquisite tenderness to palpation over the radial aspect of the wrist. Passive and active range of motion of the wrist are minimal due to pain. Her hand is warm with a palpable radial pulse, but she has elevated static two-point dis-

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_21

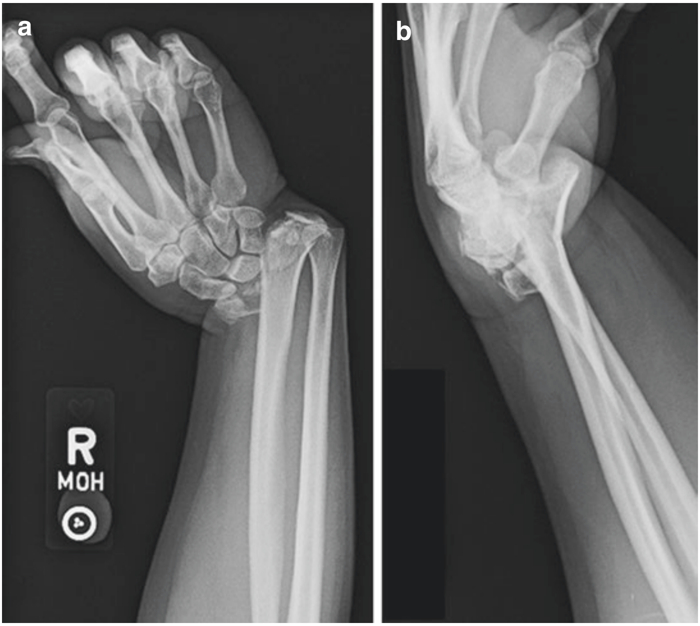

Fig. 21.1 Initial PA (**a**) and lateral (**b**) radiographs of the wrist demonstrating a comminuted distal radial metaphyseal fracture and dislocation of the radiocarpal joint. The carpus is radially and dorsally dislocated and the articular surface of the distal radius is centrally impacted

crimination >15 mm in her thumb, index, and middle fingers. Active finger flexion is limited due to pain. She can actively abduct her thumb, but the extent is also limited by pain. There is no tenderness to palpation at her proximal forearm or elbow. Elbow range of motion is full.

Initial Management On initial PA and lateral radiographs, the carpus is radially and dorsally dislocated, in addition to the articular surface of the radius being centrally impacted and the metaphyseal region being comminuted (Fig. 21.1). Initial management includes administration of appropriate antibiotics for open fractures and immediate reduction of the fracture to restore radiocarpal alignment and decompress soft tissues in order to prevent neurovascular compromise, while improving stability and allowing sufficient finger motion. Dorsally displaced fractures such as this can be reduced by extending the wrist to disengage fracture fragments and then applying longitudinal traction and pronating the distal fragment. If anesthesia is needed, a hematoma block can be performed with satisfactory results. Sedation is usually not necessary, but may be helpful. Axial traction via finger traps can help if muscle spasm prevents reduction, and may aid reduction of small intra-articular fracture fragments. A sugar-tong splint with compressive dressing for edema control is placed and repeat radiographs are taken. The distal palmar crease should be visible within the splint to allow full range of motion at the MCP and IP joints.

Imaging

Radiographs Posteroanterior, lateral, oblique, and 10-degree tilt radiographs should be obtained. Begin with examination of the distal radius, ulna, carpals, and metacarpals for fractures, paying close attention to the radial and ulnar styloid. Careful examination of carpal alignment and relationship to the radius and ulna is important. In radiocarpal dislocation, there is often dorsal (most common) or volar displacement, collapse through the radial column (manifested as radial shortening), or overlap of carpal bones with the distal radius due to proximal translocation of carpi. Collinearity of Gilula lines indicates normal alignment of the radiocarpal, proximal midcarpal, and distal midcarpal bones, and overlap of carpal bones suggests injuries to the intrinsic carpal ligaments [1]. It is important to note the location of avulsed fracture fragments off of the volar and dorsal rim (especially in post-reduction radiographs).

CT CT scans are recommended for evaluation of these complex fractures to visualize small avulsion and articular fragments, evaluate size and location of fragments, and for surgical planning. In this patient, post-reduction CT scan further delineated the extent of injury, showing the vast displacement of the scaphoid and lunate fossa, comminution of the radial column, and metaphyseal comminution (Fig. 21.2).

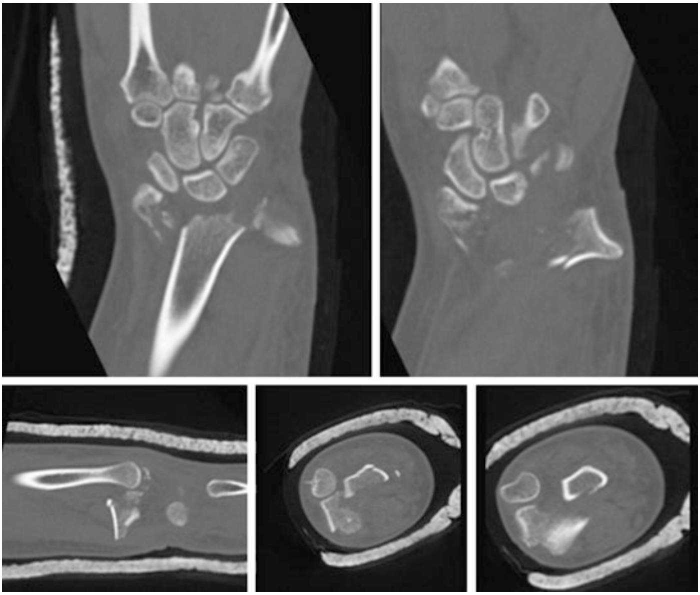

Fig. 21.2 Post-reduction CT scan further delineating the extent of injury, showing the vast displacement of the scaphoid and lunate fossa, comminution of the radial column, and metaphyseal comminution

Surgical Planning

Early detection and treatment are important to minimize patient pain and to avoid prolonged compression of the median and ulnar nerves. Following closed reduction and splinting, urgent surgical repair should be considered due to the inherent instability of these fracture-dislocations [1, 2]. Urgency is increased for irreducible and open fractures and those injuries associated with vascular or nerve injuries. Treatment is focused on obtaining stable reduction of the radiocarpal joint, which may include internal or percutaneous fracture fixation and repair of associated ligamentous injuries [1]. If fracture fragments are large, screw or buttress plating may be considered, while smaller fragments may be better addressed with suture anchors or Kirschner wire fixation [1]. Surgical approach is a function of the injury type and surgeon preference, and a combination of techniques may be necessary to achieve an adequate fixation. In general the radial, intermediate, and ulnar columns are evaluated in succession under direct visualization through a combination of incisions, while simultaneously addressing any intracarpal injuries in each of the carpal columns from lateral to medial [1]. A dorsal spanning plate is often used to provide additional stability, particularly in polytrauma patients who may have greater functional or load-bearing demands through the injured extremity.

A tourniquet should be used as appropriate and all repairs should be performed with the use of fluoroscopy. General anesthesia is preferred, as preoperative regional anesthesia may limit the ability to assess compartments and nerve function after surgery. We have a low threshold for performing concomitant carpal tunnel release given the anticipated swelling in the zone of injury.

Surgical Tact

The patient is placed in the supine position with the operative extremity on a hand table. Dumontier et al. proposed classification of radiocarpal fracture dislocations in two groups, necessitating different surgical approaches [2]. Group 1 consists of patients with isolated radiocarpal dislocation or with a small associated fracture of the tip of the radial styloid, whereas group 2 injuries involve dislocation associated with a radial styloid fracture involving at least 1/3 of the scaphoid fossa, which contains the insertions of the main extrinsic carpal ligaments [2]. Group 1 injuries likely have intraligamentous disruption of the volar and dorsal extrinsic carpal ligaments, and this unstable injury will usually progress to chronic instability with ulnar translocation [1]. While we rarely find it necessary or helpful to repair purely ligamentous injuries, the extended volar carpal tunnel incision can aid in visualization [3]. Extended carpal tunnel release and decompression of Guyon canal can be performed through a standard open incision, with our preference being to cross the wrist crease in a Brunner zig-zag fashion to minimize risk to the palmary cutaneous branch of the median nerve. As mentioned above, we have a low threshold to release the carpal tunnel and consider release of Guyon canal if there is preoperative ulnar nerve palsy.

