The EFCR Approach and the Radial Septum-Understanding the Anatomy and Improving Volar Exposure for Distal Radius Fractures: Imagine What You Could Do With an Extra Inch

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The EFCR Approach and the Radial Septum—Understanding the Anatomy and Improving Volar Exposure for Distal Radius Fractures: Imagine What You Could Do With an Extra Inch

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Abstract: Locked volar plating is the most common surgical procedure to address distal radius fractures. The extended flexor carpi radialis approach continues to be an excellent method for visualizing distal radius fractures and applying a volar plate. A new understanding of the anatomy allows for better visualization and reduction of the many different distal radius fracture patterns surgeons commonly see. Within the extended flexor carpi radialis approach, we describe the radial septum in further detail including the anatomy which comprises the radial septum triangle. Knowledge of this area allows for better visualization, more anatomic reductions, and fewer complications.

Key Words: distal radius fracture, extended FCR approach, radial septum, volar approach

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INTRODUCTION AND HISTORICAL PERSPECTIVE

Distal radius fractures are the most common fractures presenting to emergency rooms and volar fixed angle plating has become the most popular method to manage those patients needing operative care. The technique was introduced in 2001[1] using locking plate fixation with the intention of avoiding the complications observed after dorsal plating. As the volar aspect of the distal radius is concave, the volar approach provides more space for hardware application. Volar plating has been used successfully to treat a variety of distal radius fracture patterns.[1–10]

Traditionally, the distal aspect of the volar radius is reached through the Henry or flexor carpi radialis (FCR) approach.[8] These simple approaches can provide the exposure needed for the application of volar angle-stable fixation.[11–15] Unfortunately, complications including malreduction, flexor, and extensor tendon injuries are being reported after volar plating.[16–18] Flexor tendon problems stem from prominent volar hardware and malreduction. Also, extensor tendon problems result from excessively long screws inadvertently placed into the extensor tendon compartments. Despite advances in volar plate design,[19] traditional approaches to the volar radius may not provide sufficient exposure for the proper management of many distal radius fractures.

For example, articular fractures of the distal radius may include a fragment from the volar margin of the lunate fossa. Volar margin of the lunate fossa are often hard to identify radiologically and without direct visualization, these fragments may be missed; failure to properly fix these fragments may result in loss of reduction and volar carpal subluxation.[20]

The extended flexor carpi radialis (EFCR) approach was proposed as an option for management of complex distal radius fractures.[2,21,22] It provides improved access and facilitates reduction and hardware application. Using this technique, we have developed a deeper understanding of the regional anatomy. This knowledge and proper technique may prevent complications.

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INDICATIONS/CONTRAINDICATIONS

The EFCR approach is recommended for most distal radius fractures that meet the criteria for open reduction internal fixation and are considered for volar locking plate fixation. At our center, we utilize the American Academy of Orthopaedic Surgeons distal radius fracture recommendations guide[23] as radiographic parameters for fixation of distal radius fractures. Other indications for operative fixation of distal radius fractures include young active patients, polytrauma patients with complex rehabilitation issues, and functionally independent elderly patients who need a fast return to independence.

Contraindications to volar plating of distal radius fractures include: fractures that are best managed by other means, the unstable polytraumatized patient that needs immediate stabilization such as a bridge plate, patients that are at high anesthetic risks, and fractures involving an open physis in the pediatric population.

TECHNIQUE

Exposure

Obtaining sufficient volar exposure is key to achieving proper reduction and fixation when managing a complex distal radius fracture. Soft tissues must be released properly to protect the carpal tunnel contents and the radial artery, as well as to access the volar marginal fragment, the radial styloid and the dorsal aspect of the fracture.

