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

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1 Complications Associated with Volar Locking Plate Fixation of Distal Radius Fractures

2 **INTRODUCTION:**

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

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

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

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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)

48 **COMPLICATIONS OF VOLAR PLATES**

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

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56 **TENDON INJURY:**

57 Extensor tendon injuries can result as a complication of distal radius fractures
58 independent of treatment method.(28-31) Recent systematic reviews have reported the incidence
59 of this extensor tendon rupture as 0.4% (6/1,359) with conservative management(32) and 1.5%
60 (15/1,032) with dorsal plating.(33) However, the incidence of this injury has been shown to be
61 substantial following volar plate fixation of distal radius fractures, with reported rates ranging
62 from 0-4%.(34-39) While multiple extensor tendons are at risk, including the extensor digitorum
63 communis and extensor indicis,(40) the extensor pollicis longus (EPL) tendon is the most
64 frequently affected. Zenke et al(34) reported EPL rupture in 2% of a cohort of 286 patients
65 treated with volar plating, while Tarallo et al(35) reported EPL rupture rate of 1% in a cohort of
66 303 patients.

67 Incidence of extensor tendon injury has also been shown to be related to not only
68 placement of excessively long screws that are prominent dorsally, but also from direct drill-bit
69 penetration and irritation from bone fragments or comminution dorsally (FIGURE 5).(41-43)
70 Methods to avoid extensor tendon injury revolve around attention to proper surgical technique,

71 accurate placement of the plate volarly, precise screw length selection to avoid dorsal screw
72 prominence, or the use of locking pegs instead of screws to avoid the sharp tip of a screw.(40,
73 44) Prompt implant removal is recommended upon early signs of extensor tendon irritation.(42)

74 Flexor tendon injury is a major but uncommon complication of volar plating, as it does
75 not usually occur due to the longer distance between flexor tendons and the proximal volar
76 cortex of the distal radius, the recessed nature of the volar plate relative to the volar rim or
77 watershed line of the distal radius, and the potential benefit of a repaired pronator quadratus over
78 the volar plate.(45) When flexor tendon rupture does occur, it most frequently affects the flexor
79 pollicis longus (FPL) tendon, although other tendons such as the flexor digitorum profundus may
80 also rupture.(46) While one study has reported the rate of flexor tendon rupture to be as high
81 11%,(47) the majority of recent studies report no flexor tendon injury at all.(48-51) Brennan et
82 al(51) reported no cases of flexor tendon injury in a series of 151 patients treated with volar
83 plating.

84 The incidence of flexor tendon injury has been shown to be related to prominence of the
85 implant relative to the watershed line of the distal radius, where the flexor tendons would lie
86 closest to the plate or its subchondral locking screws, malreduction of the fracture with residual
87 dorsal angulation increasing plate prominence, or loose or prominent subchondral locking screws
88 (FIGURE 6).(52-56) Among the reported flexor tendon ruptures, the median interval between
89 surgery and rupture was 9 months (range 6-26), highlighting the importance of symptom
90 monitoring at final follow-up.(46) Additionally, the mean age of patients with flexor tendon
91 injuries is 61 years with a female predominance.(46, 57) Factors that may avoid flexor tendon
92 injury include placement of the volar plate proximal to the watershed line, confirming that all
93 subchondral locking screws are locked and flush, and early removal of the plate upon signs of

94 tendon dysfunction such as pain, crepitus, or triggering.(58) Closure of the pronator quadratus
95 muscle over the plate has also been suggested to decrease incidence of flexor tendon injury.(59-
96 61) However, there is no evidence that repair or closure of the pronator quadratus muscle is
97 efficacious when the distal radius is anatomically reduced and the volar plate is properly
98 positioned.(62-66)

99 In addition to tendon rupture, tenosynovitis is a frequent, though less severe,
100 complication of volar plating. Among the available literature, rates of tenosynovitis appear to be
101 similar for both the extensor and flexor tendons, varying from 0-3.8% for extensor tendons and
102 0-3.8% for flexor tendons.(8, 35, 48, 51, 67) The methods for preventing these injuries are
103 largely similar to those for preventing tendon rupture, but treatment relies largely on
104 symptomatic relief and immobilization rather than re-operation.

