SCIENTIFIC ARTICLE

# Volar Plate Position and Flexor Tendon Rupture Following Distal Radius Fracture Fixation

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**Purpose** To determine whether there were differences between plate position in patients who had postoperative flexor tendon ruptures following volar plate fixation of distal radius fractures and those who did not.

**Methods** Three blinded reviewers measured the volar plate prominence and position on the lateral radiographs of 8 patients treated for flexor tendon ruptures and 17 matched control patients without ruptures following distal radius fracture fixation. We graded plate prominence using the Soong grading system, and we measured the distances between the plate and both the volar critical line and the volar rim of the distal radius.

**Results** A higher Soong grade was associated with flexor tendon rupture. Patients with ruptures had plates that were more prominent volarly and more distal than matched controls without ruptures. Plate prominence projecting greater than 2.0 mm volar to the critical line had a sensitivity of 0.88, a specificity of 0.82, and positive and negative predictive values of 0.70 and 0.93, respectively, for tendon ruptures. Plate position distal to 3.0 mm from the volar rim had a sensitivity of 0.88, a specificity of 0.94, and positive and negative predictive values of 0.88 and 0.94, respectively, for tendon ruptures.

**Conclusions** We identified plate positions associated with attritional flexor tendon rupture following distal radius fracture fixation with volar plates. To decrease rupture risk, we recommend considering elective hardware removal after union in symptomatic patients with plate prominence greater than 2.0 mm volar to the critical line or plate position within 3.0 mm of the volar rim. *(J Hand Surg 2013;38A:1091–1096. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

**Type of study/level of evidence** Therapeutic III.

**Key words** Distal radius fracture, flexor tendon rupture, plate position, volar plate.

Flexor tendon rupture is a rare but serious complication following open reduction internal fixation of distal radius fractures with volar plates.[1,2] In several recent reports of flexor pollicis longus and flexor digitorum profundus ruptures after volar plating, authors suggest that plate prominence and/or distal plate position are the cause of the tendon ruptures.[1,3–7]

Although prominent and distal plate positions are accepted as known risk factors for postoperative tendon rupture,[3,4] the association between plate position and flexor tendon rupture is not known. Surgeons generally try to keep plate position proximal to the watershed line, but there are no current recommendations as to what distance is too prominent or too distal with respect to tendon rupture risk.

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**TABLE 1. Demographics of Patients With Ruptures and Controls**

| | Age (y)* | Sex | Time From Surgery (y)* |
|---|---|---|---|
| Ruptures (n = 8) | Mean, 66 (range, 48–76) | F 5, M 3 | Mean, 3.8 (range, 1.2–6.3) |
| Controls (n = 17) | Mean, 66 (range, 57–72) | F 14, M 3 | Mean, 4.3 (range, 2.3–5.7) |

Time from surgery indicates the time elapsed between the index distal radius fracture fixation and the time of rupture or the time of latest follow-up evaluation (for the control group).
*$P$ values > .05 between groups.

Soong and colleagues[7] recently described a grading system for classifying volar plate prominence following distal radius fracture fixation. In their paper, they also attempted to associate Soong grade with tendon rupture risk, but their conclusions were limited by having only 3 cases of flexor tendon ruptures in their paper.

We analyzed a larger cohort of patients with flexor tendon attrition following volar plating to identify plate positions associated with flexor tendon injury. We hypothesized that a higher Soong grade would be associated with flexor tendon rupture. We also hypothesized that volar plate position in patients with confirmed flexor tendon ruptures would be farther distal and more prominent than volar plate position in a matched cohort of patients without ruptures.

## MATERIALS AND METHODS

After approval from our institutional review board, we identified 8 patients who were treated at our tertiary care center for flexor tendon ruptures a mean of 3.8 years (± 1.8 SD) following volar plating of distal radius fractures (Table 1). Four patients had flexor pollicis longus ruptures and 4 had 1 or more flexor digitorum profundus ruptures. We collected demographic data on these 8 patients, and we randomly selected an age- and sex-matched cohort of 17 control patients from our distal radius database who did not sustain tendon ruptures after a mean of 4.1 years (± 1.2 SD) since surgery (Table 1).

