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Complications Associated with Volar Locking Plate Fixation of Distal Radial Fractures.

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INTRODUCTION:

Distal radius fractures are among the most common orthopaedic injuries. Of 590,193 fractures of the upper extremity documented in the United States in 2009, distal radius fractures were the most common.(1) Additionally, they comprise one-sixth of all fractures seen in the emergency room.(2) In recent years, incidence of this already common fracture has continued to increase in pediatric, adult, and elderly populations alike.(3)

However, despite the high incidence of distal radius fractures, consensus regarding optimal treatment strategy still does not exist. Current treatment options include closed reduction, closed reduction with percutaneous pinning, intramedullary fixation, external fixation, and various open reduction and internal fixation strategies.(4, 5) Of these, open reduction and internal fixation with plates has seen a steady increase in use over the past two decades due to purported faster functional recovery and better radiographic alignment,(6) although better radiographic outcome does not necessarily translate to better long-term functional outcome in all groups.(7, 8) During this time there has been a simultaneous decreased use of dorsal plating due to concerns for extensor tendon irritation,(9) and a concomitant increase in the use of volar locked plating of distal radius fractures, particularly among newer surgeons.(10)

Volar locked plating of distal radius fractures has grown in popularity for several reasons including a consistent and reproducible surgical approach, broad range of fractures patterns that a volar plate can treat, and a reasonable complication profile compared to other operative fixation methods with a reportedly lesser rate of tendon injury.(11) However, there remain fractures that should not be treated with volar plating, including highly comminuted fractures which may be better managed with wrist arthrodesis.(12, 13) Additionally, the exact incidence and pattern of complications from volar locking plates for distal radius fractures are not well understood.

EVOLUTION OF VOLAR LOCKING PLATE TECHNOLOGY

Volar plating of distal radius fractures has been a surgical option since the introduction of AO principles of fracture fixation. Initially, volar plates were primarily indicated for buttress reduction and fixation of volar shear fractures, aka volar Barton's fractures.(14, 15) (FIGURE 1) Later, the indication for volar plating increased with the introduction of non-locked but lower profile volar plates with increased screw fixation options and smaller subchondral screws, such as the volar T plate (FIGURE 2).(16) Although popular upon their introduction, these volar plates still required bicortical fixation of the distal subchondral screws resulting in prominent and sharper screws dorsally putting the dorsal extensor tendons at risk.(17-19) The original non-locking plate design also required distal placement on the radius, therefore also putting at risk the flexor tendons volarly.(20)

In 2000, Orbay et al.introduced volar fixed-angle locking plates in an effort designed to provide stable internal fixation of distal radius fractures with the goals of earlier mobilization and less risk of tendon dysfunction (FIGURE 3).(21-23) This new locking plate design improved resistance to stress and allowed for lower profile screws volarly recessed into the plate, as well avoidance of screw prominence dorsally.(24)

Starting in 2005, variable-angle (polyaxial) locking screw technology has been incorporated into locking volar plates (FIGURE 4).(25) This design allows the surgeon to direct the angle and position of the screws instead of following pre-designated screw position. Moreover, the use of variable-angle locking screws allow placement of fixation within the radial styloid, targeting higher quality bone. It also facilitated avoidance of joint penetration.(26)

COMPLICATIONS OF VOLAR PLATES

While the increased usage of volar plating was intended to avoid the high frequency of tendon complications in dorsal plating, these complications have not been eliminated entirely, and the volar plate is associated with additional complications that do not commonly occur with dorsal plates.(27) These complications include, but are not limited to: nerve dysfunction, tendon dysfunction, and hardware failure. The remainder of this review will focus on the complications associated with volar locked plating of distal radius fractures.

TENDON INJURY:

Extensor tendon injuries can result as a complication of distal radius fractures independent of treatment method.(28-31) Recent systematic reviews have reported the incidence of this extensor tendon rupture as 0.4% (6/1,359) with conservative management(32) and 1.5% (15/1,032) with dorsal plating.(33) However, the incidence of this injury has been shown to be substantial following volar plate fixation of distal radius fractures, with reported rates ranging from 0-4%.(34-39) While multiple extensor tendons are at risk, including the extensor digitorum communis and extensor indicis,(40) the extensor pollicis longus (EPL) tendon is the most frequently affected. Zenke et al(34) reported EPL rupture in 2% of a cohort of 286 patients treated with volar plating, while Tarallo et al(35) reported EPL rupture rate of 1% in a cohort of 303 patients.

