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Mobility of the Flexor Pollicis Longus Tendon After Volar Locking Plate Fixation of Distal Radius Fractures: A Prospective Ultrasound Study

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Abstract

Introduction:

Distal radius fractures are among the most common upper extremity fractures encountered in clinical practice. Flexor pollicis longus (FPL) tendon rupture is a well-documented complication of volar locking plate (VLP) fixation. This prospective study used transverse ultrasound (US) to evaluate FPL tendon mobility on the distal radius during finger motion in patients treated with VLP fixation, comparing the operated side with the contralateral non-operated side.

Methods

Twenty-two patients (18 men, 4 women; mean age [42 ± 12] years) who underwent VLP fixation for distal radius fractures were evaluated at 6 months postoperatively. Transverse US was used to measure the position of the FPL tendon as X and Y coordinates relative to a fixed bony reference point on the distal radius at 60-degree wrist dorsiflexion, with the thumb interphalangeal (IP) joint in flexion, neutral, and extension positions. Operated and non-operated sides were compared. All surgical procedures were performed by or under the supervision of the senior author, and all US examinations were conducted by a single experienced musculoskeletal sonologist.

Results

The FPL tendon showed a trend toward greater volar (Y-axis) and ulnar (X-axis) displacement on the operated side across all three thumb positions; however, none of these differences reached statistical significance ($p > 0.05$ for all comparisons). The mean X-coordinate on the operated side was 1.26 cm in flexion versus 1.41 cm on the non-operated side ($p = 0.198$). The mean Y-coordinate was 0.25 cm versus 0.16 cm ($p = 0.087$). The mean IP joint range of motion (ROM) of the thumb was significantly lower on the operated side compared to the non-operated side ($p = 0.001$). No FPL tendon ruptures or clinically significant complications were observed in any patient during the study period.

Conclusion

Following VLP fixation, the FPL tendon demonstrated a non-significant volar and ulnar shift relative to the contralateral side, contrary to the dorsal shift reported in previous studies. This finding may be attributed to meticulous pronator quadratus repair, early postoperative mobilization, and plate positioning proximal to the watershed line. This study is the first to report a volar FPL shift pattern using a contralateral comparison design, highlighting the influence of surgical technique on tendon kinematics. US remains a valuable, non-invasive tool for postoperative monitoring of FPL tendon position. Larger studies incorporating fracture reduction parameters are needed to confirm these findings.

Introduction

Distal radius fractures are among the most common fractures of the upper extremity, with an estimated incidence of 178 to 252 per 100,000 person-years among adults [1]. Volar locking plate (VLP) fixation has become the standard surgical treatment for unstable distal radius fractures, offering stable fixation and enabling early mobilization [1,2]. Despite its widespread adoption, VLP fixation is associated with several complications, among which flexor pollicis longus (FPL) tendon rupture is one of the most significant, with reported incidence ranging from 0.5% to 12% [3,4].

FPL tendon rupture following VLP fixation is primarily attributed to chronic attrition of the tendon against a prominent plate or screw head. Contributing factors include plate design, fracture collapse, suboptimal plate placement, and implant prominence at or distal to the watershed line [3,5,6]. Soong et al. [3] introduced a grading system for plate prominence based on lateral radiographs, demonstrating that higher-grade prominence is associated with increased risk of flexor tendon complications. Kitay et al. [5] further identified that plate prominence greater than 2.0 mm volar to the critical line and plate position within 3.0 mm of the volar rim were associated with attritional flexor tendon rupture. More recently, Lv et al. [6] identified reduced volar tilt, Soong grade 2, plate-to-cortical lip distance (PCLD) greater than 2 mm, and plate-to-volar rim distance (PVRD) less than 3 mm as significant risk factors for FPL attrition or rupture in a series of 338 patients. Park et al. [7] further corroborated these findings, identifying PCLD, sagittal carpal alignment (SCA), and radius-volar lip distance (RVLD) as significant predictive factors for flexor tendon rupture.

Diagnostic ultrasound (US) has emerged as a valuable tool for assessing the relationship between the FPL tendon and the volar plate. US offers technical simplicity, low cost, non-invasiveness, real-time capability, and portability [8,9,10]. Kadoma et al. [8] demonstrated the utility of US in assessing FPL tendon position after plate fixation. Kara et al. [12] used US to evaluate FPL tendon thickness and tendon-to-plate distance following VLP fixation. More recently, Kim et al. [11] showed that ultrasonographic classification of FPL-plate contact configuration (indentation vs. smooth contact) can predict tendon attrition with a sensitivity of 100% and specificity of 80%.

