

## ORIGINAL ARTICLE

# Volar Plate Fixation for the Treatment of Distal Radius Fractures: Analysis of Adverse Events

Luigi Tarallo, MD,\* Raffaele Mugnai, MD,\* Francesco Zambianchi, MD,\* Roberto Adani, MD,†  
and Fabio Catani, MD\*

**Objectives:** Determining the rate of specific adverse events after volar plating performed for distal radius fractures.

**Design:** Retrospective.

**Setting:** University level I trauma center.

**Patients:** We searched the electronic database of all surgical procedures performed in our department using the following keywords: distal radius fracture, wrist fracture, and plate fixation. We identified 315 patients, 12 of whom were lost at follow-up.

**Intervention:** Volar plate fixation for the treatment of distal radius fractures.

**Main Outcome Measurements:** At an average follow-up of 5 years, 303 patients were evaluated through medical records and clinical and radiographic assessment for specific adverse events after volar plate fixation.

**Results:** Adverse events were observed in 18 patients (5.9%). Implant-related adverse events, including tendon impairments, intra-articular screws, and screw loosening, were observed in 15 patients (5.0%). Extensor tendon impairments were represented by 5 cases of extensor tenosynovitis and 3 cases of rupture of the extensor pollicis longus due to screws protruding dorsally. Flexor impairments were represented by 2 cases of tenosynovitis and 2 cases of flexor pollicis longus rupture. Screw penetration into the radioulnar joint was observed in 1 case. Loss of reduction was identified in 3 cases. One patient had a deep postoperative infection treated with operative debridement. One patient experienced injury to the median nerve during routine implant removal unrelated to tendon issues.

**Conclusions:** The majority of adverse events after volar plate fixation were due to technical errors in implant placement. In our cohort, tendon impairments were the most frequently observed; among these, extensor tendon impairments were the most represented (50% of all adverse events). All 12 tendon-related adverse events were due to technical shortcomings with implant placement.

**Key Words:** wrist, radius, fracture, complications, plate, tendon, adverse events

**Level of Evidence:** Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2013;27:740–745)

## BACKGROUND

Locking plate fixation for distal radius and for other fractures has become increasingly popular across the developed world over the past 5 years.<sup>1–3</sup> The popularity of this method is based on the stable restoration of the anatomy, short period of immobilization, and early return to previous activity level.<sup>4,5</sup> Previous studies suggest that restoration of normal alignment and articular congruity after a distal radius fracture promotes good functional results<sup>6,7</sup> and prevents the development of late osteoarthritis.<sup>8</sup> Over the past decade, volar plating has gained widespread use.<sup>9–11</sup> However, recent studies report volar plating complication rates as high as 22%–27%.<sup>5,12</sup>

In this retrospective study, we evaluated the occurrence of adverse events after volar locking plate fixation in a large cohort of patients with unstable fractures of distal radius with long-term follow-up based on the medical records and clinical and radiographic assessment.

## PATIENTS AND METHODS

We reviewed all the volar plating procedures performed for distal radius fractures from January 2000 to January 2010 in a single trauma center. The inclusion criteria were as follows: aged 18 years or above with volar plate fixation of a distal radius fracture with a minimum 1 year of follow-up. Patients with dementia or neurologic diseases were excluded. We searched the department's surgical electronic database using the following keywords: distal radius fracture, wrist fracture and plate fixation, and identified 318 patients. Three cases were excluded, as they did not meet the inclusion criteria.

It is our routine practice to invite all the surgically treated patients to receive hospital consultation at 2 weeks, 1 month, 3 months, 6 months, and 1 year postoperatively. Some patients were followed for a longer time, depending on surgeon's indications or patients needs. We retrospectively reviewed all the available medical records in our department. For those patients whose records were not available, between January and December 2011, we organized clinical and radiographic assessment. Of the 315 cases included, 137 had complete

Accepted for publication March 8, 2013.

From the \*Orthopaedics and Traumatology Department, Policlinico di Modena, University of Modena and Reggio Emilia, Modena, Italy; and †Hand and Microsurgery Department, Policlinico GB Rossi, Azienda Ospedaliera Universitaria Verona, Verona, Italy.