For analysis, we selected the postoperative standard lateral wrist plain radiograph with the thinnest profile of the volar plate for each patient according to the methods described by Soong and colleagues.[7] In all of the chosen lateral radiographs, the pisiform was noted to project over the distal portion of the scaphoid, signifying a proper lateral view. Three blinded orthopedic surgery resident reviewers graded the lateral radiographs for plate prominence relative to the volar critical line using the Soong grading system.[7] Using a picture archiving communication system (PACS), we drew a line along the volar cortex of the radial shaft. We then drew the "critical line"[7]: a line parallel to the volar radial cortex touching the most volar tip of the distal radius (Figure 1A). We graded plates dorsal to this volar critical line as grade 0, plates that either touched the critical line or protruded volar to the line as grade 1 (if they were also proximal to the volar rim), and plates on or distal to the volar rim as grade 2 (Fig. 1B).

The blinded reviewers also quantified plate prominence by measuring the distance in millimeters between the plate and the volar critical line–the plate–to–critical line (PCL) distance. We quantified distal plate position by measuring the distance between the distalmost extent of the plate and the most distal portion of the volar rim–the plate–to–volar rim (PVR) distance (Figure 1A). To account for potential magnification errors, plate length was measured on the lateral view and compared with manufacture-reported plate lengths. The PVR and PCL measurements were all normalized based on these measurements, and the correction was negligible (mean normalization factor, 1.01; SD, 0.04). Plate position on posteroanterior radiographs was also analyzed to determine whether the plates were well centered on the distal radius or ulnarly or radially deviated. To assess for a potential plate/patient size mismatch, the width of the plate was measured at the level of its greatest width and compared with the width of the radius at the same level. The ratio of plate width to radius width was compared between patients in all 3 groups. All radiographs were also assessed for potential loss of fracture reduction and prominent hardware.

We calculated interobserver reliability between readers using intraclass correlation coefficients for PCL and PVR measurements and kappa statistics for Soong grade. We used chi-square analysis to determine the association between Soong grade and flexor tendon rupture. We used 1-way analysis of variance tests with Bonferonni adjustments to compare the mean PCL and PVR distances between our 2 patient groups. A post-hoc power analysis showed that group sample sizes of 17 controls and 8 ruptures had greater than 90% power to detect the normalized PCL and PVR differences in

