During the past decade, volar plating of distal radius fractures has become an increasingly popular surgical technique. However, rupture of the flexor pollicis longus tendon has been reported after plate fixation. The prevalence of flexor pollicis longus tendon rupture ranged from 0.17% to 12%. Adham et al suggested that some ruptures of the flexor pollicis longus tendon could be attributed to the design of the plate or screw, long-term use of steroids, collapse of the fracture, suboptimal placement of plates, or incorrect use of plates. On the other hand, these authors suggested that proper placement of the volar plate, with the distal edge in the concavity of the distal ends of the radius, is necessary to prevent complications. This placement eliminates the possibility of contact between the plate and the flexor pollicis longus tendon. Repair of the pronator quadratus muscle provides soft tissue coverage between the plate and the flexor tendon. The average distance between the distal edge of the normal radius and the flexor pollicis longus tendon was reported as 1.94 mm (range, 1.2-2.6 mm), and contact...
between the plate and the flexor pollicis longus tendon is difficult to avoid if the plate is placed more distally.9,10

Although implant removal has been performed to prevent rupture of the flexor pollicis longus tendon, it is not always necessary. If the risk of tendon rupture could be predicted, it would be possible to select cases for plate removal. The current authors hypothesized that they could estimate the degree of risk of flexor pollicis longus tendon rupture if ultrasonography correctly showed the relation between the flexor pollicis longus tendon and the plate. The authors assessed the distance between the plate and the flexor pollicis longus tendon with ultrasonography and compared the distance with intraoperative findings. The goal of this study was to assess the flexor pollicis longus tendon and intermediate tissue with ultrasonography.

**Materials and Methods**

Patients and families were informed that data from the case would be submitted for publication and gave their consent. The study was approved by the ethics committee of the study hospital. During the past 2 years, 79 patients (81 wrists) underwent volar locking plate (LC-DRP VA Plate; Synthes GmbH, Solothurn, Switzerland) fixation for distal radius fracture. All patients had follow-up with radiography and ultrasonography. Among 79 patients (81 wrists), 27 patients (28 wrists) underwent removal of the plate because of symptoms or displacement of the plate. In other cases, the plate was removed to avoid future complications, including rupture of the flexor pollicis longus tendon.

Mean age of the study participants was 52 years (range, 16-86 years). The right wrist was affected in 15 cases, and the left wrist was affected in 13 cases. Implant removal was performed an average of 210 days (range, 70-389 days) after fixation.

The prominence of the plate from the radius was measured on a lateral radiograph. A critical line (plate) was drawn tangential to the most volar extent of the volar rim of the plate, parallel to the volar cortical bone of the radial shaft.10,11 In the same way, a critical line (radius) was drawn tangential to the most volar extent of the volar rim of the radius, and the distance between these lines was measured. The authors defined this distance as “plate prominence (radiograph)” and expressed it as positive if the plate protruded from the radius (Figure 1A). Patients underwent radiographic evaluation an average of 49 days (range, 22-183 days) after volar plate fixation.

Ultrasonography (HI VISION Avius; Hitachi, Tokyo, Japan) and a linear probe with a frequency of 14 to 16 MHz were used. All examinations were performed by an author (M. Takahara) who was familiar with ultrasonography. Longitudinal images of the flexor pollicis longus tendon and the distal volar margin of the plate were obtained with the wrist in neutral position and maximum extension (Figures 1B-C). The same author also examined whether the dorsal surface of the flexor pollicis longus tendon was compressed volarly at the distal volar margin of the plate. The minimal distance between the flexor pollicis longus tendon and the plate was measured. This distance was defined as “tendon-plate distance (ultrasound)” (Figure 1D). Ultrasonography was performed an average of 184 days (range, 62-404 days) after volar plate fixation.

During plate removal, patients were evaluated to identify injury of the flexor pollicis longus tendon. The same author who performed the ultrasound examinations (M. Takahara) grossly assessed the intermediate tissues between the flexor pollicis longus tendon and the distal volar margin of the plate. The tissue was divided into 2 groups: (1) thick tissue that included muscle or fibrous tissue that covered the plate and (2) thin, membrane-like tissue through which the plate was visible (Figure 2).