The authors report no conflicts of interest.

Reprints: Luigi Tarallo, MD, Orthopaedics and Traumatology Department, Policlinico di Modena, Via del Pozzo 71, 41124 Modena, Italy (e-mail: tarallo.luigi@policlinico.mo.it).

Copyright © 2013 by Lippincott Williams & Wilkins

**TABLE 1.** Description and Incidence of Each Type of Adverse Event Occurred

Adverse Event	Mechanism	Absolute Frequency, N (%)	Relative Frequency (%)
Extensor tendon	Synovitis	5 (1.6)	27.8
	EPL rupture	3 (1.0)	16.7
Flexor tendon	Synovitis	2 (0.7)	11.1
	FPL rupture	2 (0.7)	11.1
Loss reduction	Screw loss of purchase	2 (0.7)	11.1
	Lunate facet loss of reduction	1 (0.3)	5.6
Joint stiffness	Screw penetration in the DRUJ	1 (0.3)	5.6
Nervous	Median nerve lesion	1 (0.3)	5.6
Infection	Unknown	1 (0.3)	5.6
Total adverse events		18 (5.9)	100

DRUJ, distal radioulnar joint.

medical records. One hundred seventy-eight were incomplete; of these, 166 patients were reviewed and 12 patients were lost at follow-up because it was not possible to reach them. At a mean 4.7-year follow-up, 303 patients were reviewed with a dropout rate of 3.8%.

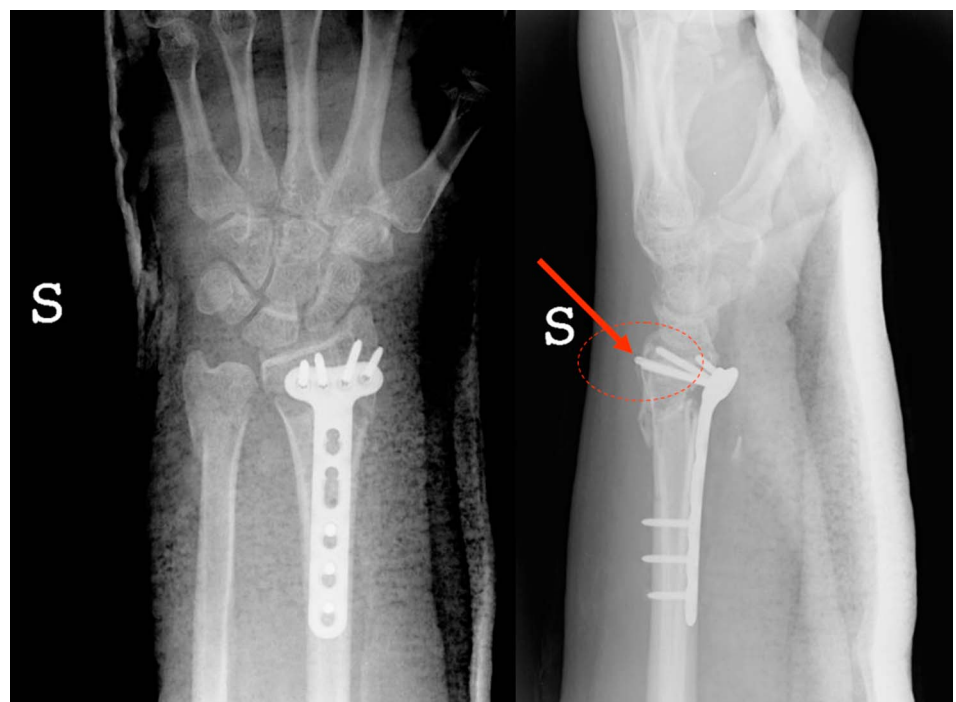
Patients age ranged from 18 to 87, with an average of 56 years; 118 patients were male and 185 were female. Fractures were classified according to the OTA/AO classification system: A3 (31 cases), B3 (93 cases), C1 (76 cases), C2 (58 cases), and C3 (45 cases). When an intra-articular

fracture was suspected, a computer tomography (CT) was performed for preoperative planning.