Nanno et al. [9,10] pioneered the use of transverse US to evaluate FPL tendon movement on the distal radius during wrist and finger motion. In their 2016 study of patients with VLP fixation, they observed a significant dorsal shift of the FPL tendon on the operated side compared to the unaffected side [9]. In a subsequent 2018 study of 25 patients, they demonstrated that this dorsal and ulnar shift persisted while the plate was in situ and reversed to a volar shift after plate removal, suggesting that adhesions between the FPL tendon and the pronator quadratus (PQ) muscle or plate may influence tendon position [10].

However, the existing literature has several limitations. First, the evidence base is predominantly from a single research group, and the generalizability of these findings to different surgical practices, implant designs, and patient populations remains uncertain. Second, the influence of surgical technique, particularly PQ repair and early mobilization protocols, on postoperative FPL tendon kinematics has not been adequately investigated. Third, recent studies have identified plate positioning parameters and

fracture reduction quality as critical determinants of FPL tendon health, yet their relationship to tendon mobility patterns has not been explored using US [6,7].

The aim of this study was to evaluate FPL tendon mobility on the distal radius using transverse US in patients treated with VLP fixation for distal radius fractures, comparing the operated and non-operated sides, and to correlate these findings with clinical outcomes. We hypothesized that FPL tendon displacement would differ between the operated and non-operated sides and that these differences would correlate with clinical symptoms.

Methods

Study Design and Ethical Approval

This was a prospective, single-center, comparative study conducted at a teritiary care centre in India. Institutional ethics committee approval and institutional research committee clearance were obtained prior to patient enrolment. The study was conducted in accordance with the Declaration of Helsinki and the ICMR National Ethical Guidelines for Biomedical and Health Research. Written informed consent was obtained from all participants, all of whom were aged 18 years or above.

Participants: Patients who underwent VLP fixation for distal radius fractures during the study period [2021–2023] were screened for eligibility. The inclusion criteria were: (1) age 18 years or above; (2) distal end of radius fracture treated with VLP fixation during the study period; (3) no history of wrist pathology restricting wrist joint movements; and (4) willingness to provide written informed consent. The exclusion criteria were: (1) associated fractures of the same limb; (2) fracture or deformity of the contralateral limb; (3) history of wrist pathology restricting wrist joint movements; (4) pathological fracture other than osteoporotic fractures; (5) previous wrist surgeries or trauma; (6) diabetes mellitus; (7) rheumatoid disease; (8) triggering of thumb; and (9) cervical spine disease.

[A total of 27 patients were screened, of which 5 were excluded (lost follow-up). Twenty-two patients met the eligibility criteria and were included in the study.]

Surgical Procedure

All surgical procedures were performed by or under the direct supervision of the senior author, Professor of Orthopaedics. Open reduction and internal fixation were performed through a standard volar approach (Henry's approach) using a volar locking plate system. Volar locking plate system Nebula Surgicals was used in 14 patients (63.6%), and Bonetec was used in 8 patients (36.4%). In all cases, the plate was positioned proximal to the watershed line, and the PQ muscle was meticulously repaired over the plate following fixation. Early range of motion exercises were initiated postoperatively as per the institutional protocol.

Postoperative Assessment

Patients were evaluated at 6 months postoperatively. Clinical assessment included measurement of thumb IP joint ROM on both the operated and non-operated sides using a goniometer. The presence of any FPL tendon-related complications, including tenosynovitis, triggering, or rupture, was documented.

Ultrasound Examination: All US examinations were performed by a single experienced musculoskeletal sonologist (Associate Professor, Department of Radiology) with more than 20 years of experience in musculoskeletal imaging, using a GE healthcare logiq e7 ultrasound machine equipped with a high-frequency linear transducer: 15 MHz probe. The sonologist was aware of the operated side but was blinded to the clinical findings.

The participant was seated with the forearm supinated, the elbow at approximately 45-degree flexion, and the shoulder in the neutral position. The forearm was fixed to a custom-made examination table to ensure consistent positioning across all patients (Fig. 1). The custom table was designed to maintain the forearm in a stable, reproducible position during the examination, minimizing variability in measurements.