Identify and mark the 2 flexion creases of the wrist and the palpable prominence formed by the distal pole of the scaphoid and trapezial ridge. An 8-cm incision is made from the distal pole of the scaphoid, proximally along the FCR tendon. An apex-radial dart is used to avoid crossing the flexion creases at a right angle and resultant hypertrophic scarring. The point of the dart is distal of the 2 wrist flexion creases. Note: the FCR points toward the medial epicondyle, so it angles medially across the arm. Note: make sure you have truly marked the FCR tendon and not the more medial palmaris longus tendon.

Branches from the palmar cutaneous or superficial radial nerves occasionally cross the distal FCR tendon sheath, these must be managed properly to prevent the formation of a painful neuroma. If the branches cannot be avoided safely, they are pulled and cut, and allowed to retract proximally away from the surgical plane.

FCR Tendon Sheath

The FCR tendon sheath thickens distally as it courses through the transverse carpal ligament. The ligament divides into superficial and deep leaves, which insert into the trapezium, and form a fibroosseous tunnel for the tendon. The FCR tendon courses over the distal pole of the scaphoid before entering this tunnel; afterwards, it heads toward the base of the second metacarpal. The FCR tendon has a complex insertion that includes fibers inserting into the trapezium at the tunnel.

Open the FCR tendon sheath and release it distally past the level of the superficial radial artery. Release and reflect the superficial radial artery laterally away from the surgical field. This small artery may be ligated if necessary, but preservation is preferred. Split the origin of the abductor pollicis brevis muscle distal to the artery and release the superficial leaf of the FCR sheath at the trapezium (where it dives down at ∼45-degree angle).

After releasing the superficial aspect of the FCR sheath, divide the FCR fibers inserting into the trapezium to allow retraction of the tendon medially (ulnarly). Expose and incise the floor of the FCR sheath along the entire length of the incision, including at the trapezial tunnel. Distally, identifying the flexor pollicis longus (FPL) facilitates dissection as the floor of the sheath separates the FCR from the FPL defining a safe cutting plane. Both leaves of the FCR sheath, superficial and deep, must be released at the level of the trapezium (2 cm beyond the flexion creases) to allow maximal medial retraction of the median nerve and flexor tendons (Fig. 1). This will provide ample exposure of the distal and ulnar aspect of the distal radius and allow comfortable management of a volar marginal fragment.

During dissection, the motor branch of median nerve is not at risk, as it is distal and superficial to the thenar muscles. At this point, a carpal tunnel release can be done by releasing both leaves of the FCR sheath to the very distal edge of the carpal ligaments.[24] Note: the FPL angles toward the thumb at the distal edge of the ligament, using the distal edge of the carpal tunnel as its pulley; therefore, care should be taken to protect the FPL tendon.

Midlevel Dissection

More proximally, after bluntly dissecting through the floor of the FCR sheath, elevate the FPL from the radius in a radial-to-ulnar direction, and divide any perforating branches from the radial artery and attachments to the brachioradialis tendon. This maneuver completely opens the space between the flexor tendons, radius, and pronator quadratus (PQ) (space of Parona). Release the synovial reflection (carpal bursa) that separates the space of Parona from the carpal tunnel to communicate both spaces and increase exposure (Note: these reflections run from the surface of PQ and the volar radius directly anterior to the flexor tendons and are perpendicular to the volar surface of the bone).

The Radial Septum

The radial septum is the distal aspect of the lateral wall of the flexor compartment and consists of several converging connective tissue structures.[2] It is continuous with the lateral aspect of the radius and the radiocarpal ligaments in its deep aspect, and to the FCR tendon sheath superficially. Proximally, the radial septum consists of the thin intramuscular membrane spanning from the lateral edge of the radius to the brachioradialis (Fig. 2). Distally, the radial septum is more substantial and forms the lateral wall of the carpal bursa, ending distally as the FCR converges with the carpal bones.