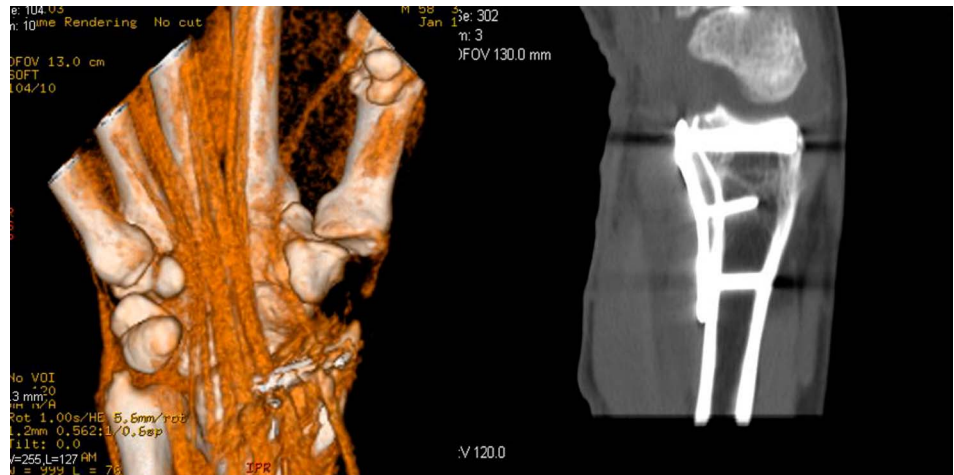
The operations were performed with a palmar approach through the flexor carpi radialis tendon sheath. The distal and radial borders of the pronator quadratus were elevated, and the volar aspect of the radius was exposed subperiosteally. The plate was placed directly on the radius after the reduction of the fracture, and the adequate positioning of plate and screws was confirmed by intraoperative fluoroscopy. The pronator quadratus muscle was replaced over the plate and fixed to the radius with loose sutures. The implants included the following anatomically contoured locking plates: Acumed Acu-Loc (Acumed, Hillsboro, OR), 63 cases; Synthes LCP (Synthes, Paoli, PA), 85 cases; Hand Innovations DVR (DePuy, Miami, FL), 92 cases; and Aptus (Medartis, Kennett Square, PA), 63 cases. A below-elbow wrist splint was used for 2 weeks in all cases. At the end of the second week, the sutures were removed and physiotherapy started. Adverse events, including soft-tissue impairments (tendinitis and tendon rupture), osseous complications (loss of reduction, loss of fixation, and radial shortening due to collapsed fracture site), implant failure, symptoms of carpal tunnel syndrome not noted before surgery, other nervous complications, compartment syndrome, and infection, were evaluated and recorded.

**RESULTS**

Adverse events were observed in 18 cases (5.9%) (Table 1). Extensor tendon impairments were the most frequent and were represented by 5 cases of extensor tenosynovitis and 3 cases of extensor pollicis longus (EPL) rupture. The diagnosis of extensor tenosynovitis is primarily based on the symptoms of pain, swelling, tenderness, and dorsal



**FIGURE 1.** Postoperative x-rays showing that the plate is too prominent volarly at the distal edge due to inadequate reduction and the plate positioning too radial. The screws penetrate both dorsally and radially.



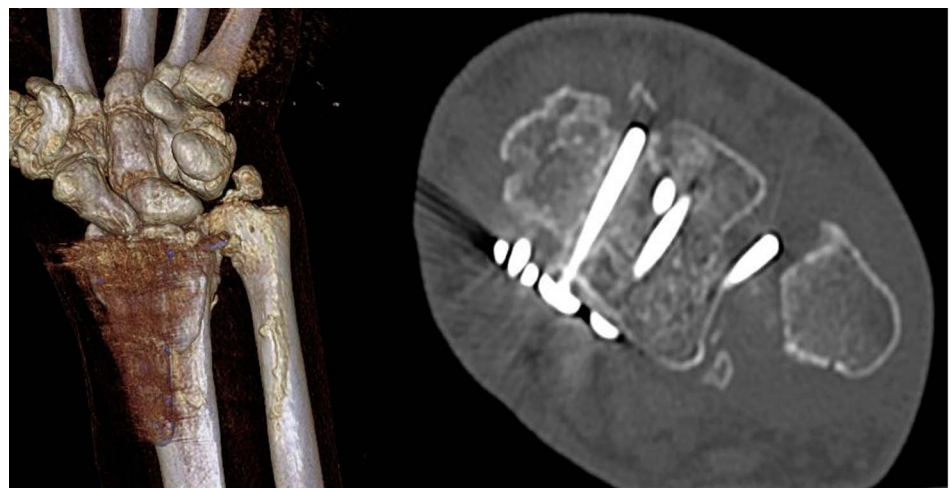
**FIGURE 2.** CT taken 6 months after surgery showing the plate placed distal to the watershed line, with resultant impingement with flexor tendons and FPL rupture. Editor’s note: A color image accompanies the online version of this article.