For most injuries with the typical comminution through the radial column, we will perform a dorsal approach. Provisional fixation is obtained with Kirschner wires and the radial length and inclination of the distal radius. We typically use buttress plating to secure the radial column, using 2.0, 2.4, and/or 2.7 mm mini-fragment plates. Fractures of the intermediate column are also addressed with similar buttress plates. The scaphoid and lunate fossae are evaluated during reduction, with effort taken to minimize articular displacement and step-off. Smaller osseous fragments with extrinsic ligament and capsular attachments can be secured with smaller Kirschner wires or reapproximated with the aid of suture anchors. For radiocarpal dislocations, we prefer to use a low-profile dorsal bridging plate for neutralization [4] (Fig. 21.3). The bridge plate is typically left for 3 months.

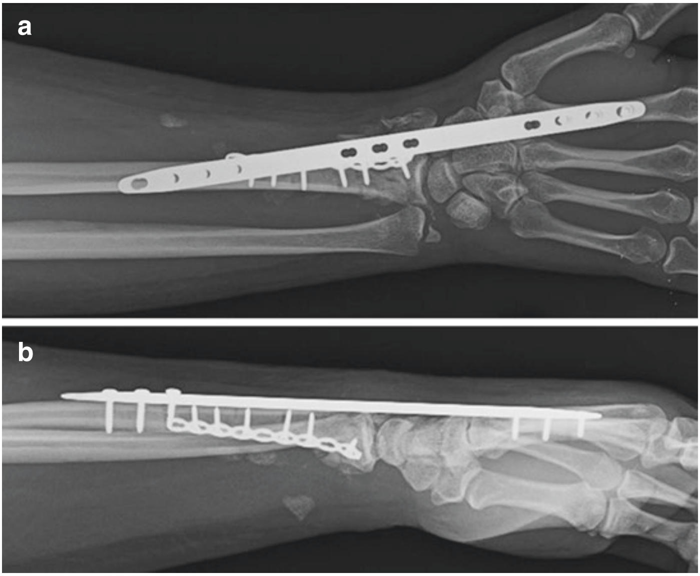

Fig. 21.3 Four-week postoperative PA (**a**) and lateral (**b**) radiographs. Following a carpal tunnel release and open fracture irrigation and debridement, a contoured 2.0 mm recon plate was placed along the volar intermediate column to buttress the volar lunate facet fragment. The dorsal spanning plate was applied to secure the radiocarpal reduction. Restoration of radiocarpal colinearity can be seen on the lateral film (**b**)

Depending on the fracture pattern, fractures involving the volar-lunate facet of the distal radius can be secured through the dorsal approach (with screws through the dorsally based intermediate column buttress plate) or through the extended carpal tunnel approach. For the latter, buttress plating is used through an approach between the ulnar neurovascular bundle and the flexor tendons.

Following completion of osteosynthesis plating and reduction of the radiocarpal joint, we assess the stability of the distal radioulnar joint in all positions of the forearm. If there is an associated ulnar neck fracture or a large ulnar styloid fracture, we will address this with plating or tension band fixation. If DRUJ instability persists, we prefer to splint the patient in the position of maximum stability rather than pinning across the distal forearm.

Postoperative Protocol

A sugar-tong splint is applied with the forearm and wrist in neutral, leaving the fingers free for motion. If DRUJ instability is noted, the sugar-tong splint is applied in the position of maximum DRUJ stability. Serial neurologic examination and evaluation of forearm compartments are performed for the first 12–24 hours. For open fractures, antibiotics should be continued up to 72 hours in type III fractures or no more than 24 hours after closure/soft tissue coverage (all types) [5]. Adequate multimodal pain control and anti-edema measures should be started. Early active and passive mobilization of fingers is important while in the splint. Provided that there are no other ipsilateral upper extremity injuries, shoulder and elbow motion is encouraged. We limit weight-bearing to 5 lbs. during the initial 6 weeks after surgery. Load-bearing through a platform-assisted device is permitted if necessitated by co-existing injuries.

Follow-Up

The patient should be instructed to follow up 10–14 days after surgery unless they are experiencing worsening neurologic symptoms in the hand or other emergent complication. Follow-up radiographs are used to assess maintenance of reduction. Peripheral nerve function is compared to preoperative and immediate postoperative function. Gentle forearm motion is started immediately. Wrist immobilization is continued via short-arm cast or a custom clamshell orthosis until 6 weeks after surgery. If a dorsal spanning plate was placed, it is removed at 3 months after surgery. Strengthening is started after a functional arc of wrist motion has been obtained, focusing on synergistic grip. The most common complication is decreased wrist flexion and extension, which can be up to 40% reduction in total arc range of motion [1, 2]. Early stiffness and decreased range of motion should prompt referral to occupational therapy. Persistent joint instability should be watched closely and may require further surgical repair of potentially missed injuries. Post-traumatic arthritis, chronic instability, and other issues may arise overtime and require late follow-up if symptoms appear.

Tips and Tricks

1. Early detection and treatment are necessary to avoid neurovascular compromise and late wrist dysfunction.
2. Radiocarpal dislocation is a severe, unstable injury, and urgent surgical fixation should be performed in most cases.
3. Fixation of the radial styloid and other avulsed fracture fragments are the most important steps in repair.
4. Surgical repair is based on the injury classification and associated injuries and may require a combination of multiple types of repair and surgical approaches.
5. Surgeons should have a low threshold to perform carpal tunnel release if concerned for development of acute carpal tunnel syndrome or delayed median nerve compression, and consider release of Guyon canal if there is preoperative ulnar nerve palsy.

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22 Perilunate Dislocation: ORIF

Ali Azad and Steven Z. Glickel

Case Presentation/Examination/Initial Management/Radiographs

We present the case of a 45-year-old right-hand-dominant male without significant medical history who presented to our emergency department with the complaint of bilateral wrist pain after a fall from a height of 10 feet onto his outstretched hands resulting in forceful axial load and extension of both wrists. Upon initial presentation, a complete work-up including physical exam, imaging, and laboratory studies determined that he had no other injuries, and wrist radiographs showed bilateral perilunate dislocations (PLD).