Before removal of the plate, no patient had pain, crepitus, or functional loss during thumb motion. Changes in symptoms after removal of the implant and their relation to intraoperative findings were examined. The correlation between plate prominence (radiograph) and tendon-plate distance (ultrasound) was statistically examined with Spearman’s rank correlation coefficient. The relation between intraoperative findings and plate prominence (radiograph) and the relation between intraoperative findings and tendon-plate distance (ultrasound) were analyzed with the Mann-Whitney U test.
Mean plate prominence (radiograph) was 1.6 mm (range, -0.8 to 4.3 mm). Ultrasonography showed localized deformity of the flexor pollicis longus tendon in 2 cases (7.1%) and compression of the flexor pollicis longus tendon at the distal volar margin of the plate in 11 cases (39.3%). Mean tendon-plate distance (ultrasound) was 0.7 mm (range, 0-2.6 mm) in neutral position and 0.5 mm (range, 0-2.6 mm) in maximum wrist extension. The latter distance tended to be shorter ($P=.38$), although the difference did not reach statistical significance. The shorter distance, representing the minimum tendon-plate distance, was a mean of 0.5 mm (range, 0-2.6 mm), and this value was used for statistical analysis. Age did not statistically correlate with the distance between the flexor pollicis longus tendon and the volar margin of the plate ($r=-0.117, P=.5767$).

Intraoperative findings showed that the intermediate tissue was the pronator quadratus muscle in 5 cases (18%); dense, fibrous tissue in 4 cases (14%); and thin, membrane-like tissue through which the plate was visible in 19 cases (68%). In 1 case, the flexor pollicis longus tendon had a partial rupture of 8 mm, representing 10% of its width on the dorsal side of the tendon. This patient had no preoperative symptoms involving the flexor pollicis longus tendon. Plate prominence (radiograph) was 1.8 mm, tendon-plate distance (ultrasound) was 0.4 mm, and thin, membrane-like intermediate tissue was found.

Changes in symptoms after implant removal were reviewed in the medical charts. The relation between changes in symptoms and intraoperative findings was examined. One patient had relief of pain during active flexion of the index finger, and another had relief of wrist dullness. The intermediate tissue was dense, fibrous tissue in the former case and pronator quadratus muscle in the latter case, and the flexor pollicis longus tendons were intact in both patients.

A negative relation was found between plate prominence (radiograph) and tendon-plate distance (ultrasound) ($r=-0.535, P=.0055$). The more the plate protruded from the radius on radiography, the closer to the plate the flexor pollicis longus tendon appeared on ultrasonography (Figure 3).

No significant relation was found between plate prominence (radiograph) and the intermediate tissue between the flexor pollicis longus tendon and the plate ($P=.1149$). However, the 2 patients who showed no plate prominence (radiograph) had dense, fibrous tissue over the plate (Figure 4).

A strong relation was found between tendon-plate distance (ultrasound) and the intermediate tissue (intraoperative) ($P=.0001$). When the tendon-plate distance (ultrasound) was shorter, the intermediate tissue (intraoperative) was thinner (Figure 5). Thin, membrane-like intermediate tissue was found in 10 of the

and Fisher’s exact test. $P<.05$ was considered statistically significant.

**RESULTS**

Mean plate prominence (radiograph) was 1.6 mm (range, -0.8 to 4.3 mm). Ultrasonography showed localized deformity of the flexor pollicis longus tendon in 2 cases (7.1%) and compression of the flexor pollicis longus tendon at the distal volar margin of the plate in 11 cases (39.3%). Mean tendon-plate distance (ultrasound) was 0.7 mm (range, 0-2.6 mm)
11 cases (91%) with compression of the flexor pollicis longus tendon shown on ultrasonography \((P=.0491)\).

**Discussion**

Soong et al\(^4\) focused on plate implant prominence on postoperative lateral radiographs. They found no ruptures in a group of patients treated with the DVR plate (DePuy Orthopaedics, Inc, Warsaw, Indiana), perhaps as a result of the lower profile of the plate. These authors concluded that prominence of the plate at the watershed line of the distal part of the radius may increase the risk of tendon injury.\(^{11}\)

Brown and Lifchez\(^{12}\) reported a 75-year-old woman who had rupture of the flexor pollicis longus tendon, even though the pronator quadratus was returned to its native position after volar locking plate fixation. According to Douthit,\(^3\) the overall bulk of the pronator quadratus is variable, and the muscle can be relatively thin in middle-aged women. Brown and Lifchez\(^{12}\) speculated that pronator quadratus plate coverage may not protect tendons adequately.

