Seven Deadly Sins of Volar Distal Radius Fracture Fixation

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Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest The authors report no conflicts of interest.

ABSTRACT

Distal radius fractures are common injuries, accounting for 17.0% of all emergency department visits. Operative treatment is an option when indicated. Volar plating has become the most frequently used mode of fixation. Although fixed angle volar locking plates allow for reliable and stable fixation, complications have been reported. Complications include flexor and extensor tendon rupture, intra-articular screw penetration, malreduction, loss of reduction, carpal tunnel syndrome, implant failure, and complex regional pain syndrome. We propose seven principles to avoid these preventable outcomes and tips to succeed.

Keywords: Radius, Wrist, Hand

INTRODUCTION

Distal radius fractures are common injuries, accounting for 17.0% of all emergency department visits.[1,2] In people over the age of 50, the mechanism of injury is most often a fall onto an outstretched hand. Closed reduction and immobilization are options for stable, extra-articular fractures.[3]

In unstable, intra-articular distal radius fractures, surgical options include closed reduction and percutaneous fixation, external fixation, intramedullary nailing, open reduction internal fixation (ORIF) with volar or dorsal plating, and ORIF with fragment specific fixation.[4] The goal of surgical fixation is to re-establish radial inclination, volar tilt, length, and articular congruity to improve range of motion, comfort, function, and potentially decrease the risk of post-traumatic arthritis.[5,6] Volar plating has become the most frequently used mode of fixation in the treatment of unstable distal radius fractures.[7] Fixed angled anatomic volar locking plates provide stable fixation in osteoporotic and comminuted fractures with the goal of avoiding extensor tendon and other soft-tissue injuries common in dorsal plating. Complications have been reported, including flexor and extensor tendon rupture, intra-articular screw penetration, malreduction, loss of reduction, carpal tunnel syndrome (CTS), implant failure, and complex regional pain syndrome.[8-10]

We have identified seven preventable outcomes, the seven "deadly sins," in distal radius volar plating. We propose strategies for avoiding these potential outcomes.

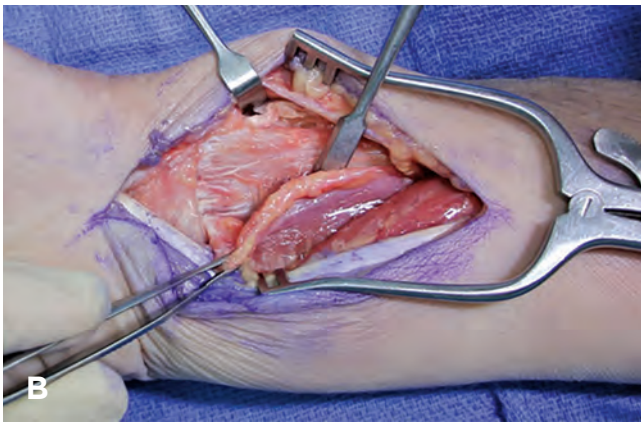
I. Inadequate Exposure

Inadequate exposure can lead to difficulty with fracture visualization and may result in malreduction and difficulty with accurate implant placement. In subacute injuries, dorsal callus and hematoma formation can be considerable and make adequate reduction of fractures difficult.

The flexor carpi radialis (FCR) approach is often used to gain adequate exposure. The FCR tendon sheath should be released past the trapezial ridge distally (Figure 1A). The radial septum is delineated, and the first dorsal extensor compartment is released to free the radial styloid fragment. The brachioradialis is step-cut for later repair and also releases the radial styloid fragment. The pronator quadratus is elevated from the watershed line at the tuberosity just proximal to the lunate facet and elevated radial to ulnar to the level of the distal radial ulnar joint (DRUJ). The ulnar cortical border of the distal radius is visualized and used for adequate reduction of the distal fragment. The watershed line should be clearly visible at the proximal reflection of the carpal bursa (Figure 1B). After releasing the radial septum, including the first extensor compartment and brachioradialis, the next step is pronation of the proximal fragment. Pronation of the proximal fragment facilitates dorsal periosteal and callous release, which frees the distal fragment to facilitate reduction (Figure 1C). Adequate exposure facilitates visualization of the surrounding nerves, arteries, and tendons and decreases the force of retraction across these structures. This exposure provides excellent visualization and facilitates fracture reduction.[11]