crepitius. Radiographs revealed an excessive length of 1 or more screws of the distal branch of the plate in all such cases, after which the plate and the screws were removed. Intraoperatively, marked hypertrophy of the synovial sheaths of the tendons and fibrillar degeneration were reported. In 1 case, after treatment of an extra-articular fracture, a 45-year-old woman experienced EPL tendon rupture without antecedent symptoms. The postoperative x-rays indicated that the plate was too prominent volarly at the distal edge due to inadequate reduction and placement of the plate too radial. The screws penetrated both dorsally and radially (Fig. 1). The patient underwent tendon reconstruction by transfer of the extensor indicis proprius, achieving good functional results. Flexor tendon impairments were observed less frequently, with 2 cases of flexor tenosynovitis and 2 cases of flexor pollicis longus (FPL) rupture: in all 4 cases, a Synthes LCP 2.4 of the type that intentionally rests on the watershed line had been implanted. In 1 case, a 48-year-old male experienced FPL rupture 6 months after surgery. The postoperative x-rays showed that the high-profile implant (Synthes LCP plate, first design) was placed distal to the watershed line, resulting in irritation or injury of the FPL (Fig. 2).

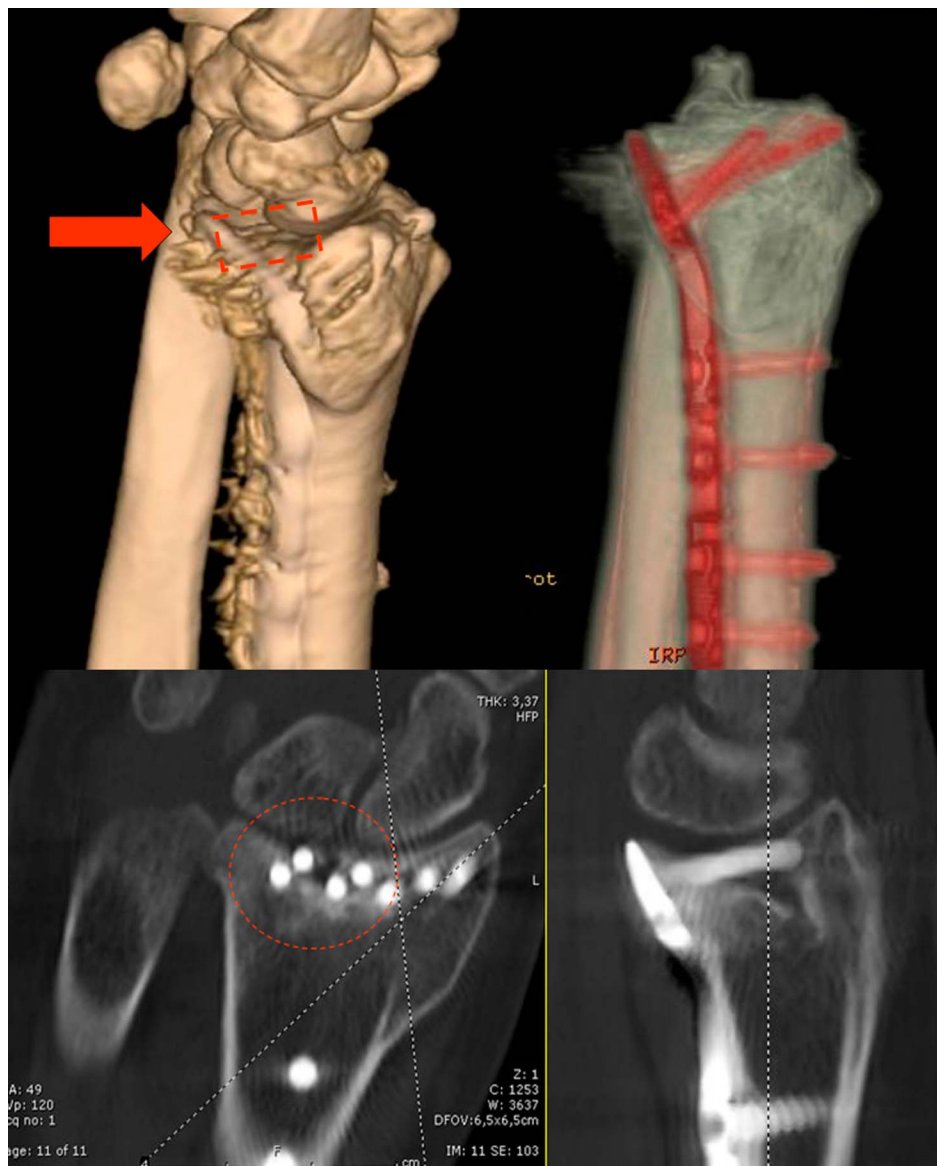
Another patient experienced screw penetration into the distal radioulnar joint. Clinical examination at 1 month showed