On clinical examination, there was diffuse soft tissue swelling, deformity, and tenderness to palpation of both wrists. The remainder of the examination did not detect any concomitant injuries. Of particular importance, a thorough neurovascular examination was performed to assess hand vascularity and median nerve status. Direct contusion from the force of the initial injury and/or increased carpal pressure from swelling and hematoma can produce median nerve compression symptoms, which can progress to acute carpal tunnel syndrome requiring urgent release.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_22

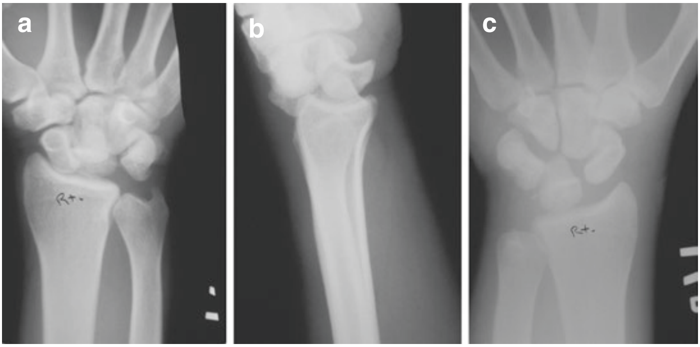

Fig. 22.1 Initial injury radiographs showing a right dorsal perilunate dislocation. (**a**) PA, (**b**) lateral, and (**c**) traction radiographs

Bilateral hand, wrist, and forearm radiographs were obtained in the emergency department. Imaging demonstrated bilateral wrist injuries consistent with dorsal perilunate dislocations (Herzberg stage 1; Mayfield stage 3; lesser arc injury) (Fig. 22.1). Due to a 25% incidence of missed diagnosis, clinicians must maintain a high level of suspicion and radiographs must be scrutinized for the defining characteristic of this injury, which is dislocation of the capitate head from the lunate concavity. Other notable findings on PA and lateral radiographs of perilunate dislocations include associated carpal or radial styloid fractures, loss of carpal height, disruption of Gilula's lines, intercarpal overlap particularly of the capitate and lunate, intercarpal joint space widening, scaphoid flexion (scaphoid ring sign), and volar lunate subluxation/dislocation. Traction radiographs can further delineate the injury pattern and characterize instability by demonstrating pathologic intercarpal separation in the setting of ligamentous injury (Fig. 22.1c). Computed tomography (CT) is usually unnecessary. However, it can have a role if there are associated fractures, in defining unusual variants and may be more useful in the setting of delayed or chronic presentations than for acute injuries.

Urgent closed reduction was performed in the emergency department under sedation to relieve median nerve pressure, decrease edema, and limit chondral damage. The patient was

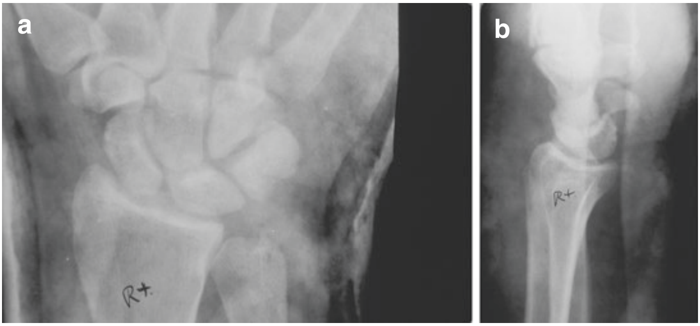

Fig. 22.2 Post-reduction radiographs. (**a**) PA and (**b**) lateral

placed in the supine position with 90 degrees of elbow flexion and finger trap suspension with counterweights on the arm. Prior to manipulation, traction was maintained for 5–10 minutes. Reduction was performed by extending the wrist while applying palmar counter-pressure over the lunate, then slowly flexing the wrist with direct pressure over the capitate head in the palmar and distal directions. PA and lateral radiographs were obtained to confirm carpal alignment and successful reduction (Fig. 22.2). The extremity was immobilized in a sugar-tong splint and repeat neurovascular examination was performed to evaluate median nerve status following reduction. The patient was discharged from the emergency department after a period of observation with a tentative plan for operative fixation of both wrists.

Surgical Planning: Timing, Equipment

In the absence of acute carpal tunnel syndrome and/or an irreducible dislocation, our preference is to perform definitive surgical treatment 3–5 days following closed reduction once swelling has decreased. The goal of surgery is to achieve and maintain anatomic carpal alignment to allow for ligamentous healing. Our preferred surgical approach to achieve this goal is the combined volar dorsal approach. The volar component allows for exposure and repair of volar ligaments, direct reduction of midcarpal and perilunate dislocations, and can be extended distally allowing decompression of the carpal tunnel. The dorsal component allows for excellent visualization of the midcarpal joint and proximal row, allowing for repair of intrinsic and extrinsic ligamentous injuries. The equipment necessary to successfully treat these injuries includes K-wires, suture anchors for a straightforward perilunate dislocation (lesser arc injuries), and implants of choice for fracture stabilization (partially threaded cancellous screw, headless compression screw, radial column plate, etc.) for greater arc injuries involving fractures of the carpal bones and/or radial styloid.

Surgical Tact: Position, Approach, Fixation Technique

The procedure was performed in the supine position under general anesthesia because it was bilateral. A unilateral injury would usually be performed with a regional nerve block and intravenous sedation. Each extremity was approached in a similar manner without significant side-to-side variability.

An extended carpal tunnel approach was used to address volar pathology and decompress the carpal tunnel. Skin and subcutaneous tissue were sharply incised with an ulnarly directed proximal chevron at the wrist crease to avoid injury to the palmar cutaneous branch of the median nerve. Antebrachial fascia and palmar fascia were divided. The transverse carpal ligament was then divided to completely decompress the median nerve and to expose the volar ligaments. A transverse rent in the volar extrinsic ligaments was encountered which is invariably what is found in perilunate dislocations. The lunate was visualized through the rent and found to be reduced within the lunate fossa. The rent in the volar ligaments and capsule was repaired with nonabsorbable braided 2–0 suture with the wrist in neutral. Care was taken to avoid imbrication in order to prevent restriction of wrist motion postoperatively.

For the dorsal approach, a transverse incision was made at the level of the radiocarpal joint. A longitudinal incision might also be used. Blunt dissection was carried down to the level of the extensor retinaculum. The branches of the superficial radial nerve were identified and protected. The distal most fibers of the fourth extensor compartment retinaculum were released, but the majority of the fourth compartment retinaculum was retained to prevent bowstringing of the extensor tendons. The third extensor compartment retinaculum was completely released and the extensor pollicis longus (EPL) tendon was transposed and retracted. A rent was identified in the dorsal capsule, which was extended proximally and distally to visualize the proximal row. Both the scapholunate (SL) ligament and lunotriquetral (LT) ligament were found to be torn from the scaphoid and lunate, respectively. Small osteochondral fragments were noted, with likely origin from the dorsal lip of the lunate and capitate head, and removed from the midcarpal joint. Dorsal to volar K-wires in the scaphoid and lunate were used as joysticks to reduce carpal malalignment. The lunate was placed in neutral and temporarily stabilized with a dorsal radiolunate K-wire. The scaphoid was then extended to restore the scapholunate angle. Once a normal scapholunate relationship was obtained, the joint was stabilized with a radial to ulnar K-wire followed by a second K-wire placed through the scaphoid into the capitate. With the lunotriquetral intercarpal relationship also restored, additional skeletal stability was achieved with a K-wire from the triquetrum into the lunate and another from the triquetrum into the capitate (Fig. 22.3). With intercarpal relationships restored and stabilized, the scapholunate ligament and lunotriqu-

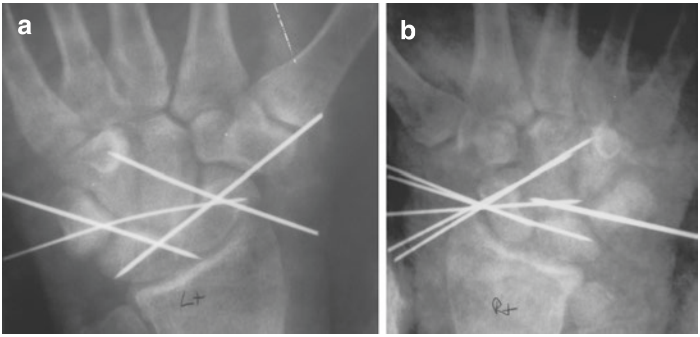

Fig. 22.3 PA views of the right (**a**) and left (**b**) wrist following open reduction internal fixation with intercarpal K-wires

etral ligaments were repaired. There was sufficient residual ligament stump to perform a primary repair of both ligaments. In the event that primary repair is not possible which is usually the case, our preferred repair method is to use suture anchors.