The reference point (P) was defined as the vertex of the palmar bony prominence of the radiolunate fossa of the distal radius on the watershed line [3,9]. The distance from the centroid of the FPL tendon to this reference point was measured along the X-axis (radio-ulnar direction, positive value indicating ulnar displacement) and Y-axis (volar-dorsal direction, positive value indicating volar displacement) using transverse US imaging (Fig. 2). Measurements were obtained with the wrist in 60-degree dorsiflexion and the thumb IP joint in three positions: full flexion, neutral, and full extension.

The 60-degree wrist dorsiflexion position was chosen based on the methodology established by Nanno et al. [9], who demonstrated that wrist dorsiflexion with finger flexion is the optimal position for evaluating FPL tendon irritation after volar plating, as this position maximizes tendon excursion over the distal radius.

Statistical Analysis

Data were analyzed using [SPSS version 20.0]. Continuous variables were expressed as mean and standard deviation (SD). The normality of data was assessed using the [Shapiro-Wilk test]. Differences in FPL tendon coordinates between the operated and non-operated sides were compared using the [paired t-test / Wilcoxon signed-rank test]. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 22 patients were included in the study. The demographic and clinical characteristics are summarized in Table 1.

Table 1
Demographic and Clinical Characteristics (N = 22)

Variable	Value
Age (years), mean ± SD	[42 ± 12]
Sex, n (%)	Male: 18 (81.8%); Female: 4 (18.2%)
Diabetes mellitus, n (%)	5 (22.7%)
Hypertension, n (%)	4 (18.2%)
Side of fracture, n (%)	Left: 14 (63.6%); Right: 8 (36.4%)
Mechanism of injury, n (%)	Fall: 10 (45.5%); RTA: 10 (45.5%); Others: 2 (9.1%)
AO/OTA fracture type, n (%)	C2: 12 (54.5%); C1: 7 (31%) ; A2: 2 (9.1%);
Implant type, n (%)	Nebula: 14 (63.6%); [Other: 8 (36.4%)]

Among the 22 participants, 18 (81.8%) were men and 4 (18.2%) were women, with a mean age of 42 ± 12 years. Five patients (22.7%) had diabetes mellitus and four (18.2%) had hypertension. The left radius was fractured in 14 patients (63.6%) and the right in 8 (36.4%). The mechanism of injury was a fall in 10 patients (45.5%) and a road traffic accident in 10 patients (45.5%). The most common AO/OTA fracture type was C2 (n = 12, 54.5%). The Nebula VLP system was used in 14 patients (63.6%).

FPL Tendon Displacement

The FPL tendon coordinates are presented in Table 2. The X-axis represents the radio-ulnar direction (positive = ulnar), and the Y-axis represents the volar-dorsal direction (positive = volar). All measurements are in centimeters.

Table 2
FPL Tendon Coordinates: Operated vs. Non-Operated Sides

Position	Side	Mean (cm)	SD	p-value
X-axis, Flexion	Operated	1.26	0.49	0.198
X-axis, Flexion	Non-operated	1.41	0.10	-
Y-axis, Flexion	Operated	0.25	0.16	0.087
Y-axis, Flexion	Non-operated	0.16	0.11	-
X-axis, Neutral	Operated	1.31	0.48	0.244
X-axis, Neutral	Non-operated	1.45	0.17	-
Y-axis, Neutral	Operated	0.22	0.16	0.127
Y-axis, Neutral	Non-operated	0.16	0.11	-
X-axis, Extension	Operated	1.26	0.50	0.408
X-axis, Extension	Non-operated	1.37	0.15	-
Y-axis, Extension	Operated	0.25	0.18	0.387
Y-axis, Extension	Non-operated	0.20	0.14	-
All p-values > 0.05 (not significant).				

Across all three thumb positions, the mean X-coordinate was lower on the operated side, indicating a relative ulnar shift. In flexion, 1.26 ± 0.49 cm versus 1.41 ± 0.10 cm (p = 0.198). In neutral, 1.31 ± 0.48 cm versus 1.45 ± 0.17 cm (p = 0.244). In extension, 1.26 ± 0.50 cm versus 1.37 ± 0.15 cm (p = 0.408). None reached statistical significance.