FIGURE 1. Release of both the superficial and deep leaves of the flexor carpi radialis sheath to allow retraction of the median nerve and flexor tendons. full color online

The distal part of the radial septum consists of dense connective tissue. There are no clear tissue planes separating it from the underlying wrist ligaments or the overlying FCR sheath but the appearance of its fibers is distinct. Volar wrist ligament fibers are parallel and compact, whereas septal fibers are disorganized and loose. The distal segment of the radial septum extends from the volar radial tuberosity[25] toward the scaphoid. It is a 3-dimensional structure, narrow proximally and wider distally, having a floor (volar carpal ligaments) and a roof (FCR sheath), and therefore, a triangular wedge shape. This region is called the radial septum triangle (RST). The apex (peak) of the triangle is located proximally at the volar radial tuberosity. The base is distal and broad extending from the scaphoid tuberosity to the lateral wall of the carpal tunnel, which defines the medial edge of the RST (Fig. 3). The radial artery parallels the lateral edge of the RST before diving beneath the first extensor compartment toward the dorsum of the hand. The radial artery and the radial sensory nerve are always located lateral to the radial septum.

Release the radial septum proximally by incising along the superficial border of the brachioradialis (Fig. 2). Dissect in

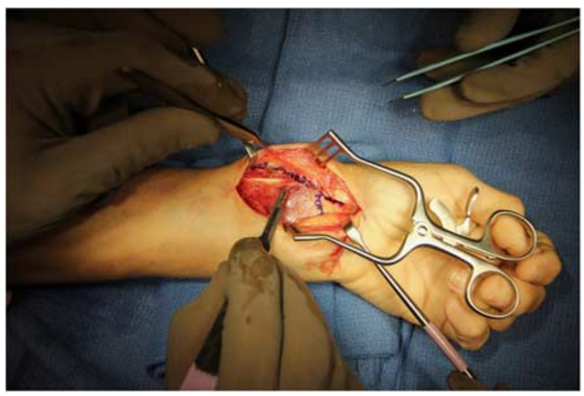

FIGURE 2. Proximally, the radial septum consists of the thin intramuscular membrane spanning the lateral edge of the radius to the brachioradialis. Release the radial septum proximally by incising along the superficial border of the brachioradialis. full color online

a distal direction and avoid dissecting between the brachioradialis and the radius. As brachioradialis begins to insert on the radial styloid, forming the floor of the first extensor compartment, the radial artery and septum will cross over to the volar surface of the radius (exactly at the location where the radial pulse is palpated on physical examination). The first extensor compartment cannot be visualized without retracting the radial artery radially and rolling it over the edge of the radial styloid. The investing fascia that tethers the artery to the direct volar surface of the radius is the radial septum and divide the radial septum to allow visualization of the first extensor compartment.

Expose the first extensor compartment, release it, and mobilize its tendons. This prevents the first compartment tendons from pulling against the fibroosseous tunnel and acting as a deforming force on the radial styloid. Now palpate to identify the volar radial tubercle, where the apex of the RST is located (Fig. 4), and dissect distally in the plane between the RST and the volar wrist ligaments. Continue elevating the RST distally until the radial artery is visualized passing underneath the first extensor compartment.

Releasing the radial septum greatly enhances exposure of the lateral aspect of the distal radius and allows dividing the brachioradialis tendon, a major deforming force of the distal radius fracture. Releasing its distal part or RST, allows safe lateral retraction of the radial artery and radial sensory nerve and provides the distal and lateral exposure necessary to manage articular fractures with lateral column comminution.

Exposing the Volar Radius

The volar surface of the distal radius is not flat but presents 2 elevations, the prominent volar rim of the lunate fossa and the volar radial tubercle. Between them is a depression, the interfossa sulcus. The watershed line is the distal rim of the pronator fossa and runs as a ridge between the summits of