Incidence of extensor tendon injury has also been shown to be related to not only placement of excessively long screws that are prominent dorsally, but also from direct drill-bit penetration and irritation from bone fragments or comminution dorsally (FIGURE 5).(41-43) Methods to avoid extensor tendon injury revolve around attention to proper surgical technique, accurate placement of the plate volarly, precise screw length selection to avoid dorsal screw prominence, or the use of locking pegs instead of screws to avoid the sharp tip of a screw.(40, 44) Prompt implant removal is recommended upon early signs of extensor tendon irritation.(42)

Flexor tendon injury is a major but uncommon complication of volar plating, as it does not usually occur due to the longer distance between flexor tendons and the proximal volar cortex of the distal radius, the recessed nature of the volar plate relative to the volar rim or watershed line of the distal radius, and the potential benefit of a repaired pronator quadratus over the volar plate.(45) When flexor tendon rupture does occur, it most frequently affects the flexor pollicis longus (FPL) tendon, although other tendons such as the flexor digitorum profundus may also rupture.(46) While one study has reported the rate of flexor tendon rupture to be as high 11%,(47) the majority of recent studies report no flexor tendon injury at all.(48-51) Brennan et al(51) reported no cases of flexor tendon injury in a series of 151 patients treated with volar plating.

The incidence of flexor tendon injury has been shown to be related to prominence of the implant relative to the watershed line of the distal radius, where the flexor tendons would lie closest to the plate or its subchondral locking screws, malreduction of the fracture with residual dorsal angulation increasing plate prominence, or loose or prominent subchondral locking screws (FIGURE 6).(52-56) Among the reported flexor tendon ruptures, the median interval between surgery and rupture was 9 months (range 6-26), highlighting the importance of symptom monitoring at final follow-up.(46) Additionally, the mean age of patients with flexor tendon injuries is 61 years with a female predominance.(46, 57) Factors that may avoid flexor tendon injury include placement of the volar plate proximal to the watershed line, confirming that all subchondral locking screws are locked and flush, and early removal of the plate upon signs of tendon dysfunction such as pain, crepitus, or triggering.(58) Closure of the pronator quadratus muscle over the plate has also been suggested to decrease incidence of flexor tendon injury.(59-61) However, there is no evidence that repair or closure of the pronator quadratus muscle is efficacious when the distal radius is anatomically reduced and the volar plate is properly positioned.(62-66)

In addition to tendon rupture, tenosynovitis is a frequent, though less severe, complication of volar plating. Among the available literature, rates of tenosynovitis appear to be similar for both the extensor and flexor tendons, varying from 0-3.8% for extensor tendons and 0-3.8% for flexor tendons.(8, 35, 48, 51, 67) The methods for preventing these injuries are largely similar to those for preventing tendon rupture, but treatment relies largely on symptomatic relief and immobilization rather than re-operation.

NERVE:

Carpal tunnel syndrome (CTS) is the most common nervous tissue-related complication associated with volar locked plating of distal radius fractures.(42, 68) However, CTS may occur after distal radius fracture regardless of treatment method, with reported rates ranging from 0-20% with conservative management(69-72) and 0-14% with volar plating.(42, 48, 68, 73, 74) Zhao et al compared 7 treatment methods for distal radius fractures, including volar plating, and found no significant difference in the incidence of CTS among the different treatment options.(75) In a series of 282 patients treated with volar plating, Ho et al found an incidence of CTS of 3.2%,(76) which is similar to the 3.8% incidence in the general population.(77) With this in mind, it is a challenge to determine the true incidence of CTS following volar plate fixation. Moreover, determining this incidence is further complicated by the fact that a carpal tunnel release (CTR) is often done prophylactically with volar plating of distal radius fractures in various published series.(78, 79)

While the existence of a cause-and-effect relationship of volar plating and CTS is not entirely clear, and performing prophylactic CTR remains controversial, it remains essential to perform a thorough history and physical in all distal radius fracture patients to identify CTS symptoms prior to operative management, and care should be taken not to injure the median nerve during surgery.(80) In fact many of the median nerve injuries seen post-operatively are likely related to intra-operative damage rather than compressive neuropathy and would not respond to carpal tunnel release. Moreover, the risk factors for CTS after distal radius fracture should be understood and include: fracture severity and displacement resulting in nerve contusion or compression (FIGURE 7), prolonged deformity and swelling, prominent hardware, retractor placement intra-operatively, use of an extensile carpal tunnel approach rather than a trans-FCR or Henry surgical approach,(81) and post-operative splinting or casting tight or in wrist flexion.(82) Frequency of surgical carpal tunnel release following this complication varies widely, with release rates from 0-100% reported for CTS as a complication of both conservative and operative management.