The mean Y-coordinate was higher on the operated side across all positions, indicating a relative volar shift. In flexion, 0.25 ± 0.16 cm versus 0.16 ± 0.11 cm (p = 0.087). In neutral, 0.22 ± 0.16 cm versus 0.16 ± 0.11 cm (p = 0.127). In extension, 0.25 ± 0.18 cm versus 0.20 ± 0.14 cm (p = 0.387). None were statistically significant.

Clinical Outcomes

The mean ROM of the thumb IP joint was significantly lower on the operated side (p = 0.001) (Table 3). No FPL tendon ruptures, tenosynovitis, triggering, or other complications were observed during the 6-month follow-up. None required early plate removal.

Table 3
Thumb IP Joint ROM and Clinical Outcomes

Parameter	Operated	Non-Operated	p-value
IP joint ROM (degrees), mean ± SD	0-74.5 ± 5.7	0–80 ± 0	0.001
FPL complications, n	0	0	-
Plate removal, n	0	-	-

Discussion

This prospective study used transverse US to evaluate FPL tendon mobility on the distal radius in 22 patients who underwent VLP fixation for distal radius fractures, comparing the operated and non-operated sides at 6 months postoperatively. The principal finding was that the FPL tendon on the operated side demonstrated a consistent trend toward volar and ulnar displacement relative to the contralateral side across all three thumb IP joint positions, although these differences did not reach statistical significance. Additionally, the IP joint ROM of the thumb was significantly reduced on the operated side ($p = 0.001$), though no FPL tendon ruptures or clinically significant complications were observed.

The observed volar shift of the FPL tendon in our study is contrary to the findings of Nanno et al. [9], who reported a significant dorsal shift of the FPL tendon on the operated side in patients with VLP fixation evaluated by transverse US. In their 2018 follow-up study, Nanno et al. [10] found that the FPL tendon shifted dorsally and ulnarly while the plate was in situ, with a reversal to volar shift after plate removal. The ulnar shift observed in our study is consistent with their findings; however, the accompanying volar shift, rather than dorsal, represents a notable divergence.

Several factors may explain this discrepancy. First, in all our patients, the PQ muscle was meticulously repaired over the plate following fixation. The repaired PQ may act as a cushion or interposition between the plate and the FPL tendon, potentially displacing the tendon volarly. Nanno et al. [10] hypothesized that adhesions between the FPL tendon and the PQ muscle or plate influence tendon position, as evidenced by the volar shift observed after plate removal in their study, which they attributed to adhesion release. Our practice of PQ repair and early mobilization may have minimized such adhesions, resulting in a tendon position more similar to the post-plate-removal state described by Nanno et al. [10]. Bhat et al. [13] also emphasized the importance of PQ repair in their study correlating FPL tendon status on US with plate position on radiographs, finding that PQ repair was associated with preserved tendon integrity.

Second, early postoperative mobilization was initiated in all our patients, which may have further reduced adhesion formation between the FPL tendon and the underlying plate-PQ construct. Early mobilization is known to promote tendon gliding and prevent peritendinous fibrosis.

Third, the plate was positioned proximal to the watershed line in all our cases, which may have minimized the mechanical impingement that drives the FPL tendon dorsally. Soong et al. [3] demonstrated that plate prominence at or beyond the watershed line is a key risk factor for flexor tendon complications.

Fourth, implant design differences may contribute. Stepan et al. [14] demonstrated that FPL-specific plate designs with distal cutouts significantly reduced plate-tendon contact area compared to standard plates, and that increased volar tilt was associated with reduced contact. The Nebula plate, used in 63.6% of our patients, features a low-profile distal edge that may influence tendon kinematics differently from the plates used in Nanno et al.'s studies.

The significant reduction in IP joint ROM on the operated side ($p = 0.001$), despite the absence of FPL rupture, warrants discussion. This finding suggests that even in the absence of frank tendon injury, subclinical tendon irritation, postoperative stiffness, or altered tendon kinematics may affect thumb function. The reduced ROM may reflect a combination of postoperative stiffness, altered tendon gliding, and the natural history of recovery after distal radius fracture fixation.