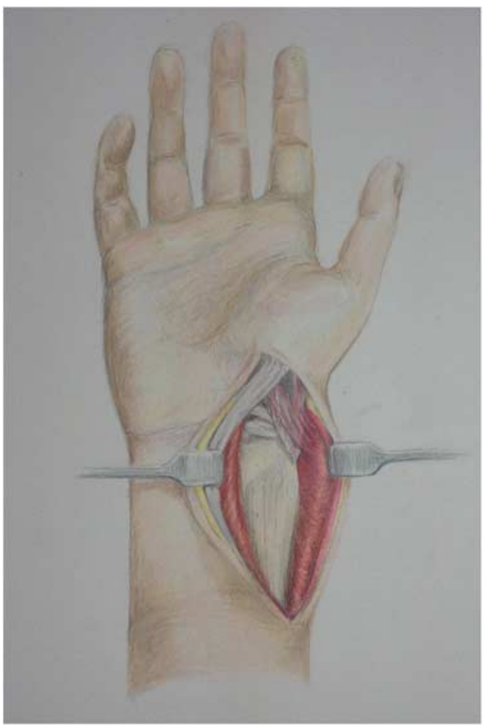

FIGURE 3. Drawing of the radial septum triangle. full color online

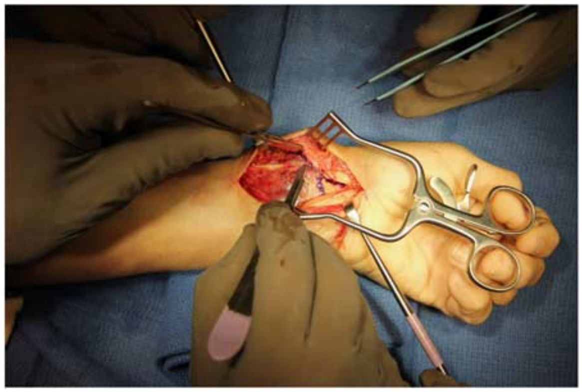

FIGURE 4. Distal dissection in the plane between the radial septum triangle and the volar wrist ligaments. full color online

these 2 elevations and along the interfossa sulcus. Flexor tendons come closest to the radial surface along the watershed line. The PQ muscle is located several millimeters proximal to the watershed line; between these 2 structures is the transitional fibrous zone (TFZ), a zone of thick periosteum that attaches to the volar radius just before the origin of the volar radiocarpal ligaments.

First, identify the location of the watershed line by palpating along the distal radius for the volar rim of the lunate fossa, which is the most volarly prominent part of the distal radius. Incise the periosteum along the watershed line from medial to lateral across the width of the radius to the volar radial tubercle. Then incise the periosteum proximally along the length of the PQ insertion. Elevate sharply the TFZ and PQ in a proximal and medial direction creating an ulnar-based flap (Fig. 5). Occasionally, these 2 structures have been separated by the injury. Avoid stripping the ulnar border of the radius, as perforators from the anterior interosseous artery are located here and are the proximal fragment's main blood supply. Elevate the soft tissues covering the radius to the level of the watershed line, allowing visualization and optimal fixation of volar ulnar fragments.

Releasing the Brachioradialis

The brachioradialis courses on the intramuscular septum, gently approaching the radius and inserting into the floor of the first extensor compartment. Inveterate extra-articular fractures and displaced fragments of the scaphoid fossa or radial styloid are often difficult to reduce because of the pull of this structure. Hence, its release is often of great value. The insertion on the radial styloid should not be disrupted, but any other attachments to the proximal fracture fragments should be released. Divide the tendon proximal to the metaphysis to fully mobilize the distal fragment. A step-cut tenotomy facilitates its subsequent repair and provides an anchor point for later repair of the PQ (Fig. 6).