II. Anatomical Structures within the Surgical Field

Anatomical structures to be aware of include the median nerve, palmar cutaneous branch of the median nerve, and radial artery. The surgeon should be aware



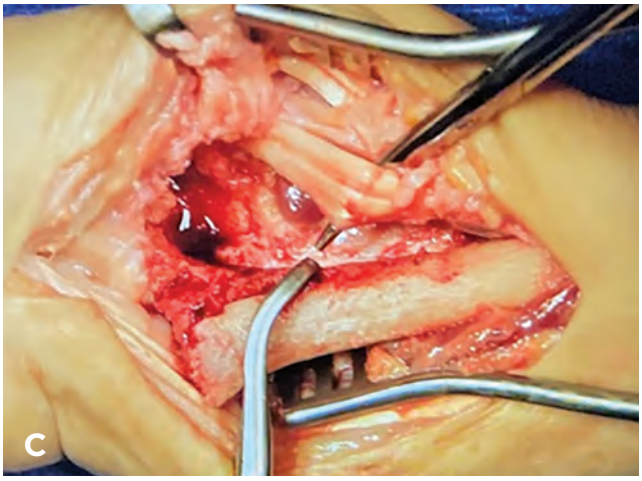


Figure 1. *A) A photograph of dissection in the extended flexor carpi radialis (FCR) approach. B) Release of FCR sheath to the scaphoid tuberosity distally. C) Complete exposure with final removal of pronator quadratus. Example of pronation of the proximal fragment in the extended FCR approach for volar fixation of distal radius fractures.*

of the standard approach and proximity of these structures to retractors and other instruments.

Median nerve injury and CTS are known to occur acutely after distal radius fractures. An article describing postoperative median nerve injuries after distal radius fixation has been reported in the literature.[12] Carpal tunnel release should be performed if patients present acutely with CTS symptoms that

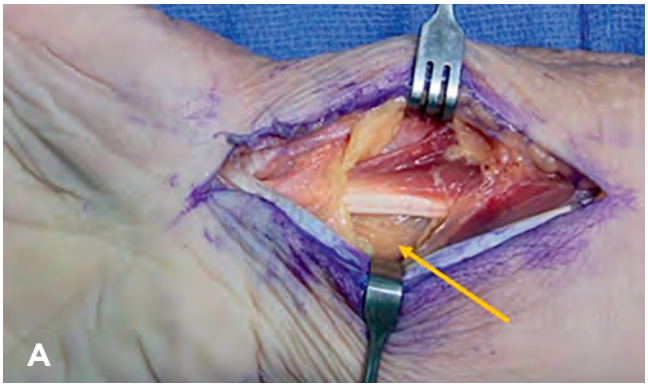


Figure 2. *Photographs of dissections in the extended flexor carpi radialis (FCR) approach. A) The arrow points to the median nerve that lies medial to the FCR tendon encased in fatty tissue. B) Tenotomies identifying a branch of the radial artery distal near the radial septum. C) Forceps identifying the palmar cutaneous branch of the median nerve ulnar to the FCR tendon.*

do not improve with closed fracture reduction. If there is a concern for compartment syndrome caused by accompanying severe forearm or hand injury, fasciotomies and carpal tunnel release should be performed. In patients who have underlying CTS, accompanying surgical release of the carpal tunnel may be considered. The median nerve is protected by applying retraction across the FCR tendon in the extended FCR approach (Figure 2A).