limited pronation–supination with pain. The CT evaluation demonstrated screw tip impingement with the ulnar head (Fig. 3). Subsequent plate removal achieved complete restoration of motion and pain relief. Loss of reduction after plate fixation was observed in 3 cases. In 2 cases, we observed proximal diaphyseal screw loosening. In these cases, a Synthes LCP with conventional instead of locking screws was used. Both patients were symptomatic with swelling and required plate removal. The other case occurred in an 80-year-old patient treated for a distal radius articular fracture C2 type. The initial reduction and fixation were apparently adequate, as determined on the basis of an intraoperative x-ray evaluation. CT scan at 4 years revealed penetration of the distal peg of the DVR plate into the lunate facet due to loss of bone support (Fig. 4). Despite this, the patient had no pain or substantial motion limitation and refused any other surgical treatment. No cases of implant failure were observed.

Neurologic adverse events included 1 case of median nerve injury after volar plate removal performed elsewhere. In this case, a median nerve graft with sural nerve was performed (Fig. 5). Clinical results at 1-year follow-up revealed 2-point discrimination test of 9 and 11 mm for the thumb, 10 and 12 mm for the index finger, and 12 and 13 mm for the middle



**FIGURE 3.** CT evaluation demonstrating screw penetration into the radioulnar joint and screw tip impingement with the ulnar head. Editor’s note: A color image accompanies the online version of this article.



**FIGURE 4.** CT scan at 4 years of follow-up, showing that the distal peg of the DVR, sustaining the articular surface of the lunate fossa, penetrated the articular space. Editor’s note: A color image accompanies the online version of this article.