Beyond CTS, complex regional pain syndrome (CRPS), formerly known as reflex sympathetic dystrophy (RSD), is the second most commonly reported nervous tissue-related complication following volar plating of distal radius fractures, with reported incidence ranging from 0-9%.(37, 38, 42, 68, 83) However, due to its variable presentation and inconsistent diagnostic criteria, the exact incidence is difficult to compute. As CRPS is a challenging and potentially devastating complication, emphasis must be placed on early recognition and emergent treatment. The primary feature of CRPS is continued pain out of proportion to the injury, but it is often associated with hyperesthesia, changes in skin blood flow, edema, and restriction of motion, among other manifestations.(84, 85)

Although a consensus for management of CRPS has yet to be established, there exists evidence in support of the use of pain management, intravenous immunoglobulin (IVIG), aerobic exercise, intrathecal clonidine/baclofen, mirror therapy, and many other treatments.(86) Because no single treatment option has emerged as being superior, clinicians should focus on starting multimodal therapy as early as possible. Some recent efforts have aimed at prevention with prophylactic vitamin C supplementation.(87-89) In a systemic review and meta-analysis of 875 patients given prophylactic vitamin C after wrist fracture, Aïm et al found that daily supplementation with 500 mg for 50 days leads to a significantly decreased risk of developing CRPS (RR 0.54 [95% CI, 0.33-0.91]; P=0.02).(87) However, more recent studies have called into question the efficacy of Vitamin C in preventing CRPS.(89, 90)

Additional nervous-tissue-related complications with volar plating that have been reported include injury to the palmar cutaneous branch of the median nerve(92, 93) and radial and ulnar nerve neuropathies,(74, 94) but these are all less frequent.

HARDWARE:

Hardware-related complications appear to be less common than both tendon and nerve-related complications with volar plating of distal radius fractures. Reported rates of hardware complications range from 0-7%, with malunion being the most commonly reported problem.(38, 48, 51, 68, 74) (FIGURE 6 & 8) Other hardware-related complications include screw loosening, intra-articular screw placement, loss of reduction, and broken plate and screws. In a prospective study of 228 patients treated with volar plating, Lattmann et al reported a hardware complication rate of 0.9% (2/228),(38) with both being a result of loss of reduction. A similarly large study by Wichlas et al that retrospectively studied 225 patients treated by volar plate reported only one hardware complication (malunion), resulting in a 0.4% (1/225) complication rate.(48) However, a prospective study of 100 patients treated by volar plate conducted by Kato et al found a hardware complication rate of 7% (7/100), all of which were malunions.(74) Care should be taken intra-operatively to prevent malunion by ensuring anatomic reduction with minimal dorsal angulation, proper placement of locking screws in subchondral bone, and sufficient depth of screws. While bone grafting is often used for fractures with large bone gaps, they are associated with significant morbidity,(95) and recent evidence supports the notion that bone grafting is not necessary with the use of volar plating.(35, 96, 97) If malunion occurs despite these measures, corrective osteotomy should be performed as soon as the diagnosis is confirmed radiographically.(98)

OTHER COMPLICATIONS:

Other complications that may be encountered with volar plating of distal radius fracture include but are not limited to finger or wrist contracture, chronic pain, trigger finger, or radioulnar synostosis. Additionally, there are many inherent complications with any surgical operation including infection, incision dehiscence, cellulitis, abscess, and hematoma. Of these, infection appears to be the most common, affecting between 0-2.6% of patients.(35, 48, 51, 83, 99) There exist also complications specific to any plating, that are not specific to the plate type, such as re-fracture or peri-prosthetic fracture secondary to new trauma.