The palmar cutaneous branch of the median nerve typically branches off the radial side of the median nerve 5 cm to 6 cm proximal to the wrist crease, runs with the median nerve for 2 cm to 3 cm, and then runs

along the ulnar border of FCR (Figure 2B). The anatomy of the palmar cutaneous nerve is variable. Care should be taken to sharply incise the volar ulnar aspect of the deep FCR sheath because the palmar cutaneous branch is typically deep to the sheath and lies ulnar.[13]

The radial artery branch that traverses the distal radius volarly is at risk during release of the radial septum distally in the extended FCR approach (Figure 2C). One case report in the literature reports a radial artery pseudoaneurysm after volar distal radius ORIF following postoperative collapse and dorsal displacement of the fracture.[14]

III. Malreduction

Malreduction can lead to injury of the flexor tendons, particularly the flexor pollicus longus (FPL) and flexor digitorum profundus (FDP) of the index finger. In general, acceptable closed reduction parameters include radial height of 8 mm to 12 mm, radial inclination of 21° on anteroposterior view and a neutral tilt of 10° volar tilt on lateral, and intra-articular step-off of less than 2 mm.[15] Many of the newer volar fixed angle plates are designed to fit on the volar surface of distal radii. The plate can be used to facilitate anatomical reduction because the fracture can be reduced to the plate contour. Plates may not fit well when anatomic reduction is not achieved, leading to problems such as intra-articular screw penetration and loss of fixation if the screws are not placed subchondral. Adequate reduction using fixed angle devices is key to fixation of distal radius fractures. The extended FCR approach provides excellent visualization of the volar distal radius and facilitates the reduction of complex distal radius fractures.

Loss of reduction is most often the result of inadequate fixation of the multiple distal fracture fragments. Malreduction of the fracture can also lead to inadequate fixation because the volar plates are designed to capture the fragments in near anatomical reduction. Loss of fixation presents most commonly with dorsal collapse, loss of reduction of the volar lunate facet, or radial shortening.[8] A cadaveric study showed that radii with distal screws placed over 4 mm proximal to the subchondral bone had significantly more radial shortening than when fixed with screws closer to the subchondral bone.[16] Fragment-specific fixation can be particularly useful in volar marginal fragment fractures, in which capturing the volar-ulnar corner is critical for radiocarpal stability.[17] Using the anatomical plate as a guide followed by reduction and fixation into the proximal shaft, the distal fragment first technique can be used where distal locking screws are placed to capture the distal fragment. This technique helps correct volar tilt.[18] Surgeons should aim for anatomic reductions with the subchondral placement of screws and should consider various reduction techniques such as using the plate as a reduction tool.

After treatment of distal radius fractures, DRUJ problems can be a considerable source of morbidity, often owing to the healing of the distal radius fracture in a malreduced position. Contralateral wrist radiographs can be helpful and used as a guide to re-establish anatomical ulnar variance, owing to the variability across individuals. The extended tangential view can help assess intra-articular reduction of the sigmoid notch, DRUJ alignment, and screw breakthrough into the DRUJ.[19,20] Distal radius malunion can restrict forearm rotation and alter DRUJ kinematics, causing pain and instability.[21,22]

IV. Plate Placement

Plate placement may lead to flexor tendon irritation. Rupture can lead to intra-articular screw penetration because the plates are anatomical. Improper plate placement can also contribute to the loss of fixation because the distal fragments are not well stabilized. One of the benefits of volar plating is the decreased risk of tendon irritation and rupture, unlike dorsal plating. The correct technique should be employed to maximize this benefit.