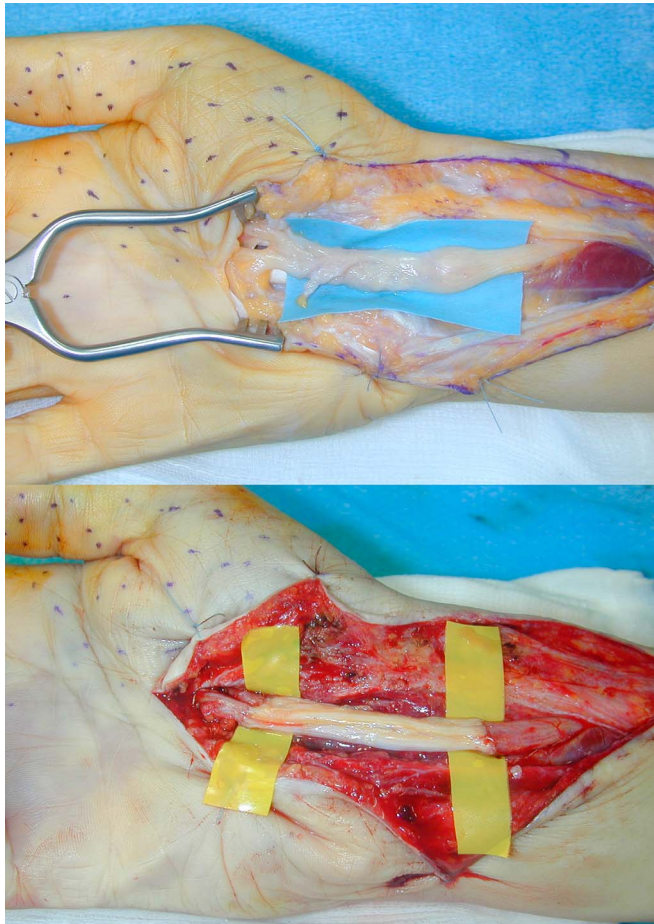
finger. Palmar abduction was at M4 by Medical Research Council (MRC) scale criteria. In addition, we observed 4 cases of postoperative new-onset carpal tunnel syndrome symptoms, but because the best current evidence suggests that this complication is unrelated to the injury or the treatment,<sup>13</sup> we did not include this pathology in the count of adverse events.

Finally, 1 case of infection involving a draining fistula from a volar scar was reported and resolved following plate removal after fracture union (Fig. 6).

### DISCUSSION

Because the fixation of distal radius fractures using volarly placed locking plates has become increasingly popular across the world over the past decade,<sup>1-3</sup> the analysis of adverse events and technical aspects to reduce their occurrence represents a particularly relevant issue.

In our cohort, extensor tendon impairments were the most frequent. We observed 5 cases of extensor tenosynovitis and 3 cases of EPL rupture due to excessive screw length with dorsal cortical penetration. The close proximity of the extensor tendons to the dorsal cortex and the limited volume of the dorsal compartments compromised by screws may also be a factor in ischemic tendon rupture.<sup>14</sup> The irregular anatomy of the dorsal cortex of the distal radius or the presence of dorsal bone fragments may lead to unrecognized dorsal cortex perforation by screw tips, even when the screws are inserted under fluoroscopic control. The distal radial articular surface has an obliquity in both anteroposterior (AP) and lateral planes and is concave in >1 plane, with an average ulnar inclination of 23 degree and an average volar tilt of 11 degree.<sup>15</sup> Standard AP and lateral radiographs are usually taken with the x-ray beam perpendicular to the forearm and, hence, may not accurately represent the articular anatomy of the fracture fixation. Because



**FIGURE 5.** Intraoperative image of median nerve lesion sustained during volar plate removal and requiring sural nerve graft. Editor’s note: A color image accompanies the online version of this article.

imprecise depth measurement and misinterpretation of the fluoroscopic images can easily lead to penetration of the dorsal cortex,<sup>16</sup> proper positioning must be confirmed using intraoperative radiographic imaging. Recently, additional views to better visualize the articular surface have been proposed<sup>17</sup>: In particular, orienting the forearm in such a manner to produce an image parallel to the radiocarpal joint on both AP (11-degree elevation) and lateral (23-degree elevation) projections have been suggested.<sup>14</sup> In addition, Ozer et al<sup>18</sup> promoted the dorsal tangential view (45-degree Supination View and 45-degree Pronation View) as a simple method to improve accuracy of fluoroscopy. Many authors routinely insert a screw 2 mm shorter than the measured length while avoiding drilling through the dorsal cortex because the distal screws of a locking plate maintain reduction as a fixed angle system when closely applied to the subchondral zone.<sup>12,19,20</sup> However, downsizing of the screws is not recommended in all cases: When approaching comminuted intra-articular fractures (ie, C type), very distal fixation using multiple screws, with dorsal cortex engagement, may be necessary for optimum stability.<sup>4,15</sup>