An important consideration raised by recent literature is the role of fracture reduction quality in FPL tendon positioning. Lv et al. [6], in a study of 338 patients, demonstrated that reduced volar tilt was significantly associated with FPL attrition or rupture ($p = 0.005$), along with Soong grade 2, PCLD greater than 2 mm, and PVRD less than 3 mm. Park et al. [7] identified PCLD, SCA, and RVLD as significant predictive factors for flexor tendon rupture, emphasizing the importance of accurate anatomic reduction and optimal plate positioning. These findings suggest that inadequate fracture reduction with loss of volar tilt may alter the spatial relationship between the FPL tendon and the volar plate, potentially exacerbating tendon-plate contact and attrition. In our study, plate positioning relative to the watershed line was confirmed intraoperatively, but formal radiographic analysis of fracture reduction parameters (palmar tilt, teardrop angle, Soong classification) was not performed. This limits our ability to determine whether fracture reduction quality influenced the observed FPL tendon displacement pattern.

The absence of statistically significant differences in FPL tendon coordinates between the operated and non-operated sides, despite observable trends, may be attributable to the small sample size. With 22 patients, our study may have been underpowered to detect a true difference in tendon displacement, representing a potential Type II error. The standard deviations on the operated side were notably larger than those on the non-operated side, suggesting greater variability in tendon position after surgery, which may reflect individual variations in surgical technique, fracture pattern, and healing response.

Recent studies have further demonstrated the utility of US in predicting FPL tendon complications. Kim et al. [11] showed that ultrasonographic contact configuration classification (indentation vs. smooth contact) predicted FPL attrition with a sensitivity of 100% and specificity of 80%. These findings, combined with our results, support the routine use of US for postoperative monitoring of FPL tendon position in patients treated with VLP fixation. Late FPL ruptures have been reported up to 10 years after VLP fixation [15], underscoring the need for ongoing surveillance beyond the 6-month mark.

This study contributes to the existing literature in several ways. First, it is the first to report a volar FPL shift pattern in the presence of an in-situ volar plate, challenging the prevailing understanding that VLP fixation causes a dorsal shift. Second, it highlights the potential influence of surgical technique, particularly PQ repair and early mobilization, on postoperative tendon kinematics, a factor not previously discussed in the literature. Third, it provides data from a different patient population and surgical setting than the existing studies, which are exclusively from a single Japanese research group, thereby contributing to the generalizability of US-based FPL assessment methodology.

This study has several limitations. First, the sample size of 22 patients may have been underpowered to detect statistically significant differences in tendon displacement; the observed trends warrant confirmation in a larger cohort with an adequate power calculation. Second, no radiographic analysis of fracture reduction parameters (palmar tilt, teardrop angle, Soong classification, PCLD, PVRD) was performed, which are known to influence FPL tendon position and the risk of attrition [6,7]. Third, the study assessed FPL tendon position but did not evaluate direct tendon-plate contact configuration, which has been shown to be predictive of attrition [11]. Fourth, all US examinations were performed by a single sonologist, which limits assessment of inter-rater reliability and generalizability. Fifth, the unequal gender distribution (18 men, 4 women) precluded meaningful subgroup analysis. Sixth, patients were evaluated at 6 months postoperatively; late FPL tendon ruptures have been reported up to 10 years after surgery [15], and the absence of complications at 6 months does not preclude late events. Finally, functional outcomes were limited to IP joint ROM; the absence of validated patient-reported outcome measures (QuickDASH, PRWE) limits the clinical correlation.

Future studies should include a larger prospective cohort with an a priori power calculation, incorporation of radiographic fracture reduction parameters correlated with US findings, longitudinal follow-up with serial US examinations at multiple time points, a pre- and post-plate removal comparison study, correlation with validated patient-reported outcome measures and grip/pinch strength, and assessment of FPL-plate contact configuration alongside coordinate measurements.

In conclusion, following VLP fixation of distal radius fractures, the FPL tendon demonstrated a non-significant volar and ulnar displacement on the operated side compared to the contralateral side, contrary to the dorsal shift reported in previous studies. This finding may be attributed to meticulous PQ repair, early postoperative mobilization, and plate positioning proximal to the watershed line. IP joint ROM was significantly reduced on the operated side, though no FPL ruptures occurred. This study is the first to report a volar FPL shift pattern with an in-situ volar plate, highlighting the potential influence of surgical technique on postoperative tendon kinematics. US remains a valuable, non-invasive tool for postoperative monitoring of FPL tendon position. Larger studies incorporating fracture reduction parameters and long-term follow-up are needed to confirm these findings.