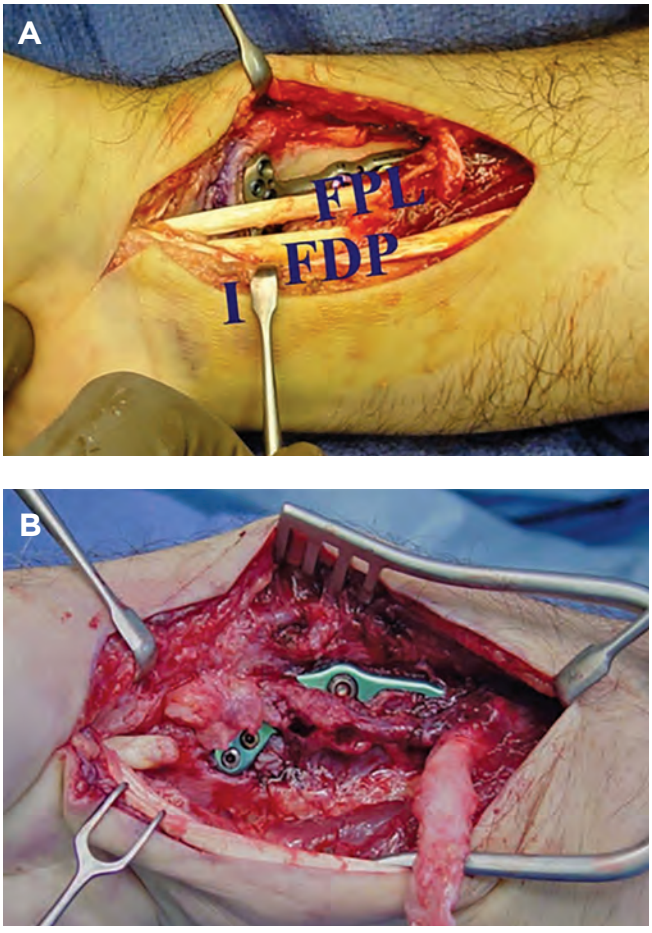


Figure 3. *A) In the extended flexor carpi radialis approach: Identification of the watershed line (I), flexor digitorum profundus (FDP) to the index finger, and flexor pollicis longus (FPL) in relation to a volar fixed-angle distal radius plate. B) FPL rupture in a patient who was taken back to the operating room for exploration after inability to extend their thumb after distal radius volar open reduction internal fixation.*

The watershed line is a ridge on the distal radius just distal to the pronator quadratus and proximal to the volar ligaments of the wrist. Plates placed distal to this line have been shown to have increased rates of flexor tendon injury, most commonly to the FPL and FDP of the index finger (Figure 3A and 3B).[23,24] Screw-back out has also been reported to cause flexor tendon problems.[16,25,26] Re-establishing adequate volar tilt and repairing the pronator quadratus may also aid in the protection of the flexor tendons because the pronator quadratus can be used to cover the entire distal portion of the plate. Anatomic fixed angle plates should be placed proximal to the watershed line. Care should be taken to restore volar tilt and repair the pronator quadratus to minimize the risk of flexor tendon injury.

V. Screw Trajectory/Placement

Screws can be placed with a trajectory that may lead to intra-articular breakthrough, loss of fixation if not placed subchondral, or rupture of the extensor tendons. Screws can inadvertently be placed into the joint (Figure 4), as reported in a series by Arora et al.[25] The goal of fixed angle, volar locked plating is plate placement proximal to the watershed line and the subchondral placement of screws. The 30° lateral allows a tangential view of the radiocarpal joint and is the best method of assessing subchondral screw placement because it provides excellent visualization of the articular surface.[27] Screw lengths should be checked and shortened if needed based on tangential lateral fluoroscopy. The extended tangential view can also be used to evaluate screw lengths. Collapse of intra-articular fractures can also result in penetration of the joint by screws.

Fixed angle anatomic distal radius plates rely on subchondral placement. Bicortical fixation of distal pegs or screws is not required. One technique to avoid tendon or intra-articular complications involves drilling distal screws unicortically instead of bicortically. In a biomechanical study, Wall et al[28] showed unicortical locking screws of at least 75.0% length produced similar construct stiffness to bicortical screws. Pegs or screws will lock into the plate, minimizing the risk of projection past the dorsal cortex.

Figure 4. *A sagittal computerized tomography scan of volar distal radius plate with distal intra-articular extension of screw.*

While extensor tendon rupture is much less common with volar fixation of distal radius fractures compared to dorsal fixation, extensor tendon rupture and synovitis have been reported.[29-32] Prominent dorsal screws and drill tip penetration have been thought to contribute to extensor tendon rupture. Lister's tubercle can make it challenging to identify dorsal screws that are prominent. Live fluoroscopy, the dorsal tangential, or the skyline view can aid in the evaluation of screw lengths dorsally.[33] Fracture type has been shown to be associated with extensor pollicis longus (EPL) rupture risk. A retrospective review of patients with distal radius fractures treated at a single institution with volar locking plates found a 5.7% EPL rupture rate.[32] EPL rupture was found to have a high association to patients with fracture extension into or through Lister's tubercle.[32] Similarly, Lee et al[34] found a higher association of EPL rupture in patients with "displaced dorsal beak fracture of Lister's tubercle." Callus formation, even without screw or drill penetration, can narrow the EPL groove.