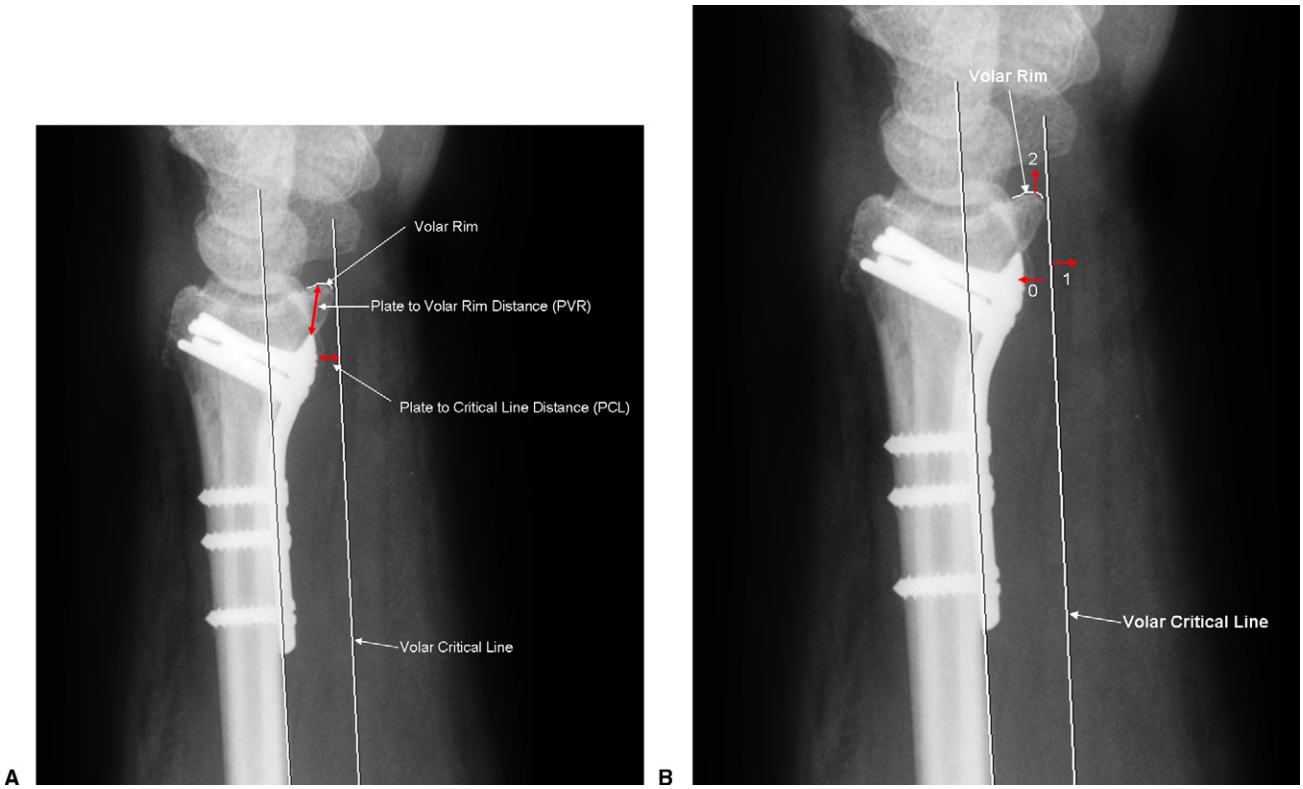


**FIGURE 1: A** The measurements of plate position and prominence are demonstrated on this facet lateral radiograph. The plate–to–critical line distance (PCL) is measured with negative values for plates dorsal to the critical line (like the plate in this figure) and positive values for prominent plates volar to the critical line. The plate–to–volar rim (PVR) distance is measured with positive numbers for plates proximal to the volar rim (as demonstrated in the figure) and negative values for plates distal to the volar rim. The facet lateral radiograph in this figure was chosen for clarity, but for analysis, all PCL and PVR measurements were made on standard lateral radiographs. **B** The plate is Soong grade 0 because it is both dorsal to the volar critical line and proximal to the volar rim. Soong 1: plates volar to the volar critical line (but proximal to the volar rim). Soong 2: Distal plates that extend to the level of the volar rim or beyond.

the 1-way analysis of variance analysis. We also used analysis of variance to compare the plate–to–radius width ratios between the 2 groups. We used a receiver operating characteristic curve to determine the PCL and PVR distances that were most predictive of flexor tendon rupture, and we calculated the sensitivity and specificity for flexor tendon rupture at each of those values.

## RESULTS

Consistent with our hypothesis, a higher Soong grade was associated with flexor tendon rupture after volar plating ($P < .001$). Seventy-five percent of the ruptures were grade 2 compared with none of the controls (Table 2). All of the ruptures occurred at least 6 months after the index distal radius fracture fixation.

Quantitative measurements of PCL and PVR were also associated with flexor tendon injury. The mean PCL distance in the rupture group (2.9 mm) was significantly greater than the mean PCL distance in the control group (−0.1 mm) ($P = .001$). The mean PVR distance in the rupture group (1.0 mm) was also significantly shorter than that of the control group (6.2 mm) ($P < .001$) (Fig. 2). Interobserver reliability between the 3 readers was high. The kappa interclass correlations were greater than 0.90 for all measurements, indicating strong agreement between readers.

**TABLE 2. Soong Grade of Patients With Tendon Ruptures Versus Controls**

| | Soong Grade 0 | Soong Grade 1 | Soong Grade 2 | *P* |
|---|---|---|---|---|
| Ruptures | 0 | 2 | 6 | <.001 |
| Controls | 7 | 10 | 0 | Reference |

Patients with tendon ruptures were more likely to have had a higher Soong grade than control patients ($P < .001$).