Dorsal Intrafocal Exposure

Dorsally displaced fractures often present with an intact dorsal periosteum enveloping an organized hematoma, which impedes restoration of volar tilt and results in volar plate prominence and injury to flexor tendons. Displaced articular fractures may be difficult to reduce or may present impacted central articular fragments that require direct manipulation. Other fractures may be old and present with a contracted dorsal periosteum or considerable dorsal callus impeding reduction.[22]

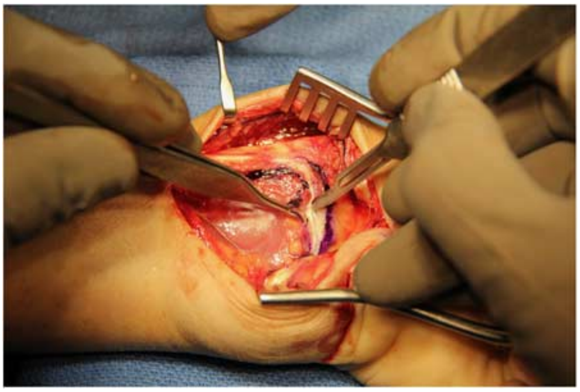

FIGURE 5. Incision of the periosteum along the watershed line from medial to lateral across the width of the radius to the volar radial tubercle, and incise the periosteum proximally along the length of the pronator quadratus insertion. Elevate sharply the transitional fibrous zone and pronator quadratus in a proximal and medial direction creating an ulnar-based flap. full color online

Therefore, there is often need to access the dorsal aspect of the fracture through the volar approach.

Use the fracture plane for exposure and rotate the proximal fragment into pronation (intrafocal exposure; Fig. 7). This maneuver, allows for hematoma removal, release of contracted dorsal periosteum, debridement of dorsal fracture callus. Manipulate the dorsal fragments into place using this exposure, eliminating the need for a separate dorsal approach. This approach also provides direct access for management of central-impacted articular fragments. Bone graft can be placed in the rare cases when the central fragments are too comminuted to maintain a reduced position before hardware application. Supinate the proximal radius back into place and reduce the fracture by aligning the volar fracture line and restoring volar tilt. A properly designed plate will act as a template to help restore volar tilt. Applying traction and the use of a bolster facilitates reduction.

Plate Application

Volar locking plates provide both subchondral support of the articular surface and buttressing of palmar fragments. Complex fractures require both modes of fixation. Proper plate placement is necessary to optimize stability. The plate should be placed distal enough to locate the fixed angle elements close to the subchondral bone and provide optimal volar buttressing but proximal enough to avoid intra-articular hardware and volar plate prominence. Volar plates must be placed at least 2 mm proximal to the watershed line to prevent encroaching into the space for the flexor tendons.[26] Also, proper screw length is very important, as screws should be long enough to provide adequate support to the dorsal subchondral bone but short enough not transgress the dorsal cortex to prevent extensor tendon injury.[27]

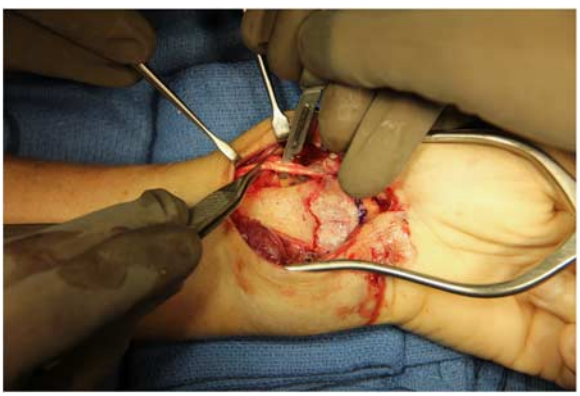

FIGURE 6. A step-cut tenotomy. full color online

Radiographs and Closing

After obtaining fixation, confirm reduction, screw length, and proper placement using anteroposterior, axial and 30-degree elevated lateral fluoroscopic views.[28] The sigmoid notch can be evaluated using the dorsal tangential view.[29] Repair the brachioradialis so it can serve as an attachment for the PQ muscle. Repair the TFZ back to the watershed line to cover the distal edge of the volar plate. This serves to further protect the flexor tendons. Now suture the PQ muscle to the repaired brachioradialis and TFZ (Fig. 8). Suture the FCR tendon back to its original position on the trapezium and FCR sheath to restore its function of supporting the distal pole of the scaphoid. Close the incision in your normal manner.