The second most common type of adverse events was flexor tendon impairment. Although previous studies demonstrate that rupture of the FPL tendon represents the major complication of volar plate fixation, occurring in 2%–12% of patients,<sup>21–23</sup> we reported 2 cases (0.7%) of flexor tenosynovitis and 2 cases (0.7%) of FPL rupture. It has been shown that implants placed distal to the watershed line can exert pressure on the flexor tendons and cause injury.<sup>12,24</sup> In our study, all cases of flexor tendon impairments occurred when a first-generation Synthes LCP plate was used to fix the fracture: This plate is characterized by a single distal row of locking pegs. The high incidence of adverse events using this kind of plate can be explained by the need to place the implant distal to the watershed line for stability, frequently leading to flexor tendon irritation. Although the Acumed plate



**FIGURE 6.** X-ray images showing infection of a distal radius fracture treated with DVR plate and its removal after 2 years: 2 months after surgery, the articular surface at the distal radioulnar joint is modified, with reduction of the ulnar variance.

also offers the same design at the watershed line, we did not experience flexor tendon impairment when performing fixation with this device. Low rate of flexor tendon impairment was also reported when the Hand Innovation DVR plate was used. This is in agreement with a study by Soong et al<sup>25</sup> and could be due to the fact that this plate intentionally rests on the watershed line with a relatively low profile at its distal portion, minimizing flexor tendon irritation. Tanaka et al<sup>26</sup> suggested that correct plate positioning (on or proximal to the watershed line) lowers the incidence of FPL impingement because the contact pressure between the FPL and the distal plate edge increases slightly or not, compared with that of the unimplanted distal radius. Conversely, if the plate distal edge is beyond the watershed line, the contact pressure between the FPL and the distal plate edge increases significantly compared with that of the normal distal radius.<sup>27</sup>

Finally, loss of reduction after plate fixation was observed in 3 cases: 2 cases of loss of screw purchase, occurring in older adults and probably due to the reduced bone mineral density and the use of conventional, instead of locking screws and 1 case of loss of the lunate facet reduction. As previously reported, this could be due to the difficulties in maintaining the volar lunate fragment reduction in comminuted patterns.<sup>28,29</sup> Harness et al<sup>30</sup> described 7 cases of carpal subluxation after fixation loss of a volar lunate facet fragment. Five patients were symptomatic and underwent revision surgery. Rozental and Blazar<sup>5</sup> reported loss of reduction of the lunate facet in 2 of 41 patients; however, both patients were satisfied with their outcome, requiring no further surgery. Other complications described in the literature such as compartment syndrome, implant fracture, or vascular injury were not encountered.

In our study, the overall rate of adverse events was 5.9%. In a recent retrospective study of 180 patients treated with volar plating, Phadnis et al<sup>31</sup> reported a 15% overall adverse event incidence at a mean of 30 months (including major complications like deep infection, tendon rupture, acute carpal tunnel syndrome, and chronic regional pain syndrome in 11 patients). The larger series of 303 patients in our study, showing a lower adverse events rate, supports the use of low-profile volar locking plates for the treatment of distal radius fractures. The retrospective structuring of our assessment, ignoring functional evaluation, can be viewed as a limitation of our study. Nevertheless, the large number of patients evaluated with at least 1 year of follow-up represent the main strength of our study. We believe that future studies are needed to better understand risk factors and possible strategies aimed at reducing or avoiding adverse events after volar plate fixation in the treatment of distal radius fractures.