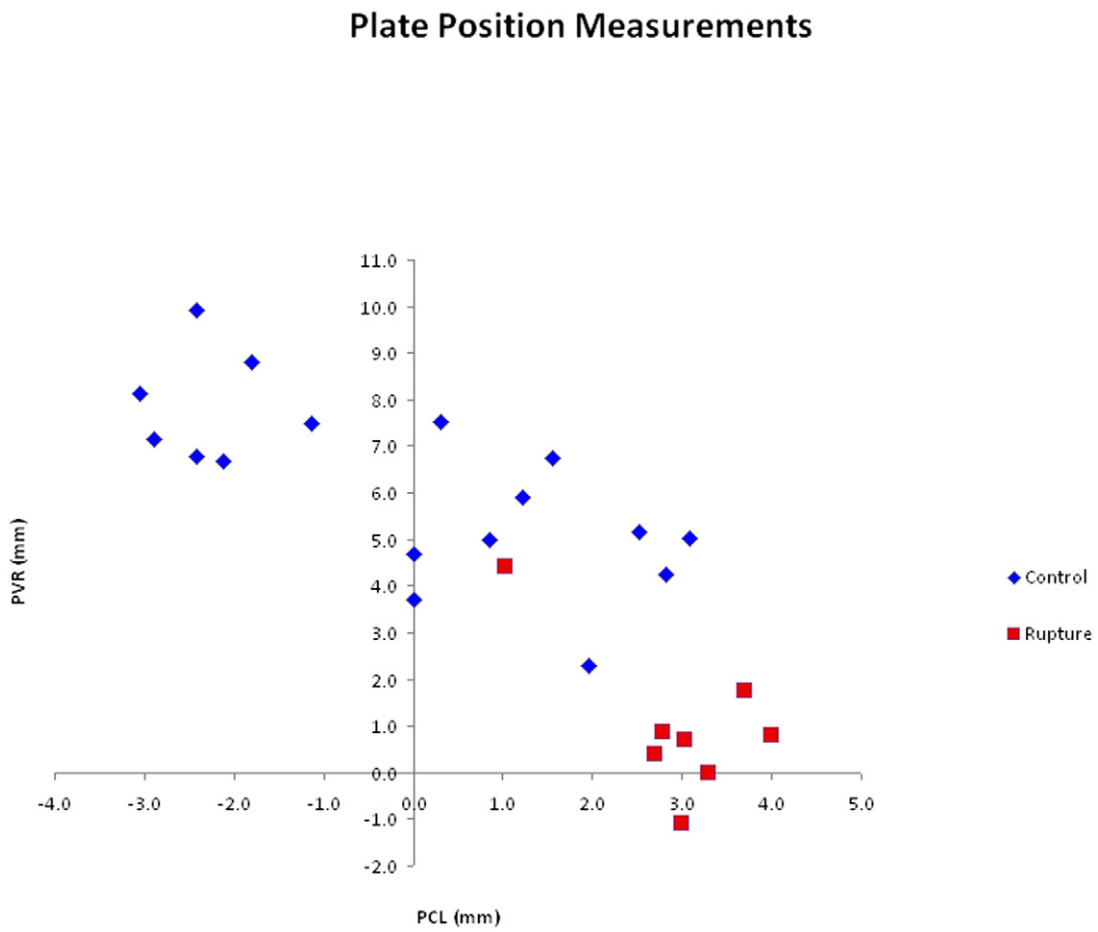


**FIGURE 2:** Plate–to–volar critical line (PCL) and plate–to–volar rim (PVR) distances are associated with flexor tendon injury. Scatter plot demonstrates the plate position measurements for each patient studied. Ruptures, shown in *red,* were associated with larger PCL distances and lower PVR distances.

**TABLE 3. Test Indicators of Flexor Tendon Ruptures Associated With a Plate–to–Critical Line Distance Greater than 2.0 mm and a Plate–to–Volar Rom Distance Less than 3.0 mm**

| | PCL > 2.0 mm | PVR < 3.0 mm |
|---|---|---|
| Sensitivity (95% CI) | 0.88 (0.47, 0.99) | 0.88 (0.47, 0.99) |
| Specificity (95% CI) | 0.82 (0.56, 0.99) | 0.94 (0.69, 0.99) |
| Positive predictive value (95% CI) | 0.70 (0.35, 0.92) | 0.86 (0.47, 0.99) |
| Negative predictive value (95% CI) | 0.93 (0.66, 0.99) | 0.94 (0.69, 0.99) |
| Odds ratios (95% CI) | 32.67 (2.85, 374.13) | 112.0 (6.1, 2057.3) |

CI, confidence interval; PCL, plate–to–control line; PVR, plate–to–volar rim.

The receiver operating characteristic curves identified key threshold PCL and PVR distances associated with strong positive and negative predictive values for flexor tendon rupture (Table 3). Plate prominence greater than 2.0 mm beyond the volar critical line and plate position distal to 3.0 mm from the volar rim both had high sensitivity and specificity for flexor tendon rupture (Table 3). Receiver operating characteristic analysis revealed an area under the curve of 0.85 for a PCL distance of 2.0 mm and an area under the curve of 0.91 for a PVR distance of 3.0 mm.

There were a variety of plate types included in each patient group, including volar plates from TriMed (Santa Clarita, CA), Medartis (Basel, Switzerland),

**TABLE 4. Volar Plate Types**

| | Volar Plate Types (number of patients) |
|---|---|
| Ruptures | Synthes 2.4 LCP distal radius plates (5)<br>Acumed Acu-Loc volar distal radius plate (1)<br>Medartis 2.5 distal radius plate (2) |
| Controls | TriMed volar bearing plate (10)<br>Hand Innovations DVR locking plate (6)<br>Medartis 2.5 distal radius plate (1) |

LCP, locking compression plate.