Rehabilitation

After surgery, place the patient in a well-padded postoperative dressing. Elevate. Start immediate finger motion, forearm rotation, and functional use of the hand with a weight restriction of 5 to 10 lbs. At the first postoperative visit, have the patient make a fist. Remove the postoperative dressing and transition the patient to well-molded short-arm splint in extension. At this time and under supervision of a therapist, initiate forearm rotation and active wrist range of motion. Strengthening is started at the 8 week postoperative mark. Passive wrist motion exercises are seldom performed. Weight restrictions should be maintained until radiographic union has been achieved, usually at 6 to 10 weeks.

EXPECTED OUTCOMES AND COMPLICATIONS

Multiple series of volar plating with high complication rates have been reported in the literature[16–18] but our experience with the EFCR approach does not reflect this. Complications from volar plating can be avoided with meticulous technique and a thorough understanding of the wrist anatomy. A commonly reported complication is flexor tendon rupture[26,30–33]; however, the incidence of flexor tendon rupture

FIGURE 7. Rotation of the proximal fragment into pronation to gain intrafocal exposure to allow hematoma removal, release of contracted dorsal periosteum, debridement of dorsal fracture callus, and management of central-impacted articular fragments. full color online

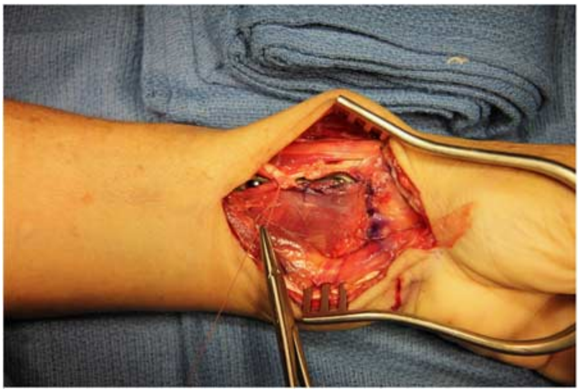

FIGURE 8. Repair of the brachioradialis. Repair the transitional fibrous zone back to the watershed line. Suture the pronator quadratus muscle to the repaired brachioradialis and transitional fibrous zone. Suture over the flexor carpi radialis tendon back into its original position. full color online

is negligible after proper reduction and plate placement.[26] Also, proper soft tissue repair may be of benefit. Another common complication is extensor tendon injury caused by prominent screws on the dorsal aspect of the radius.[27] Although, visualization of long screws is difficult in a lateral radiograph, awareness of the problem and tangential views allow the surgeon to avoid this problem.[29] Close postoperative follow-up will reveal technical mistakes and allow treatment by early hardware removal. We have observed very few cases of deep infection, shortening, loss of reduction, or hardware failure with utilization of modern locking plates. Another common problem with distal radius fractures is postfracture carpal tunnel syndrome. We screen all of our patients preoperatively for evidence of median neuropathy and frequently perform carpal tunnel release.[24]