Carpal alignment was fluoroscopically evaluated and found to be normal with appropriate placement of hardware. In particular, a normal scapholunate angle and the absence of dorsal intercalated segmental instability (DISI) were verified. The wounds were irrigated. Capsular repair was performed with absorbable 3–0 braided suture. The EPL tendon remained transposed. Skin was closed with interrupted 5–0 nylon suture. A soft dressing was applied followed by placement of short arm dorsal and volar splints allowing limited pronosupination but restricting wrist flexion/extension and ulnar/radial wrist deviation.

Postoperative Protocol/Follow-Up Radiographs/Pictures

Routine follow-up appointments were scheduled for 2 weeks, 6 weeks, 10 weeks, 3 months, 4 months, 6 months, and 1 year. PA and lateral wrist radiographs were obtained at each visit and evaluated for carpal alignment, signs of instability, and arthrosis. Specific parameters evaluated included scapholunate angle, radiolunate angle, capitolunate angle, and carpal height ratio. Postoperatively both wrists were immobilized for 10 weeks. K-wires were removed at 10 weeks, and the patient was referred for customized thermoplastic wrist resting splints. Radiocarpal motion was initiated at that time with progressive active range of motion exercises under the supervision of a hand therapist. The patient was allowed to start strengthening at 4 months.

At 1-year follow-up, the patient was pain free with functional active motion bilaterally (full composite fist, unrestricted pronation and supination; wrist flexion: R 70°, L 60°; wrist extension: R 60°, L 65°) and grip strength of 80 lbs. (Fig. 22.4). Follow-up radiographs demonstrated that carpal alignment was

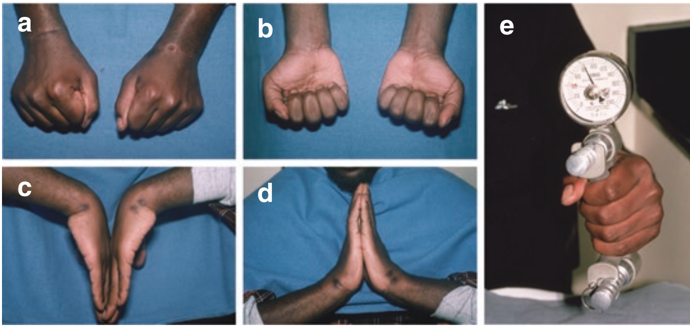

Fig. 22.4 Postoperative functional outcomes at 1 year. Composite fist (**a**, **b**), wrist flexion (**c**), wrist extension (**d**), and grip strength (**e**)

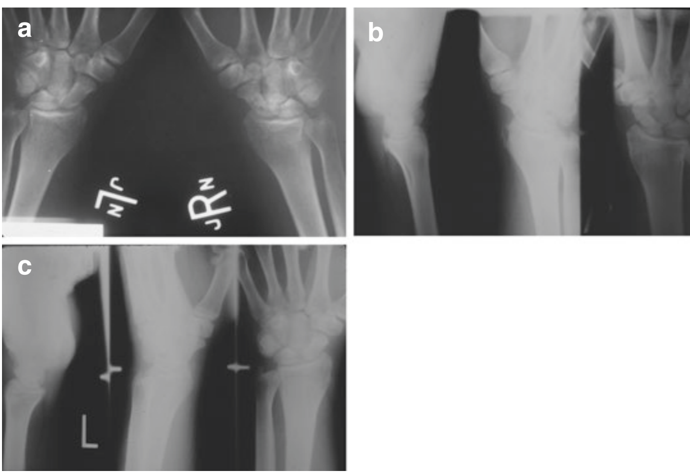

Fig. 22.5 Final radiographs at 1-year follow-up. Bilateral PA ulnar deviation view (**a**), right wrist series (**b**), and left wrist series (**c**)

well maintained with no intercarpal diastasis (Fig. 22.5). There was mild midcarpal arthrosis noted on the right wrist radiographs. Neither wrist had evidence of progressive DISI deformity.

Tips and Tricks

1. Urgent closed reduction in the emergency department is imperative to relieve median nerve pressure, decrease edema, and limit chondral damage.
2. A volar approach should be considered to repair the transverse rent in the volar ligaments and perform a carpal tunnel release if indicated.
3. Carpal realignment should begin by placing the lunate into neutral and provisionally stabilizing with a dorsal radiolunate pin.
4. A scaphocapitate K-wire provides an additional point of fixation resisting the flexion moment of the scaphoid.
5. Intercarpal scapholunate and lunotriquetral K-wires should be maintained for 8–10 weeks to provide sufficient time for interosseous ligament healing.

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23 Chronic Perilunate Dislocation: Excision and Fusion

Louis W. Catalano III and Jadie De Tolla

Case Presentation

History

A 36-year-old male with no significant past medical history presents with 1 year of right wrist pain. The patient sustained a right wrist injury in a motor vehicle accident 16 years prior. At the time, he was told that he had normal wrist X-rays and was immobilized in a cast for 6 weeks. He also sustained a closed head injury, making his wrist injury less of a priority at that time. Since the accident, he has had limited wrist range of motion and now presents with wrist pain and stiffness. The patient denies numbness and tingling.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_23

Physical Examination

Right Wrist:

- Skin intact, no edema or ecchymosis, no atrophy
- Tender to palpation over the carpal tunnel, “bony feel to it”
- No Tinel’s of the median nerve at the wrist
- Extension 40, flexion 40, full pronation and supination
- +EPL/APB/first DOI
- Sensation intact in the median, ulnar and radial distributions
- Fingers warm and well perfused, capillary refill less than 2 seconds

Preoperative Imaging

X-rays: Fig. 23.1

MRI: Fig. 23.2a, b

Fig. 23.1 Preoperative AP and lateral X-rays of a 36-year-old male with a chronic lunate dislocation and radio-carpal degenerative joint disease

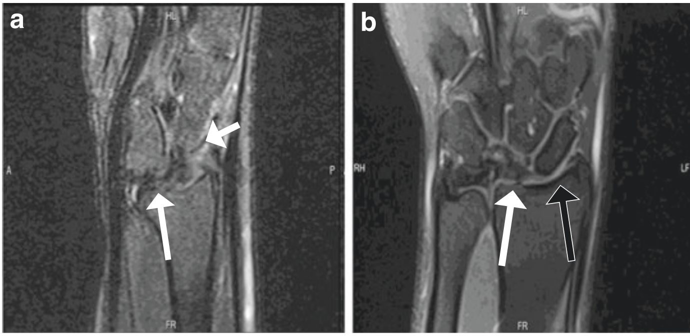

Fig. 23.2 (**a**, **b**) Preoperative sagittal (**a**) and coronal (**b**) MR images demonstrate a chronic lunate dislocation with severe cartilage loss at the lunocapitate (small white arrow) and radiolunate (large white arrow) articulations. There was no arthritis at the radioscaphoid articulation (black arrow, **b**)

Surgical Plan

Procedure

Given the presence of both radiolunate and lunocapitate arthritis (Fig. 23.2a, b), a "standard" proximal row carpectomy (PRC) could not be performed. In addition, an isolated lunate excision would not address the pain resulting from the post-traumatic arthritis. A modified PRC with a dorsal capsular interposition arthroplasty was considered, but the authors felt the patient was too young and active for this procedure. Based on these findings, he was indicated for the following.

- Open carpal tunnel release
- Lunate excision
- Scaphocapitate arthrodesis

Timing

- The patient was taken to the OR the following month on an elective basis. He had no evidence of acute or subacute carpal tunnel syndrome on exam.

Equipment

- Hand table
- Tourniquet
- Fluoroscopy
- Hand tray
- 3 mm burr
- Hand drill
- 0.062 K-wires
- Bovie and bipolar
- 3–0 Ethibond
- Plaster

Implants

- Integra Nitinol staples × 2 (12 mm × 10 mm × 10 mm)

Surgical Technique

Position

- Supine with the arm on a hand table
- Upper arm tourniquet

Approach

- Volar extended carpal tunnel approach
- Dorsal longitudinal approach to the wrist

Technique

- Carpal Tunnel Release and Lunate Excision
  - Volar extended carpal tunnel approach.
  - Incise palmar fascia.
  - Release transverse carpal ligament.