105

106 NERVE:

107 Carpal tunnel syndrome (CTS) is the most common nervous tissue-related complication
108 associated with volar locked plating of distal radius fractures.(42, 68) However, CTS may occur
109 after distal radius fracture regardless of treatment method, with reported rates ranging from 0-
110 20% with conservative management(69-72) and 0-14% with volar plating.(42, 48, 68, 73, 74)
111 Zhao et al compared 7 treatment methods for distal radius fractures, including volar plating, and
112 found no significant difference in the incidence of CTS among the different treatment
113 options.(75) In a series of 282 patients treated with volar plating, Ho et al found an incidence of
114 CTS of 3.2%,(76) which is similar to the 3.8% incidence in the general population.(77) With this
115 in mind, it is a challenge to determine the true incidence of CTS following volar plate fixation.
116 Moreover, determining this incidence is further complicated by the fact that a carpal tunnel

117 release (CTR) is often done prophylactically with volar plating of distal radius fractures in
118 various published series.(78, 79)

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

133 Beyond CTS, complex regional pain syndrome (CRPS), formerly known as reflex
134 sympathetic dystrophy (RSD), is the second most commonly reported nervous tissue-related
135 complication following volar plating of distal radius fractures, with reported incidence ranging
136 from 0-9%.(37, 38, 42, 68, 83) However, due to its variable presentation and inconsistent
137 diagnostic criteria, the exact incidence is difficult to compute. As CRPS is a challenging and
138 potentially devastating complication, emphasis must be placed on early recognition and emergent
139 treatment. The primary feature of CRPS is continued pain out of proportion to the injury, but it is

140 often associated with hyperesthesia, changes in skin blood flow, edema, and restriction of
141 motion, among other manifestations.(84, 85)

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

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

155

156 **HARDWARE:**

157 Hardware-related complications appear to be less common than both tendon and nerve-
158 related complications with volar plating of distal radius fractures. Reported rates of hardware
159 complications range from 0-7%, with malunion being the most commonly reported problem.(38,
160 48, 51, 68, 74) (FIGURE 6 & 8) Other hardware-related complications include screw loosening,
161 intra-articular screw placement, loss of reduction, and broken plate and screws. In a prospective
162 study of 228 patients treated with volar plating, Lattmann et al reported a hardware complication

163 rate of 0.9% (2/228),(38) with both being a result of loss of reduction. A similarly large study by
164 Wichlas et al that retrospectively studied 225 patients treated by volar plate reported only one
165 hardware complication (malunion), resulting in a 0.4% (1/225) complication rate.(48) However,
166 a prospective study of 100 patients treated by volar plate conducted by Kato et al found a
167 hardware complication rate of 7% (7/100), all of which were malunions.(74) Care should be
168 taken intra-operatively to prevent malunion by ensuring anatomic reduction with minimal dorsal
169 angulation, proper placement of locking screws in subchondral bone, and sufficient depth of
170 screws. While bone grafting is often used for fractures with large bone gaps, they are associated
171 with significant morbidity,(95) and recent evidence supports the notion that bone grafting is not
172 necessary with the use of volar plating.(35, 96, 97) If malunion occurs despite these measures,
173 corrective osteotomy should be performed as soon as the diagnosis is confirmed
174 radiographically.(98)

175

176 OTHER COMPLICATIONS:

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

184 Additionally, many patients have their plates removed for a number of reasons. While some
185 plates are removed as a result of other complications such as tendon rupture, infection, or

186 malunion, many patients request to have their plates removed for discomfort associated with the
187 retained plate, decreased range of motion, pain, or anxiety related to the plate. It appears as
188 though the all-cause incidence of hardware removal lies between 0-26%,(35, 48, 49, 51, 100)
189 with significant variation depending on clinician preference.