DISCUSSION

Distal radius fractures remain a challenge, and despite being the most common fracture type treated by the hand or orthopedic surgeon, there is no standardization of treatment. Locked volar plating is the most commonly performed surgical method for distal radius fixation; however, as this procedure gained wide acceptance very quickly, many experienced surgeons have little formal training on it. Although most fractures reduce easily and a simple volar exposure suffices to apply a volar plate successfully, a significant number of these injuries cannot be treated by a simple approach. This has resulted in an abundance of complications of which the most serious are flexor tendon ruptures. These occur most frequently because fracture malreduction and the lack of volar tilt results in volar plate prominence that causes flexor tendon attrition.[34] Distal radius fractures are often difficult to reduce because the commonly present intact dorsal periosteum cradles an organizing hematoma that impedes restoration of length or volar tilt. As in most fractures, debridement of the hematoma is necessary for reduction. When performing a volar approach for the common dorsally displaced distal radius fracture, removal of the organizing dorsal hematoma is impossible unless a separate dorsal incision is made or the EFCR approach is utilized. An additional dorsal incision invites unnecessary morbidity including devascularization of the distal fragments, a dorsal scar and extensor tendon adhesions. We prefer the use of the EFCR approach as it is faster and avoids a dorsal incision. This approach requires knowledge of the anatomy and is not trivial but has proven to be a very useful tool when managing the complex distal radius fracture. Disadvantages of the approach include it being technically involved and the impossibility to directly visualize the articular surface. Perceived drawbacks such as it being "too aggressive" and fears of devascularizing the proximal fragment have shown not to be true. In our experience, nonunions have been practically nonexistent; we have only observed isolated nonunions of the volar marginal fragment, which receives its tenuous blood supply in a retrograde manner from the volar capsule and has been, until recently, very difficult to fix. The EFCR approach, by virtue of extending further distal and therefore providing better exposure of the medial aspect of the radius, actually facilitates the management of this fragment.

Fractures of the distal radius will continue to rise with the growing population of the elderly in the United States and therefore, the need for open reduction internal fixation of these fractures will grow as well. We believe that the incidence of complications resulting from the management of these injuries can be greatly reduced if the understanding of the surgical anatomy of the distal radius and the technique of the EFCR approach is shared widely.

REFERENCES

1. Orbay JL. The treatment of unstable distal radius fractures with volar fixation. *J Hand Surg*. 2000;5:103–112.
2. Orbay JL, Badia A, Indriago IR, et al. The extended flexor carpi radialis approach: a new perspective for the distal radius fracture. *Tech Hand Surg*. 2001;5:204–211.
3. Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fracture of the distal radius: a preliminary report. *J Hand Surg*. 2002;27A: 205–215.
4. Orbay JL, Fernandez DL. Volar fixed-angle plate fxation for unstable distal radius fractures in the elderly patient. *J Hand Surg*. 2004;29A: 96–102.
5. Orbay J, Badia A, Khoury RK, et al. Volar fixed-angle fixation of distal radius fractures: The DVR plate. *Tech Hand Up Extrem Surg*. 2004;8:142–148.
6. Orbay JL, Touhami A. Current concepts in volar fixed-angle fixation of unstable distal radius fractures. *Clin Orthop Relat Res*. 2006;445: 58–67.
7. Protopsaltis TS, Ruch DS. Volar approach to distal radius fractures. *J Hand Surg*. 2008;33A:958–965.
8. Henry MH. Distal radius fractures: current concepts. *J Hand Surg*. 2008;33A:1215–1227.
9. Lattmann T, Dietrich M, Meier C, et al. Comparison of 2 surgical approaches for volar locking plate osteosynthesis of the distal radius. *J Hand Surg*. 2008;33A:1135–1143.
10. Fok MW, Klausmeyer MA, Fernandez DL, et al. Volar plate fixation of intra-articular distal radius fractures: a retrospective study. *J Wrist Surg*. 2013;2:247–254.
11. Becker GW, Owers KL. Suboptimal positioning of fragment-specific palmar distal radius plates. *J Hand Surg Eur*. 2012;37:371–372.
12. Chang HC, Poh SY, Seah SC, et al. Fragment-specific fracture fixation and double-column plating of unstable distal radial fractures using AO mini-fragment implants and Kirschner wires. *Injury*. 2007;38:1259–1267.
13. Gavaskar AS, Muthukumar S, Chowdary N. Fragment-specific fixation for complex intra-articular fractures of the distal radius: results of a prospective single-centre trial. *J Hand Surg Eur*. 2012;37E:765–771.
14. Grindel SI, Wang M, Gerlach M, et al. Biomechanical comparison of fixed-angle volar plate versus fixed- angle volar plate plus fragment-

specific fixation in a cadaveric distal radius fracture model. *J Hand Surg*. 2007;32A:194–199.