    Start distally where anatomy is presumed to be normal and work proximally.

    Identify and protect the median nerve in the radial aspect of the carpal tunnel.
  - Lunate Excision

    Retract the contents of the carpal tunnel radially.

    Palpate bony prominence within the carpal tunnel.

    Place a 0.062 K-wire in the lunate and confirm position with fluoroscopic images (Fig. 23.3).

    Using the K-wire as a joystick, bovie is used to release the lunate from surrounding scar tissue.

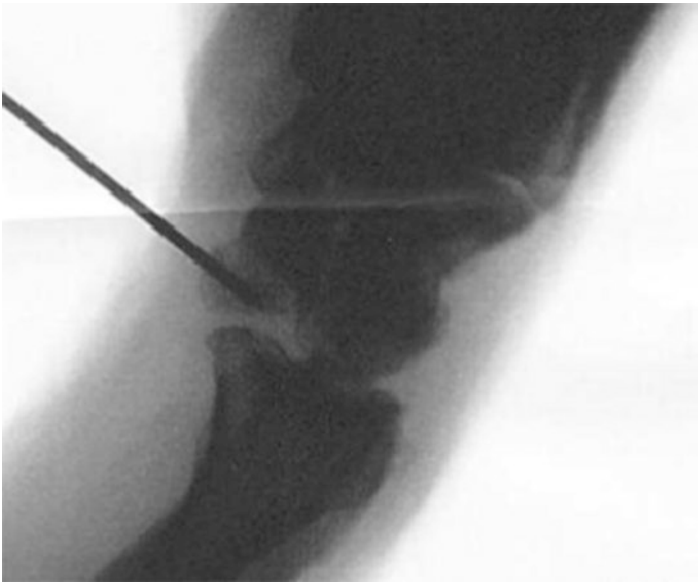

Fig. 23.3 Intraoperative fluoroscopic image demonstrates placement of a K-wire in the lunate, which can be used as a joystick to facilitate lunate excision

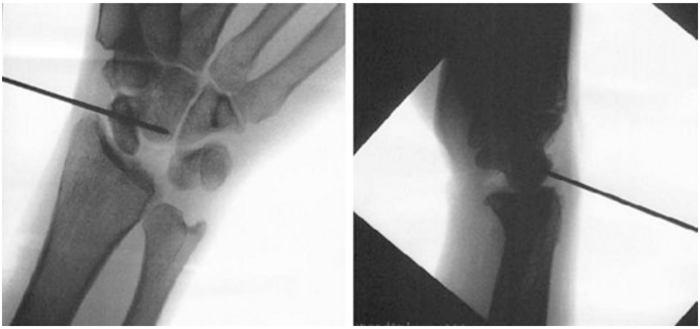

Fig. 23.4 Intraoperative fluoroscopic images demonstrate reduction of the scaphoid followed by K-wire fixation to the capitate. The radioscaphoid angle should be approximately 45 degrees

Once excised, the lunate is decorticated and saved for later use as bone graft.

Irrigate and close the volar wound in a layered fashion.

- Scaphocapitate fusion
  - Dorsal approach to the wrist

    Five cm longitudinal incision from the Lister's to the index metacarpal.

    Open retinaculum between the second and third dorsal compartments.

    Dorsal capsulotomy over the scaphoid.
  - Identify the scaphocapitate joint and confirm fluoroscopically.
  - Reduce the scaphoid and pin it to the capitate with a 0.062 K-wire (Fig. 23.4).

    Radioscaphoid angle should be ~45 degrees.
  - Remove the scaphocapitate articular cartilage with 3 mm burr.
  - Pack interval with lunate autograft.
  - Secure scaphoid and capitate with two nitinol staples (Fig. 23.5).

    Tamp staples flush to the dorsal scaphoid cortex.

Fig. 23.5 Final fluoroscopic images demonstrate reduction and fixation of the of the scaphoid and capitate with two nitinol staples. Note that the staples are tamped flush to the dorsal scaphoid cortex to avoid impingement with wrist extension

- Remove the K-wire and range the joint to ensure strong fixation.
- Evaluate for impingement – with full passive wrist extension in the OR under fluoroscopy.
- Repair the dorsal capsule and extensor retinaculum with non-absorbable sutures.
- Apply sterile dressings and a plaster wrist splint with volar and dorsal slabs.

Postoperative Protocol

Transition into a full-time, short-arm, volarly based orthosis 14 days after surgery for an additional 4 weeks. Once callus formation is visualized across the scaphoid-capitate articulation (~ 6 weeks after surgery) on radiographs, occupational therapy is initiated and the wrist orthosis is gradually weaned. Ad libitum use may begin at 9 weeks provided the wrist is pain free and the fusion mass has healed radiographically.

Follow-Up

2 Weeks Postoperative

- No pain.
- Well healed wounds.
- X-rays of the right wrist reveal a well-aligned carpus, staples in place (Fig. 23.6).

6 Weeks Postoperative

- Pain improved from preoperative level.
- Well-healed wounds, wrist extension 40, wrist flexion 50, full pronation and supination.
- X-rays of the right wrist reveal a well-aligned carpus with evidence of callus formation (Fig. 23.7).

9 Weeks Postoperative

- No pain.
- X-rays of the right wrist reveal a healed fusion mass of the SC joint and a broken staple.

Fig. 23.6 X-rays taken 2 weeks postoperative reveal a well-aligned carpus with stable hardware

Fig. 23.7 X-rays taken 6 weeks postoperative reveal a well-aligned carpus with evidence of consolidation of the fusion mass

Tips and Tricks

1. Following release of the transverse carpal ligament, placing a K-wire in the lunate and confirming its position fluoroscopically will help guide its excision from surrounding scar tissue.
2. Ensuring the radio-scaphoid angle is ~45 degrees fluoroscopically will confirm that the scaphoid is appropriately reduced prior to fixation.
3. Staples should be tamped flush to the dorsal scaphoid cortex to avoid wrist impingement.
4. Evaluate for impingement with full passive wrist extension under fluoroscopy following fixation.
5. Removal of hardware may need to be performed in the future if staples loosen or the patient presents with signs of wrist impingement.

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24 Pediatric Salter Harris Distal Radius Fracture: Pinning

Jody Litrenta

Case Presentation

A 12-year-old boy fell onto his left arm while playing ball. He was seen in an Urgent Care and a splint was placed. He presented for follow-up in the office 2 days later. On exam, he had significant swelling at the wrist without obvious angular deformity. He was able to flex and extend the digits and had sensation throughout the hand with good perfusion.

Radiographs

X-rays (wrist PA/lateral) were taken at the visit (Fig. 24.1), which demonstrated a displaced distal radius physeal fracture, Salter Harris 2.

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N. C. Tejwani (ed.), *Fractures of the Wrist*,
https://doi.org/10.1007/978-3-030-74293-5_24

Fig. 24.1 Forearm (PA/lat) at the time of injury

Treatment Options

Treatment of a displaced fracture through the physis depends on the age of the patient and the time from injury.

Timing from Injury

All patients who present immediately after injury can be treated with an attempt at closed reduction. For patients with a delayed presentation, or if the fracture loses reduction, manipulation of the displaced physis can cause growth arrest. Typically, this risk is considered significant about 7–10 days from injury when there is already some callus formation [1]. However, there is still concern that the risk of growth arrest from manipulation may be higher even sooner than this time frame. Additionally, multiple initial attempts at closed reduction should likewise be avoided.