## REFERENCES

- Chung KC, Shauver MJ, Birkmeyer JD. Trends in the United States in the treatment of distal radial fractures in the elderly. *J Bone Joint Surg Am.* 2009;91:1868–1873.
- Koval KJ, Harrast JJ, Anglen JO, et al. Fractures of the distal part of the radius. The evolution of practice over time. Where's the evidence? *J Bone Joint Surg Am.* 2008;90:1855–1861.
- Fanuele J, Koval KJ, Lurie J, et al. Distal radial fracture treatment: what you get may depend on your age and address. *J Bone Joint Surg Am.* 2009;91:1313–1319.
- Al-Rashid M, Theivendran K, Craigen MA. Delayed ruptures of the extensor tendon secondary to the use of volar locking compression plates for distal radial fractures. *J Bone Joint Surg Br.* 2006;88:1610–1612.
- Rozental TD, Blazar PE. Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. *J Hand Surg Am.* 2006;31:359–365.
- Boyd LG, Horne JG. The outcome of fractures of the distal radius in young adults. *Injury.* 1988;19:97–100.
- McQueen M, Caspers J. Colles fracture: does the anatomical result affect the final function? *J Bone Joint Surg Br.* 1988;70:649–651.
- Knick JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am.* 1986;68:647–659.
- Rein S, Schikore H, Schneiders W, et al. Results of dorsal or volar plate fixation of AO type C3 distal radius fractures: a retrospective study. *J Hand Surg Am.* 2007;32:954–961.
- Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. *J Hand Surg Am.* 2002;27:205–215.
- Musgrave DS, Idler RS. Volar fixation of dorsally displaced distal radius fractures using the 2.4-mm locking compression plates. *J Hand Surg Am.* 2005;30:743–749.
- 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.
- Ho AW, Ho ST, Koo SC, et al. Hand numbness and carpal tunnel syndrome after volar plating of distal radius fracture. *Hand (N Y).* 2011;6:34–38.
- Pichler W, Windisch G, Schaffler G, et al. Computer tomography aided 3D analysis of the distal dorsal radius surface and the effects on volar plate osteosynthesis. *J Hand Surg Eur.* 2009;34:598–602.
- Pace A, Cresswell T. Use of articular wrist views to assess intra-articular screw penetration in surgical fixation of distal radius fractures. *J Hand Surg Am.* 2010;35:1015–1018.
- Sügün TS, Karabay N, Gürbüz Y, et al. Screw prominences related to palmar locking plating of distal radius. *J Hand Surg Eur.* 2011;36:320–324.
- Matullo KS, Dennison DG. Lateral tilt wrist radiograph using the contralateral hand to position the wrist after volar plating of distal radius fractures. *J Hand Surg Am.* 2010;35:900–904.
- Ozer K, Wolf JM, Watkins B, et al. Comparison of 4 fluoroscopic views for dorsal cortex screw penetration after volar plating of the distal radius. *J Hand Surg Am.* 2012;37:963–967.
- Orbay JL. The treatment of unstable distal radius fractures with volar fixation. *Hand Surg.* 2000;5:103–112.
- Smith DW, Henry MH. Volar fixed-angle plating of the distal radius. *J Am Acad Orthop Surg.* 2005;13:28–36.
- Casaletto JA, Machin D, Leung R, et al. Flexor pollicis longus tendon ruptures after palmar plate fixation of fractures of the distal radius. *J Hand Surg Eur.* 2009;34:471–474.
- Drobetz H, Kutscha-Lissberg E. Osteosynthesis of distal radial fractures with a volar locking screw plate system. *Int Orthop.* 2003;27:1–6.
- Figl M, Weninger P, Jurkowsitsch J, et al. Unstable distal radius fractures in the elderly patient—volar fixed-angle plate osteosynthesis prevents secondary loss of reduction. *J Trauma.* 2010;68:992–998.
- Orbay J. Volar plate fixation for distal radius fractures. *Hand Clin.* 2005; 21:347–354.
- Soong M, van Leerdam R, Guitton TG, et al. Fracture of the distal radius: risk factors for complications after locked volar plate fixation. *J Hand Surg Am.* 2011;36:3–9.
- Tanaka Y, Aoki M, Izumi T, et al. Effect of distal radius volar plate position on contact pressure between the flexor pollicis longus tendon and the distal plate edge. *J Hand Surg Am.* 2011;36:1790–1797.
- Cross AW, Schmidt CC. Flexor tendon injuries following locked volar plating of distal radius fractures. *J Hand Surg Am.* 2008;33:164–167.
- Chin KR, Jupiter JB. Wire-loop fixation of volar displaced osteochondral fractures of the distal radius. *J Hand Surg Am.* 1999;24:525–533.
- Takami H, Takahashi S, Ando M. Comminuted intra-articular fracture of the distal radius with rotation of the palmar medial articular fragment: case reports. *J Trauma.* 1992;32:404–407.
- 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;86:1900–1908.
- Phadnis J, Trompeter A, Gallagher K, et al. Mid-term functional outcome after the internal fixation of distal radius fractures. *J Orthop Surg Res.* 2012;7:4.