15. Sammer DM, Fuller DS, Kim HM, et al. A comparative study of fragment-specific versus volar plate fixation of distal radius fractures. *Plast Reconstr Surg*. 2008;122:1441–1450.
16. Arora R, Lutz M, Hennerbichler A, et al. Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. *J Orthop Trauma*. 2007;21:316–322.
17. Patel VP, Paksima N. Complications of distal radius fracture fixation. *Bull Hosp Jt Dis*. 2010;68:112–118.
18. Rampoldi M, Marsico S. Complications of volar plating of distal radius fractures. *Acta Orthop Belg*. 2007;73:714–719.
19. Limthongthang R, Bachoura A, Jacoby SM, et al. Distal radius volar locking plate design and associated vulnerability of the flexor pollicis longus. *J Hand Surg Am*. 2014;39:852–860.
20. Harness NG, Jupiter JB, Orbay JL, et al. Loss of fixation of the volar lunate facet fragment in fractures of the distal part of the radius. *J Bone Joint Surg Am*. 2004;86-A:1900–1908.
21. McCann PA, Amirfeyz R, Wakeley C, et al. The volar anatomy of the distal radius—an MRI study of the FCR approach. *Injury*. 2010;41:1012–1014.
22. Wijffels MME, Orbay JL, Indriago I, et al. The extended flexor carpi radialis approach for partially healed malaligned fractures of the distal radius. *Injury*. 2012;43:1204–1208.
23. American Academy of Orthopaedic Surgeons/American Association of Orthpaedic SurgeonsLichtman DM, Bindra RR, Boyer MI, et al. AAOS guideline on the treatment of distal radius fractures. First Edition. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2009. www.aaos.org/research/guidelines/drfsummary.pdf. Accessed August 19, 2015.
24. Pensy RA, Brunton LM, Parks BG, et al. Single-incision extensile volar approach to the distal radius and concurrent carpal tunnel release: cadaveric study. *J Hand Surg*. 2010;35A:217–222.
25. Clement H, Pichler W, Nelson D, et al. Morphometric analysis of lister's tubercle and its consequences on volar plate fixation of distal radius fractures. *J Hand Surg*. 2008;33A:1716–1719.
26. Soong M, Earp BE, Bishop G, et al. Volar locking plate implant prominence and flexor tendon rupture. *J Bone Joint Surg*. 2011;93-A: 328–335.
27. Maschke SD, Evans PJ, Schub D, et al. Radiographic evaluation of dorsal screw penetration after volar fixed-angle plating of the distal radius: a cadaveric study. *Hand*. 2007;2:144–150.
28. Joseph SJ, Harvey JN. The dorsal horizon view: detecting screw protrusion at the distal radius. *J Hand Surg*. 2011;36A:1691–1693.
29. Ozer K, Toker S. Dorsal tangential view of the wrist to detect screw penetration to the dorsal cortex of the distal radius after volar fixed-angle plating. *Hand*. 2011;6:190–193.
30. Cho CH, Lee KJ, Song KS, et al. Delayed rupture of flexor pollicis longus after volar plating for a distal radius fracture. *Clin Orthop Surg*. 2012;4:325–328.
31. Valbuena SE, Cogswell LK, Baraziol R, et al. Clinical case: rupture of flexor tendon following volar plate of distal radius fracture. Report of five cases. *Chir Main*. 2010;29:109–113.
32. White BD, Nydick JA, Karsky D, et al. Incidence and clinical outcomes of tendon rupture following distal radius fracture. *J Hand Surg*. 2012;37A:2035–2040.
33. Cross AW, Schmidt CC. Flexor tendon injuries following locked volar plating of distal radius fractures. *J Hand Surg*. 2008;33A:164–167.
34. Selvan DR, Machin DG, Perry D, et al. The role of fracture reduction and plate position in the aetiology of flexor pollicis longus tendon rupture after volar plate fixation of distal radius fractures. *Hand*. 2015;10:497–502.