Age

The physis of the distal radius and ulna has significant remodeling capability. Younger children in particular can heal in anatomic alignment despite large amounts of displacement. Although an attempt at a closed reduction is always a good initial step, younger children who either have an imperfect reduction, or lose reduction, can be safely observed. However, older children are more likely to need an intervention. Growth arrest is less consequential in older children and remodeling capability is diminished. Therefore, achieving anatomic alignment is preferred. As a general rule, deformity in patients up to 10 years old can be allowed to remodel, whereas older patients may be treated surgically [2, 3]. Some authors recommend observation if there are at least 2 years of growth remaining. However, the exact threshold for surgical intervention vs. observation is not known, and some younger patients can have progressive deformity [4]. In some cases, an epiphysiodesis of the distal ulna may be considered at the time of surgical management if there is a high suspicion for growth arrest.

Surgical Indication

This patient was a 12-year-old boy with greater than 50% displacement of the physis who presented early after injury. For older children with this amount of displacement, achieving and maintaining reduction is preferred. Closed reduction is an acceptable treatment, but any closed reduction has the possibility of re-displacement. Therefore, when the reduction is being performed in the operating room, it is logical to include percutaneous pinning of the fracture and prevent displacement.

Surgical Approach

Positioning

The patient is positioned supine with a hand table. A closed reduction can be attempted prior to prepping and draping. The advantage of performing this step first is the ease of manipulating the fracture with the arm free. The hand can be suspended from an IV pole using fingertraps for the manipulation attempt once the patient is asleep. This set-up is particularly ideal if this procedure is being performed with limited assistance.

Closed Reduction

Closed reduction is done by accentuation of the deformity, traction, and direct pressure over the distal fragment. Most fractures are displaced dorsally and radially, which is also where the Thurston-Holland (metaphyseal) fragment will be. Volar displacement is less common. It is important to have good sedation to facilitate a gentle manipulation of the physis, regardless of the patient's age.

Open Reduction

If closed reduction cannot be achieved, it is often due to periosteum that gets interposed opposite the displacement. For a dorsally displaced distal radius physeal fracture, the periosteum will be found volarly.

A standard Volar Henry interval can be used to approach fracture site, finding the plane between the flexor carpi radialis and the radial artery. The interposed periosteum can be bluntly swept out of the physis using a freer. It is useful to perform blunt dissection completely so that two retractors can be placed around the radius. This helps ensure that the fracture site is mobile and free of any soft tissue impediments. For a volarly displaced fracture, the fracture site can be approached dorsally between the extensor compartments to expose and remove the interposed periosteum.

Percutaneous Pinning

Once a reduction can be achieved, a smooth K-wire is placed bicortically across the physis to maintain the alignment. During pinning, the reduction is held if necessary with pressure directly over the Thurston-Holland fragment. Fluoroscopy can confirm the reduction in AP and lateral planes, usually coming in either from the end of the hand table or the bottom of the bed. Fluoroscopy can again be used to verify the starting point of the K-wire, which will be slightly more distal on the skin than its anticipated entry into the styloid.

A stab incision is made and blunt dissection is performed with a small hemostat. This is done to protect the superficial radial nerve. The K-wire is started at the distal tip of the radial styloid in the AP and centered on the lateral projection. It helps to position the wrist laterally, using a rolled towel underneath the ulnar aspect. An assistant can then pull some traction through the thumb and ulnarly deviate the hand. To get the best trajectory, once the K-wire is started in the radial styloid, the surgeon needs to bring the drill as close as possible to the patient's hand. If needed, a second pin can be placed. The second pin can either parallel the first in the radial styloid, or can be cross-pinned starting from the dorsoulnar corner of the epiphysis.

The reduction, pin placement, and bicortical purchase can be confirmed with AP and lateral fluoroscopic imaging. The pin is then bent and cut outside the skin, with xeroform gauze wrapped around the base to protect the skin. Final AP and lateral fluoroscopic images show the pin placement (Fig. 24.2). A short arm cast or splint is then applied.

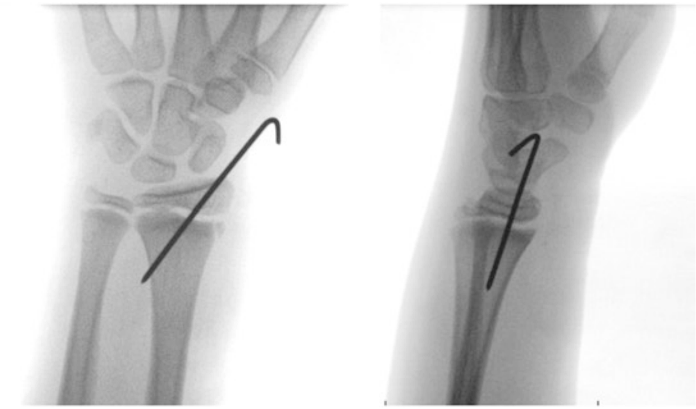

Fig. 24.2 Wrist (AP/lat) taken intraoperatively with fluoroscopy, after closed reduction and percutaneous pinning

Postoperative Protocol

A short arm cast is maintained for 4 weeks postoperatively. The cast and pin can then be removed in the office. The patient is then either placed back into a cast for an additional 2 weeks, or transitioned to a removable wrist brace to begin range of motion, depending on the patient's comfort and the amount of healing present.

Follow-up X-rays should be performed at 3 months postoperatively to monitor for any evidence of physeal arrest, such as changes in the ulnar variance or a visible bony bar [5].

Serial X-rays can be helpful to determine if growth has resumed (Fig. 24.3). Increasing ulnar variance should be addressed with an ulnar epiphysiodesis to prevent abnormal loading at the wrist.

Salient Points

- Consider the patient's age and time from injury to determine if remodeling or surgical intervention is appropriate.
- Attempt a closed reduction prior to prepping and draping with good sedation.
- If a closed reduction cannot be achieved, the interposed periosteum will be found through a surgical approach opposite the displacement.
- Percutaneously place a K-wire through the radial styloid while holding the wrist in ulnar deviation over a small towel roll.
- Monitor for postoperative growth arrest with serial X-rays and recognize ulnar epiphysiodesis may be needed for some patients.

Fig. 24.3 (**a**) Wrist (PA/lat) 4 weeks after cast removal, appearing slightly ulnar positive. (**b**) Bilateral wrist (PA/lat) 6 months after injury, demonstrating symmetric appearance of the distal radius and ulnar physes

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25 Pediatric Distal both Bone Fracture: Failed Closed Reduction

Emilie R. C. Williamson and Mara S. Karamitopoulos

Case Presentation/History/Examination/Initial Management in ED/Office

The patient was a 6-year-old otherwise healthy right-hand-dominant male who presented for evaluation of his left wrist after falling onto his outstretched arm 3 days prior to presentation. The patient was taken initially to an emergency room, where he underwent closed reduction and splinting.

At initial presentation to our office, his pain was well controlled, and he had intact neurovascular status. Physical exam was notable for mild visible deformity of the forearm, with a splint in place that was in poor condition.

Radiographs taken in the office demonstrated an acceptable reduction of a distal both-bone forearm fracture (Fig. 25.1a). The patient was placed into a long-arm cast, which was not bivalved

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https://doi.org/10.1007/978-3-030-74293-5_25

due to the lack of swelling. The patient and his mother were counseled on the risk of re-displacement, and he was instructed to return the following week for repeat radiographs.

The patient returned the following week, nearly 2 weeks after initial injury, and was doing well clinically. Radiographs demonstrated a cast index of 0.96, and a change in alignment with a 28-degree dorsal angulation of the distal radius fracture (Fig. 25.2). For this reason, the patient was indicated for closed reduction and percutaneous pin fixation of his left distal radius fracture.