Some reports have described the use of ultrasonography to assess the flexor pollicis longus tendon after volar locking plate fixation in cases of distal radius fracture. In 1 study, ultrasonography showed that the distal part of the plate and the flexor pollicis longus tendon were apposed in 19 of 20 cases.\(^8\) In another study, ultrasonography showed that the tendon and the plate were apposed in 62.5% of cases treated with fixation of a distally placed plate, whereas the tendon was never apposed with a proximally placed plate.\(^{12}\)

The current study assessed the distance between the flexor pollicis longus tendon and the plate with ultrasonography preoperatively and assessed the tendon-plate intermediate tissue intraoperatively. The tendon-plate distance (ultrasound) had a strong relation to the intermediate tissue and a negative relation to plate prominence (radiograph). These findings suggested that ultrasonographic evaluation of the flexor pollicis longus tendon and the plate was more useful than radiography in identifying the intermediate tissue between the flexor pollicis longus tendon and the volar locking plate. No previous data were found on the relation between preoperative assessment and intraoperative findings on rupture of the flexor pollicis longus tendon.

Thin, membrane-like tissue between the flexor pollicis longus tendon and the plate was histologically composed of synovial tissue. If the flexor pollicis longus tendon-plate distance (ultrasound) was less than 0.7 mm, ultrasonography showed sensitivity of 95%, specificity of 89%, accuracy of 93%, positive predictive value of 95%, and negative predictive value of 89% in detecting the intermediate tissue of thin synovial membrane through which the plate was visible \((P<.0001)\). Although both sensitivity and specificity were high, 1 false-negative finding occurred \(\text{(Table)}\).

To reach 100% sensitivity without any false-negative findings, the flexor pollicis longus tendon-plate distance (ultrasound) had to be lower than 0.9 mm, and its specificity was 44%, accuracy was 82%, positive predictive value was 79%, and negative predictive value was 100% \((P=.0062)\).

Of 10 patients who had focal compression of the flexor pollicis longus tendon on ultrasonography, 9 (90%) had thin, membrane-like intermediate tissue through which the plate was visible. The tendon-plate distance (ultrasound) can be used to identify whether the patient has thin, membrane-like intermediate tissue or dense, fibrous scar.

The current authors are often asked about future problems with volar locking plates when patients have achieved bone union and almost normal wrist function. When patients are told that there is a potential complication of flexor pollicis longus tendon rupture associated with
the plate if the flexor pollicis longus tendon is attenuated, most patients ask how they can avoid this risk. In this case, the flexor pollicis longus tendon and the intermediate tissue are assessed with lateral radiography and ultrasonography. If the tendon-plate distance is less than 0.7 mm or if the flexor pollicis longus tendon is compressed by the plate, the intermediate tissue is assessed as a synovial membrane or none (Figure 6). The tendon may have a risk of attenuation or even rupture if the floor is a plate or only a thin membrane. Plate removal is recommended for patients who are found to have only thin, membrane-like tissue.

**Conclusion**

This study assessed the flexor pollicis longus tendon and the intermediate tissue. However, the practical incidence of tendon attenuation in these cases is unknown. Follow-up is necessary with patients who have not undergone plate removal even though ultrasonography showed thinner intermediate tissue.

Intermediate tissue can change over time. Serial ultrasonography should be performed to re-evaluate the intermediate tissue. Repeated ultrasonographic evaluations were not performed in this study; therefore, no data are available on intra- or interexaminer differences. This preliminary report compared ultrasonographic findings with the intermediate tissue between the flexor pollicis longus tendon and the plate. The results showed that ultrasonography could be used to identify the intermediate tissue, suggesting that ultrasonography has the potential to predict the risk of attenuation of the flexor pollicis longus tendon. Further studies with larger samples are necessary to investigate intra- or interexaminer differences, changes over time, and diagnostic values.

**References**