Additionally, many patients have their plates removed for a number of reasons. While some plates are removed as a result of other complications such as tendon rupture, infection, or malunion, many patients request to have their plates removed for discomfort associated with the retained plate, decreased range of motion, pain, or anxiety related to the plate. It appears as though the all-cause incidence of hardware removal lies between 0-26%,(35, 48, 49, 51, 100) with significant variation depending on clinician preference.

VOLAR PLATE SPECIFIC COMPLICATIONS:

Currently, a number of volar plate options exist, including fixed-angle and variable-angle locking plates, with their own potential complication profiles:

FIXED-ANGLE LOCKING PLATES:

Locking plates were initially introduced to manage fractures in osteoporotic bone, bridging severely comminuted fractures, repairing articular fractures, and plating fractures that cannot be plated on the tension side of the bone.(24) As they have grown in popularity, volar locking plates are now the most frequently used form of implant used for internal fixation of distal radius fractures.(101) Reported rates of tendon complications range from 0-4.5%, with the EPL being the most commonly affected tendon.(38, 48, 51, 74, 94, 99, 102, 103) In a retrospective review of 206 patients treated with volar locking plates, Johnson et al found four cases of tendon rupture, including three EPL ruptures (1.5%) and one FPL rupture (0.5%).(103) Rates of nerve complications range from 0.4-14%, with CTS being the most commonly reported type.(38, 48, 51, 74, 94, 99, 102, 103) One large multi-institutional retrospective study by Satake et al identified 694 patients treated by volar locking plate, of which only 4 cases of tendon rupture (0.6%) were reported, while 18 cases of CTS (2.6%) and 3 cases of CRPS (0.4%) were reported, indicating a greater incidence of nerve complications than tendon complications.(93)

Reported rates of hardware-related complications range from 0-7%, with malunion being the most frequent.(38, 48, 51, 74, 94, 99, 102, 103)

Some studies have also directly compared the outcomes of volar non-locking and volar locking plates. One study by Obert et al retrospectively compared 31 patients treated by volar plating with non-locking screws to 121 patients treated by volar plating with locking screws and found no significant difference in the overall complication rates of the two groups (16.1% vs. 16.5%). However, no patients in the non-locking group experienced tendon ruptures, while 6 patients (5%) in the locking group did.(104) Another smaller study by Schmelzer-Schmied et al prospectively compared 15 patients treated with external fixation to 15 patients with non-locking and 15 patients with locking volar plates, finding that there were fewer complications in the volar plate groups but no difference between non-locking and locking plates (6% vs. 13%).(105) Zhang et al, in a retrospective comparison of 32 patients receiving non-locking to 25 patients receiving locking volar plates, found 10 complications (31%) in the non-locking plate group and five in the locking plate group (20%). Similarly, there were fewer major complications requiring re-operation in the locking plate group (1/25 vs. 4/32). No tendon ruptures were seen in either group.(106)

VARIABLE-ANGLE LOCKING PLATES:

Variable-angle, or poly-axial, locking plates are designed to allow the surgeon flexibility in placing the subchondral screws, and optimize placement of screws into the articular fragments, target higher quality bone, and more precisely avoid joint penetration.(26) In theory, this should allow for a more stable fixation and easier evasion of complications. In practice, reported tendon complication rates vary from 0-4%, with extensor tendon rupture being the most commonly reported complication.(49, 68, 83, 92, 107, 108) Reported rates of nerve complications range from 0.3-8%, with carpal tunnel syndrome being most common.(49, 68, 83, 107-109) Hardware complication rates are reported between 0-4%, with many studies reporting no hardware related complications at all.(49, 83, 92, 107, 108) Of the studies reporting hardware complications, malunion, screw loosening, and intra-articular screws were the only types witnessed.(68, 109) In a prospective study of 37 patients treated with variable angle volar locking plates, Fowler and Ilyas reported one case of extensor tenosynovitis (3%) from prominent dorsal screw penetration that required re-operation and one case of loosening and backing out of subchondral variable-angle locking screws (3%) that did not require further management. However, no nerve-related complications were reported.(11)