Radiographs

Fig. 25.1 Radiographs taken at initial visit, 3 days after injury

Fig. 25.2 Radiographs at first follow-up visit 2 weeks after initial injury demonstrating interval displacement of fracture with increased apex volar angulation of 28 degrees. Cast index = 0.96

Surgical Timing/Planning (Including Equipment)

The patient was taken for closed reduction and percutaneous pinning of left distal radius fracture, and application of long-arm cast, 20 days after the initial injury.

As the fracture was 3 weeks after his injury, the possibility of need for open reduction was discussed with the family.

Equipment: Mini C-arm, Kirschner wires, and casting material including Webril, stockinette, fiberglass casting.

Surgical Tact: Position, Approach, Fixation Technique

The patient was positioned supine on the operating table. The distal forearm was found to have obvious deformity in both the frontal and sagittal planes. The mini C-arm base was positioned with the monitor by the patient's head to facilitate using the C-arm as the operating "table." The patient was shielded with lead on his pelvis and thyroid, and a tourniquet was placed on the patient's upper arm in case an extensive open reduction was needed.

Under fluoroscopic guidance, an attempt was made at fracture reduction by axial traction, recreation of the deformity, and flexion. There was substantial callus noted fluoroscopically, and there was difficulty is disrupting the callus by closed means. A decision was made to proceed with mini-open reduction.

The area of the fracture was marked out fluoroscopically, and a 2 cm incision was made dorsally over the fracture site. A combination of sharp and blunt dissection was used to get down to the fracture site, and over lying periosteum was incised. An elevator was placed in the fracture site, and the distal fragment was gently levered over under fluoroscopic guidance.

The reduction was confirmed with fluoroscopy, and the location of planned pin across the distal radius was marked out on the skin. A stab incision was made over the area of planned pin insertion, and a hemostat was used to spread

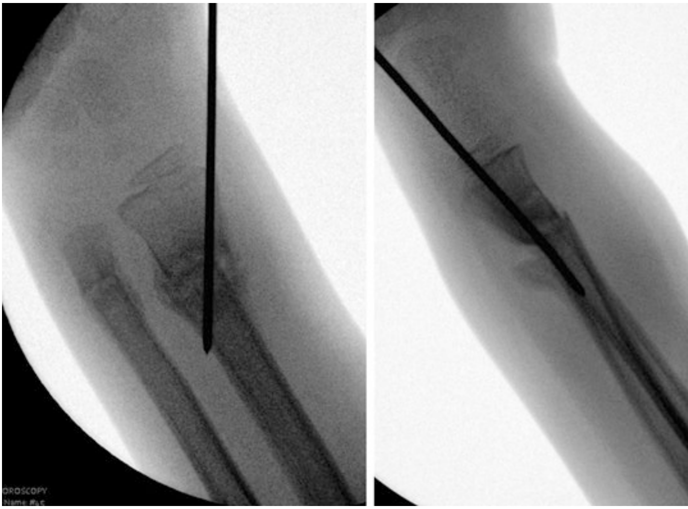

Fig. 25.3 Intraoperative fluoroscopy after pin fixation. Substantial callus is noted in both the AP and lateral planes

down to bone. Under fluoroscopic guidance, a 0.062 Kirschner wire was placed into the distal fragment. The elevator was then removed, and the pin was placed across the fracture site. Radiographic evaluation confirmed appropriate pin position and good fracture alignment in both the AP and lateral planes (Fig. 25.3). As the distal ulna fracture was healing well and appropriately aligned, a pin was not placed in the distal ulna. The pin was cut and bent.

A well-molded long-arm cast was applied. The cast was bivalved and gently overwrapped with an ACE wrap.

Postoperative Protocol

The patient was discharged home the same day of surgery. He was instructed to refrain from sports or heavy lifting with the left arm, and to continue to elevate the left hand to reduce swelling.

Follow-Up (with Radiographs)

The patient was seen 11 days after surgery. He had no pain and had been using the left hand comfortably. The cast was in good condition. Radiographs at this visit demonstrates stable post-reduction alignment (Fig. 25.4). The cast was overwrapped and he was instructed to follow-up at 4 weeks postoperatively.

The patient returned 4 weeks after surgery and cast was removed and radiographs again demonstrated no displacement

Fig. 25.4 Eleven days after surgery

Fig. 25.5 Four weeks after surgery

(Fig. 25.5). The pin was removed, and the patient was given a removable wrist brace to wear for the next 2 weeks with sports.

The patient was seen 6 weeks after surgery and had no pain or limitations on wrist range of motion. Radiographs demonstrated continued healing of the distal radius and ulna fractures (Fig. 25.6). The patient was cleared for progressive return to activities as tolerated.

Fig. 25.6 Seven weeks after surgery

Salient Points

1. Close initial follow-up is necessary to identify displacement early and prior to fracture healing.
2. Cast index can be predictive of failure of casting.
3. While closed reduction should always be attempted first in the OR, both the family and the surgeon should be prepared for open reduction when needed.

4. The need to proceed to open reduction is more common when the fracture is >2 weeks old and substantial callus has formed.
5. Open reduction can be performed through a small incision centered over the fracture site and using an elevator to lever the distal fragment into position.

Suggested Readings

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26 Pediatric Both Bone Fracture: Flexible Nails

Karim Masrouha

Case Presentation

A 6-year-old male presented to the emergency department (ED) with left forearm pain and deformity after a trip and fall while running. The fall was witnessed by his parents, and they reported no head trauma or loss of consciousness. On examination, he had a deformity of his left forearm with a pin hole defect through the skin at the volar aspect of the mid-forearm. Neurovascular examination revealed an intact anterior interosseous nerve, posterior interosseous nerve, and ulnar nerve, as well as palpable radial and ulnar pulses with a capillary refill of less than two seconds. There was no tenderness to palpation of the left elbow, humeral shaft, shoulder, or clavicle. A secondary survey did not reveal any other injuries. He was diagnosed with a Gustilo-Anderson Grade 1 open forearm fracture. Antibiotics were initiated in the ED, his wound was cleaned, and a well-padded sugar-tong splint was applied.

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https://doi.org/10.1007/978-3-030-74293-5_26

Radiographs

Anteroposterior (AP) radiographs of the left forearm showed fractures of both the ulna and the radius with shortening and malrotation of both bones (Fig. 26.1). Particularly in the setting of a single bone forearm fracture, adequate examination of the wrist and elbow joints is needed to rule-out a Monteggia or Galeazzi fracture, which are frequently missed injuries. Further imaging can be requested if examination of the remainder of the upper extremity reveals any signs or symptoms suspicious of a fracture.

Fig. 26.1 Anteroposterior (**a**) and lateral (**b**) radiographs of the left forearm showing fractures of both the radius and ulna shafts with malrotation and shortening

Surgical Timing/Planning Including Equipment

The patient was taken to the operating room (OR) on the same day, as soon as his *nil* per os status would allow. Since it was a Grade 1 "inside out" injury without gross contamination and there was no neurovascular compromise, he was taken to the OR urgently, but not emergently.

A flexible nail set provided by the manufacturer with multiple nails of all sizes should be available. If a drill bit is to be used instead of the awl provided by the manufacturer, then a drill with a 3.5 mm drill bit and a guide should also be available.

Surgical Tact: Position, Approach, Fixation Technique

The patient is positioned supine on a radiolucent table with an arm board and all bony prominences padded. The patient is brought to the edge of the operating table in order to have adequate access to the upper extremity during the procedure. Care must be taken to secure the patient's body and head while positioning. A non-sterile tourniquet is applied to the arm. The entire upper extremity is prepped and draped in the usual sterile manner. The appropriate preoperative imaging studies are brought up on the computer monitors. The upper extremity is then exsanguinated by elevation, and the tourniquet is inflated to 100 mm Hg above the systolic blood pressure.

The open wound is addressed first, by debriding the bone edges and surrounding soft tissues followed by copious irrigation with normal saline.