Hand Innovations (DuPuy, Warsaw, IN), Acumed (Hillsboro, OR), and Synthes (West Chester, PA) (Table 4). There was no statistical relationship between plate type and patient group. None of the radiographs demonstrated loss of reduction, and there were no mismatches on the posteroanterior views between plate width and bony anatomy. The mean ratio between plate width and radius width at the level of the maximum plate width was 0.80 for the rupture group, 0.82 for the irritation group, and 0.86 for the control group ($P = .45$). One patient in the rupture group had a prominent screw head that protruded 2.4 mm volar to the plate.

## DISCUSSION

Flexor tendon rupture after volar plate fixation of distal radius fractures is a rare but serious complication. In Orbay and colleagues' classic paper on volar fixed-angle fixation, they reported that "flexor tendon problems can only occur if fracture reduction is lost, as a properly applied volar plate is recessed into the concavity of the volar radius and is not in contact with these structures."[8] This may have been true with first-generation distal volar radius (DVR, DePuy, Warsaw, IN) plates, but not all volar plates are alike. Some plates are designed specifically for implantation distal to the watershed line.[7] In this area, the flexor tendons lie in close proximity to the hardware and are at increased risk for attrition owing to higher contact pressures between the tendons and the plate.[9]

Distal and prominent plate positions have long been associated with tendon rupture risk. Surgeons attempt to avoid distal and prominent plate positions when possible, but certain fracture patterns necessitate distal plate positions to achieve adequate fixation. In these circumstances, there is a paucity of data to determine what plate positions are associated with flexor tendon rupture.

Soong and colleagues[7] recently described a useful radiographic grading system to assist clinicians in assessing volar plate prominence. They also associated volar plate type with flexor tendon rupture risk, but they were unable to associate plate position with rupture risk because they had only 3 cases of flexor tendon ruptures in their study.

In our study, we quantified the association between Soong grade and flexor tendon rupture in a larger series of 8 patients. We also determined critical distances for plate prominence and position that are associated with an increased risk for tendon rupture, independent of plate type. Plates positioned more than 2.0 mm prominent to the volar critical line or within 3.0 mm of the volar rim had high positive and negative predictive values for tendon rupture. All but 1 of the 8 patients in our study with flexor tendon ruptures had PCL distances greater than 2.0 mm and PVR distances less than 3.0 mm. The 1 patient who did not meet these criteria had a prominent screw head that was thought to be the cause of his flexor tendon rupture.

These results suggest that both the Soong grading system, which is a visual estimate of plate position relative to the volar critical line and the volar rim, and the quantitative measurements of PCL and PVR distances can help surgeons identify patients at risk for tendon ruptures. Soong grade 2 patients have an increased risk of rupture, as do patients with distal plates that extend within 3.0 mm of the volar rim (PVR $< 3.0$). The quantitative measurements of plate position add to the Soong grading system by helping to differentiate the Soong grade 1 patients with an increased rupture risk: those with PCL distances greater than 2.0 mm.

We had several limitations in our study, including the retrospective design and the lack of complete intraoperative data on other potential contributing factors, such as the status of the pronator quadratus. We also had relatively few patients; however, this is one of the largest reported series of flexor tendon ruptures following volar plating.[3–5] In addition, although we accounted for magnification error by normalizing our measurements, digital measurements of PCL and PVR distances could also be influenced by rotation. All of the radiographs were obtained using standard radiography protocols, and we chose only standard lateral views where the pisiform projected over the distal scaphoid.

Consideration should be given to alterative methods of fixation for fracture patterns that require distal and prominent volar plate position to achieve adequate fixation. However, volar plates are occasionally placed in a suboptimal position with regards to tendon rupture risk (Fig. 3). The true incidence of flexor tendon rupture following volar plating of distal radius fractures is not known. By measuring Soong grade and PCL and PVR


**FIGURE 3:** Standard lateral radiographs demonstrate the prominent **A** and distal **B** plate positions in 2 Soong grade 2 patients who sustained postoperative flexor tendon ruptures.

distances on lateral radiographs, surgeons will be able to identify patients at increased risk for flexor tendon rupture. We recommend that these patients be screened carefully for symptoms of tendon irritation. All of the ruptures in this study occurred at a minimum of 6 months after the initial distal radius fracture fixation. Therefore, to decrease rupture risk, we recommend considering elective hardware removal after union at 6 months in symptomatic patients with plate prominence greater than 2.0 mm volar to the critical line or plate position within 3.0 mm of the volar rim.

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