190

191 VOLAR PLATE SPECIFIC COMPLICATIONS:

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

194

195 *FIXED-ANGLE LOCKING PLATES:*

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

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

211 Some studies have also directly compared the outcomes of volar non-locking and volar
212 locking plates. One study by Obert et al retrospectively compared 31 patients treated by volar
213 plating with non-locking screws to 121 patients treated by volar plating with locking screws and
214 found no significant difference in the overall complication rates of the two groups (16.1% vs.
215 16.5%). However, no patients in the non-locking group experienced tendon ruptures, while 6
216 patients (5%) in the locking group did.(104) Another smaller study by Schmelzer-Schmied et al
217 prospectively compared 15 patients treated with external fixation to 15 patients with non-locking
218 and 15 patients with locking volar plates, finding that there were fewer complications in the volar
219 plate groups but no difference between non-locking and locking plates (6% vs. 13%).(105)
220 Zhang et al, in a retrospective comparison of 32 patients receiving non-locking to 25 patients
221 receiving locking volar plates, found 10 complications (31%) in the non-locking plate group and
222 five in the locking plate group (20%). Similarly, there were fewer major complications requiring
223 re-operation in the locking plate group (1/25 vs. 4/32). No tendon ruptures were seen in either
224 group.(106)

225

226 *VARIABLE-ANGLE LOCKING PLATES:*

227 Variable-angle, or poly-axial, locking plates are designed to allow the surgeon flexibility
228 in placing the subchondral screws, and optimize placement of screws into the articular
229 fragments, target higher quality bone, and more precisely avoid joint penetration.(26) In theory,
230 this should allow for a more stable fixation and easier evasion of complications. In practice,
231 reported tendon complication rates vary from 0-4%, with extensor tendon rupture being the most

232 commonly reported complication.(49, 68, 83, 92, 107, 108) Reported rates of nerve
233 complications range from 0.3-8%, with carpal tunnel syndrome being most common.(49, 68, 83,
234 107-109) Hardware complication rates are reported between 0-4%, with many studies reporting
235 no hardware related complications at all.(49, 83, 92, 107, 108) Of the studies reporting hardware
236 complications, malunion, screw loosening, and intra-articular screws were the only types
237 witnessed.(68, 109) In a prospective study of 37 patients treated with variable angle volar
238 locking plates, Fowler and Ilyas reported one case of extensor tenosynovitis (3%) from
239 prominent dorsal screw penetration that required re-operation and one case of loosening and
240 backing out of subchondral variable-angle locking screws (3%) that did not require further
241 management. However, no nerve-related complications were reported.(11)

242 In addition, there have been multiple studies that have directly compared fixed and
243 variable-angle volar plates. In a retrospective chart review that included 60 patients receiving
244 fixed-angle plates and 148 receiving variable-angle plates, Mehrzad and Kim found that while
245 12% (7/60) of the patients in the fixed-angle group had hardware complications requiring re-
246 operation, none of the 148 patients receiving variable-angle plates had hardware complications
247 ($p < 0.001$).⁽¹¹⁰⁾ Marlow et al, in a retrospective study that included 42 patients receiving fixed-
248 angle plates and 65 receiving variable-angle plates, found that 12% (5/42) had complications (2
249 reduced ROM, 1 EPL tendonitis, 2 malunion) in the fixed angle group, and 8% (5/65) had
250 complications (reduced ROM, 1 CTS, 2 CRPS) in the variable angle group, with no significant
251 difference between the two.⁽⁶⁷⁾

252

253 **CONCLUSION:**

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

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

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

290

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593 **LEGEND:**

594 **FIGURE 1**

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

597

598 **FIGURE 2**

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

601

602 **FIGURE 3**

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

604

605 **FIGURE 4**

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

608

609 **FIGURE 5**

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

612

613 **FIGURE 6**

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

617

618 **FIGURE 7**

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

622

623 **FIGURE 8**

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