In addition, there have been multiple studies that have directly compared fixed and variable-angle volar plates. In a retrospective chart review that included 60 patients receiving fixed-angle plates and 148 receiving variable-angle plates, Mehrzad and Kim found that while 12% (7/60) of the patients in the fixed-angle group had hardware complications requiring re-operation, none of the 148 patients receiving variable-angle plates had hardware complications ($p < 0.001$).(110) Marlow et al, in a retrospective study that included 42 patients receiving fixed-angle plates and 65 receiving variable-angle plates, found that 12% (5/42) had complications (2 reduced ROM, 1 EPL tendonitis, 2 malunion) in the fixed angle group, and 8% (5/65) had complications (reduced ROM, 1 CTS, 2 CRPS) in the variable angle group, with no significant difference between the two.(67)

CONCLUSION:

All referenced studies used for complication rate computation are level I or II evidence, and no case series or case-control studies were included. Based on the available literature, the overall complication rate associated with volar locked plating of distal radius fractures is substantial, however may be relatively low in comparison to other operative fixation methods. While reported rates vary, nerve-related complications seem to be the most common type, although many of these are likely attributable to the fracture itself and pre- or peri-operative median nerve dysfunction, as opposed to the plate fixation. Tendon-related complications are the next most common, with extensor tendons apparently more vulnerable than flexor tendons. Hardware-related complications also occur, albeit less frequently, with malunion being the most-reported hardware failure. There has been much progress in the types of volar plates available. The newer generation variable-angle plates may be associated with less hardware-related complications as a result of more optimal placement of the screws/pegs into the distal fragments than fixed-angle volar locking plates.

There are many limitations in interpreting the relevant data and comparing the various methods of distal radius fracture fixation. In addition to differing plate type preference among different surgeons and institutions, it is likely that surgeon experience and technique play a large role in the varying rates of complications. Also, no two fractures are the same, and while all of the fractures analyzed by these studies have been labeled as distal radius fractures, it remains a challenge to know with certainty that reported complications are not related to the fracture morphology and patient characteristics than the plate itself. While nearly all studies report the AO classification of the fractures studied, the reported complications are rarely if ever sorted out by fracture type, thereby leaving room for confounding variables.

Volar plating of distal radius fractures appears to have a reasonable complication profile and has emerged as a preferred method of internal fixation for distal radius fractures. However, given their high costs and inconclusive functional benefits relative to conservative management,(111) their costs and benefits should be addressed for all patients on an individual basis. When choosing a volar plate, mixed angle locking plates were designed for use in osteoporotic bone and severely comminuted fractures, and variable angle locking plates were designed to allow targeting of higher quality bone and avoid joint penetration. However, there does not seem to be one type of volar plate that is clearly superior in terms of functionality or complication rates.(67) Therefore, care should be taken to carefully choose a plate according to the patient's and fracture's characteristics in order to minimize complications. Similarly, careful technique can likely significantly reduce the complication rates. As it appears that volar locked plating of distal radius fractures will likely remain popular for the foreseeable future, ongoing efforts should focus on plate designs and operative techniques that maximize functionality and minimize opportunity for complication.

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LEGEND:

FIGURE 1

First generation stainless steel T-shaped volar buttress plate (Synthes, Paoli, PA), requiring repair with 3.5 cortical and / or 4.0 cancellous screws.

FIGURE 2

Second generation low profile and low contact volar plate (Synthes, Paoli, PA), requiring repair with 2.7 cortical shaft screws and 2.4 subchondral screws or locking pegs.

FIGURE 3

Anatomic fixed-angle volar locking plate (Hand Innovations, Miami, PA).

FIGURE 4

Variable-angle volar locking plate (Globus, Audubon, PA), with locking subchondral screws or pegs. (A) Anterior view (B) Lateral view.

FIGURE 5

A fixed-angle volar locking plate with long subchondral screws with prominence dorsally, ultimately resulting in extensor tendon rupture.

FIGURE 6

Case of a locking volar plate with early post-operative loss of fracture reduction resulting in a malunion and secondary plate prominence on the volar side, ultimately resulting in flexor tendon rupture.

FIGURE 7

Case of a high-energy distal radius fracture with displacement and swelling. Note the prominent volar cortex (yellow circle) impinging on the median nerve with secondary nerve swelling and contusion.

FIGURE 8

Fracture malunion due to a poorly positioned plate resulting in inadequate **lunate** fracture repair and late fracture displacement of the lunate facet, referred to as facet escape, **and volar subluxation of the radiocarpal joint.**