Next, the radius is addressed as fixing the ulna first would make reduction of the radius more challenging. Under fluoroscopic guidance, the physis is identified and marked on the skin. A #15 blade is then used to make a 1–1.5 cm incision which would allow for the nail entry site to be approximately 2 cm proximal to the level of the physis. The soft tissues are bluntly dissected with a hemostat, and the extensor tendons are retracted volarly. The periosteum is sharply incised and the medullary canal is accessed using a 3.5 mm drill bit (or the manufacturer-supplied awl) with a guide to protect the soft tissues. Prior to drilling through the cortex, a fluoroscopic image is taken to confirm that the entry site is a safe distance from the physis. The drill bit is first placed perpendicular to the bone in order to go through the cortex without skiving, and is then dropped toward the hand to create and oval-shaped window which will accommodate entry of the flexible nail. The drill bit is then withdrawn and the flexible nail is introduced with a universal chuck placed close enough to the tip of the nail to allow for adequate control but with enough room to introduce part of the nail into the canal. The size of the nail selected should be large enough to fill approximately 40% of the canal diameter at the isthmus on AP fluoroscopic views. The end of the nail is curved so the tip is first introduced with the concave side facing the fracture and the nail almost parallel to the forearm. Once the tip is inserted and reaches the far cortex of the radius, the chuck is brought toward the hand and, under fluoroscopic visualization, the nail is tapped along the canal with a mallet. The nail is introduced to the fracture site, the fracture is then close reduced, and the nail is passed to the proximal radius metaphysis (Fig. 26.2a). More than 2–3 passes of the nail into the soft tissues can increase the risk of forearm compartment syndrome so if a closed reduction is not obtained, an open reduction should be performed via a modified volar Henry approach, and the nail should be passed under direct visualization. Once the nail position is confirmed with orthogonal fluoroscopic views, it is cut with sufficient length protruding from the bone to allow for future removal, but not too much to result in irritation.

The ulna is then addressed. The approach is through an incision made over the posterolateral aspect of the olecranon. This allows for the nail to be buried within the anconeus and avoids future discomfort while leaning against the elbow. Of course, a posteromedial insertion would place the ulnar nerve at risk, and should be avoided. The cortex is opened similarly to the radius and the nail is introduced, under fluoroscopic guidance, by tapping against the universal chuck with a mallet. The nail is

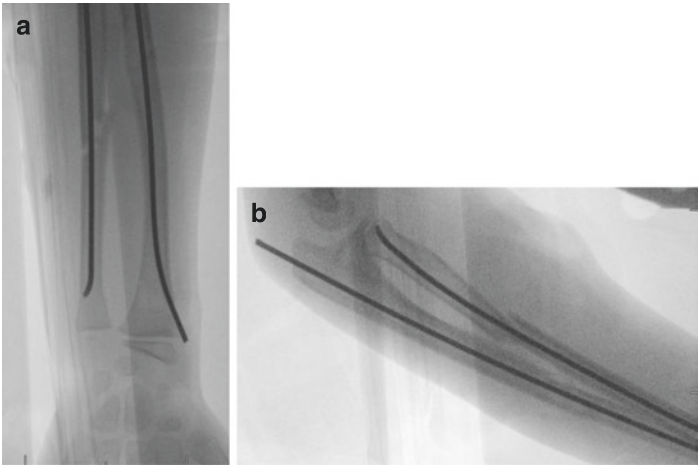

Fig. 26.2 Intraoperative anteroposterior (**a**) and lateral (**b**) fluoroscopic views showing adequate reduction of the fractures, fixed with flexible intramedullary nails

advanced to the level of the fracture, which is then reduced before passage of the nail to the distal ulnar metaphysis. Again, the nail is cut with sufficient length protruding for future removal, but buried enough to avoid irritation (Fig. 26.2b).

The wounds are then irrigated profusely and closed using dermal followed by subcuticular sutures. A long arm cast is then applied with the elbow in 90 degrees of flexion and the forearm in neutral rotation, and then bivalved. The purpose of the cast is for both comfort and to maintain rotational control, which is not obtained with the flexible nails.

Postoperative Protocol and Follow-Up

The patient is admitted for 24 hours to monitor for compartment syndrome and to receive antibiotics. The forearm is kept elevated. The initial postoperative visit should be at 1–2 weeks postopera-

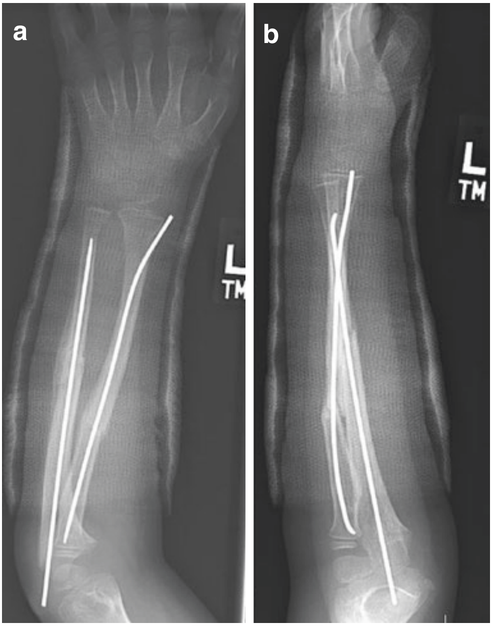

Fig. 26.3 Antero-posterior (**a**) and lateral (**b**) radiographs of the left forearm 6 weeks postoperatively demonstrating healing fractures with maintained alignment and position of the nails

tively with AP and lateral radiographs of the forearm. The patient can then be transitioned to a short arm cast at 3–4 weeks, with cast removal at 6 weeks postoperatively (Fig. 26.3). The nails are typically removed at around 6 months postoperatively (Fig. 26.4). The parents and the patient should be advised of the increased risk for refracture after nail removal and should protect the forearm with bracing, particularly during any high-risk activity, for a period of about 6 weeks after nail removal.

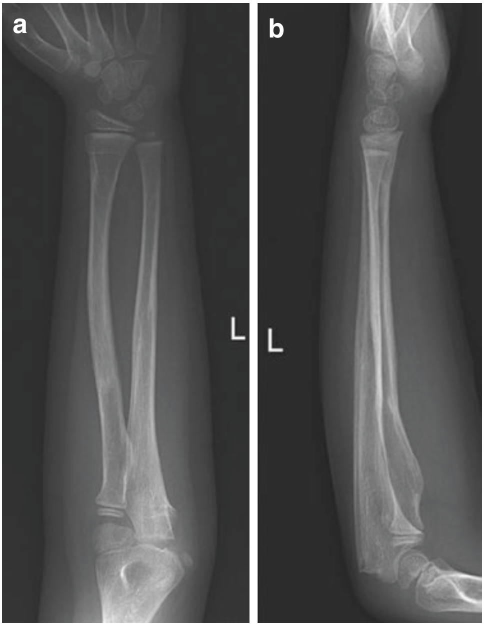

Fig. 26.4 Anteroposterior (**a**) and lateral (**b**) radiographs of the left forearm at 6 months postoperatively, following removal of hardware, demonstrating healed fractures with remodeling and anatomic alignment

Tips and Tricks

1. Select the appropriate size nail by measuring the isthmus of the radius and ulna.
2. Confirm the location of the physis and insert the nail 2 cm proximal to it to avoid injury.
3. Insert the nail by tapping with a mallet rather than pushing to have more control and avoid iatrogenic fracture or accidental passage into the soft tissues.
4. Insert the nail to the fracture site under fluoroscopic guidance and then perform the reduction.
5. Limit the number of passages through the soft tissues to two. If closed reduction is not obtained, then an open reduction should be performed to avoid multiple passes which increase the risk of compartment syndrome.

Acknowledgment The author would like to thank Dr. Jody Litrenta for providing the case images for this chapter.

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https://doi.org/10.1007/978-3-030-74293-5

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