Declarations

Author Contribution

ARR: study conception and design, data acquisition, drafting of manuscript. KR: study design, surgical procedures, critical revision. MG: ultrasound examinations, data acquisition, critical revision. MM: study conception, critical revision of intellectual content, statistical analysis, tables and figures. All authors read and approved the final manuscript

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Figures



Figure 1

Custom-made examination table setup. The participant's forearm is secured in supination with the elbow at approximately 45-degree flexion and the shoulder in neutral position, ensuring consistent and reproducible positioning for ultrasound measurement across all patients.

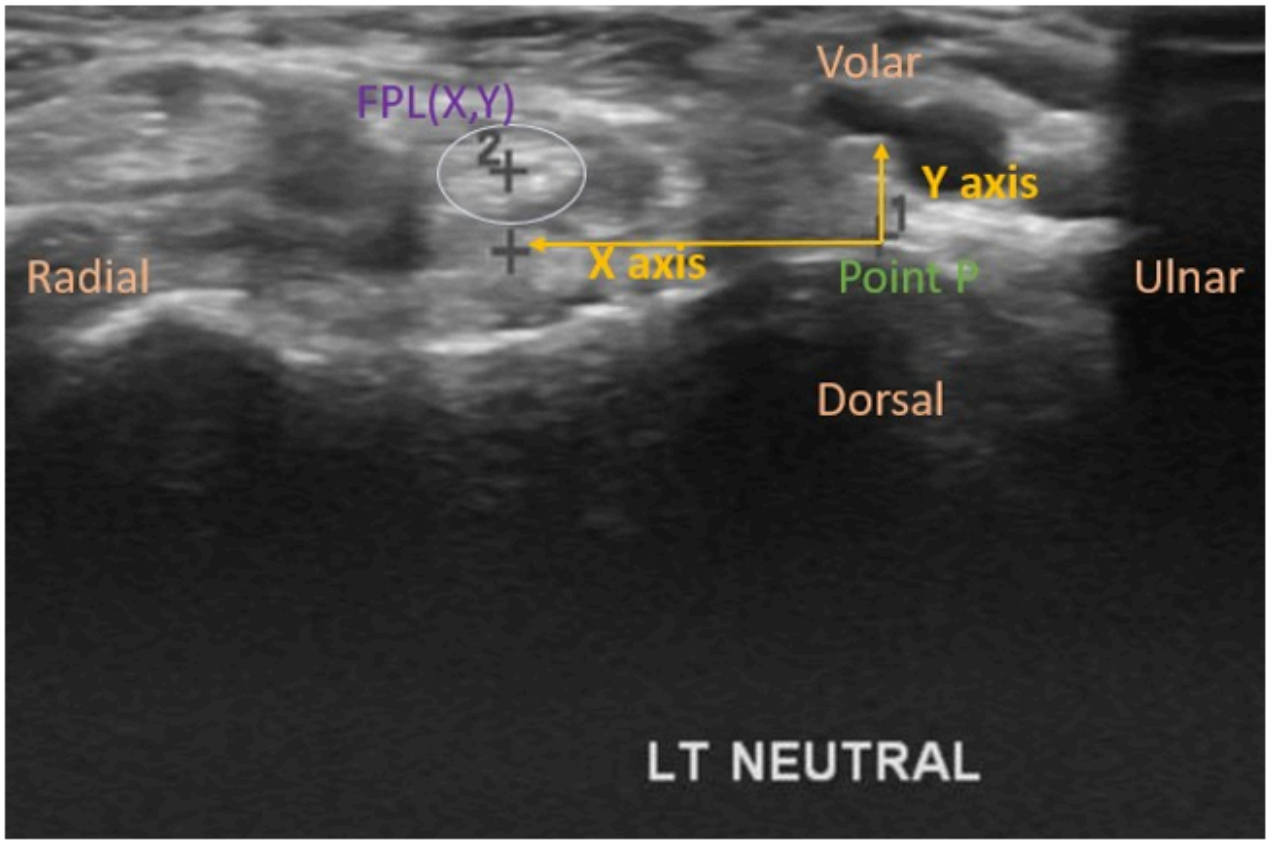


Figure 2

Transverse ultrasound measurement of flexor pollicis longus (FPL) tendon position. The reference point (P) is defined as the vertex of the palmar bony prominence of the radiolunate fossa of the distal radius on the watershed line. X-axis represents the radio-ulnar direction (positive = ulnar displacement), and Y-axis represents the volar-dorsal direction (positive = volar displacement). Measurements were obtained with the wrist in 60-degree dorsiflexion and the thumb IP joint in flexion, neutral, and extension.