VI. Postoperative Management

Inadequate pain management and delayed rehabilitation can lead to poor outcomes after distal radius fracture fixation.

Mobilization and rehabilitation after distal radius ORIF have been studied, and most surgeons advocate for a period of postoperative immobilization.[35] A recent randomized clinical trial of 133 adults found that immobilization of 1 to 3 weeks after ORIF resulted in superior function, range of motion, and pain management.[36] Lozano-Calderón et al[37] studied smaller groups of patients and found no significant differences in two groups of 30 patients who began wrist range of motion 6 weeks after volar plate fixation versus 2 weeks. While the exact length of immobilization is debated, we recommend up to 2 weeks of immobilization, depending on the fracture and surgeon preference. Hand therapy should be started soon after immobilization has been discontinued in patients with clinical stiffness. Finger and thumb range of motion needs to be emphasized whether or not the fractures are treated with surgery. Elevation of the hand and wrist can be helpful to minimize postoperative and post-injury swelling, which can adversely affect outcomes because swelling limits motion.

While distal radius ORIF and other orthopaedic bony procedures are known to be painful, the prescription of narcotic pain medications has become a large topic of debate in recent times. In a prospective series of patients undergoing upper extremity surgical procedures, Kim et al[38] found that their surgeons were prescribing on average 24 opioid pills, and patients

consumed on average 8.1 pills over an average of 3.1 days. Teunis et al[39] found that male sex and greater dorsal angulation of the articular surface on lateral radiograph were associated with requesting a second opioid prescription after locking plate fixation of distal radius fractures. We recommend prescription of no more than 20 opioid pills to patients after distal radius ORIF over 3 days to 2 weeks. Patients should be counseled to expect some postoperative pain and that additional narcotics are not recommended after the first 2-week postoperative visit.

Complex regional pain syndrome (CRPS) may occur after distal radius ORIF and can be difficult to treat.[40] Various studies have suggested that if started on the date of injury, vitamin C supplementation for 50 days may decrease the risk of CRPS after distal radius fracture, while follow-up studies have shown no benefit.[41-43] While the evidence is controversial, vitamin C supplementation is quite benign, and we recommend 500 mg daily to our patients for 50 days post-injury.

VII. Removal of Implants

Volar-locked plates rarely need to be removed, but if there is evidence of tendonitis or tendon rupture, one should not hesitate. Patients may describe a sudden loss of active range of motion of a finger, indicating tendon rupture. In tendonitis, patients often present with dorsal swelling proximal and distal to the extensor retinaculum. Early removal of symptomatic plates is important in preventing tendon rupture.

The rate of plate removal ranges from 3.0% to 10.0% in the literature, most commonly for flexor tendon rupture or irritation.[44,45] Timeframe of rupture is on average 6 months to 26 months postoperatively. Patients should be counseled about warning signs of flexor tendon irritation, including difficult and painful flexion of the thumb, fingers, and volar wrist synovitis.[46] If patients do present with any of these warning signs or symptoms, they should be offered removal of the implant.

CONCLUSION

Distal radius fractures are common. Fixed angle volar locking plates are the most common fixation method for distal radius fractures, with excellent outcomes if done technically well. Complications of volar plating include flexor and extensor tendon injury, malreduction, intra-articular screw penetration, nerve and artery injury, and pain and stiffness. The extended FCR approach can aid in visualization, reduction, and proper plate placement proximal to the watershed line, with the goal of anatomic reduction and distal screw placement subchondral and extra-articular. Tangential lateral, extended tangential, and live fluoroscopy can aid in the examination of screw lengths dorsally. A period of up to 2 weeks of immobilization should be followed by encouraged range of motion and hand therapy. Opioids should be prescribed for no more than 2 weeks. Patients should be counseled to expect some pain postoperatively. Vitamin C may be prescribed for 50 days after the initial fracture. If patients present with concerning signs of tendonitis or tendon rupture, plates should be removed, and patients with ruptures should be treated with appropriate tendon procedures. Avoiding the "seven deadly sins" proposed above can lead to fewer complications in the surgical treatment of distal radius fractures.

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