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ARTICLE

# An investigation of dynamic ulnar impingement after the Darrach procedure with ultrasonography

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**ABSTRACT**

Dynamic ulnar impingement is a common and painful symptom after the Darrach procedure. However, the current detection method with *static* radiographs often falls short of examining the *dynamically* symptomatic wrists. We, therefore, investigate the utility of ultrasonography to assess dynamic ulnar impingement. In this cross-sectional study, 20 patients, with 22 wrists, who had undergone the Darrach procedure were evaluated at a mean of 55 months (range, 25–171) from the index procedure. Real-time ultrasonographic imaging in the axial plane of the bone and soft tissue was performed during three different dynamic testing methods, including weight-stressed (WS), pronation-supination (PS), and forceful fist clenching (FC), to investigate ulnar impingement. Dynamic radiographs were obtained for comparison. Clinical outcomes were evaluated with grip strength and patient-reported outcomes including pain in daily activities on a numeric rating scale (NRS), the Patient-Rated Wrist Evaluation (PRWE), and the Quick Disability of the Arm, Shoulder and Hand (QDASH). Ultrasonographic ulnar impingement found during PS method was associated with worse pain and function, yet impingement diagnosed with dynamic radiographs or ultrasonography with WS and FC method was not associated with worse outcomes. While radiographic impingement was found in a total of 12 wrists (55%), ultrasonography with the WS and PS method revealed true bone contact in only 2 (9%) and 4 (18%) of the wrists, respectively. The addition of ultrasonography may be valuable in follow-up evaluations after the Darrach procedure.

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Darrach procedure; distal radioulnar instability; distal ulnar resection; dynamic ulnar impingement; ultrasonography

## Introduction

Distal ulna resection was first described by Moore in 1880, and popularized by Darrach with his publication [1], and was therefore named the Darrach procedure. The procedure was later utilized to address the pain and mechanical blocking of forearm rotation caused by advanced distal radioulnar joint (DRUJ) arthritis. It has also been an important component in the reconstruction of attritional ruptured extensor tendons of the hands affected by rheumatoid arthritis (RA) [2,3].

The original procedure described the mere resection of the distal ulna and generally resulted in good early outcomes. However, ulnar stump instability, presented largely in the form of ulnar dorsal subluxation and painful dynamic impingement, may present in more than half of the population in mid- to long-term follow-up [4–8]. Many ulnar stump stabilization techniques were developed to address the shortcomings, including tenodesis using all or part of the extensor carpi ulnaris (ECU) tendon [9–11], the flexor carpi ulnaris (FCU) tendon [12,13], or both tendons [14], and an interposition procedure with pronator quadratus (PQ) [15]. Counterintuitively, among most patients with radiographic presence of ulnar impingement after the modified Darrach procedure, only a few patients were symptomatic [15–17].

Currently, the most well-accepted method to detect dynamic ulnar impingement is the weight-stressed view proposed by Lees and Scheker [18]. The technique utilizes anteroposterior radiographs taken with the patient holding a 2.2-kg weight, with the elbow flexed, and the forearm in neutral rotation. It is a swift and readily available imaging modality in outpatient settings. However, the *static* radiographic view of a single, coronal plane may fall short in demonstrating the nature of a *dynamic* pathology [19]. Since ulnar impingement is a dynamic incident, "real-time" imaging using ultrasonography may provide additional information.

The aim of this study was to evaluate dynamic ultrasonography with three different maneuver techniques for the examination of radioulnar impingement after the Darrach procedure. We compared ultrasonographic and radiographic findings for associations between the diagnosis with different imaging and clinical outcomes. It was hypothesized that dynamic ulnar impingement confirmed with a proper method of ultrasonography was associated with a worse patient-reported outcome of the wrist.

## Materials and methods

### *Patient selection*

This was a cross-sectional study of patients who had undergone the Darrach procedure between January 2010 and October 2018 in this hospital. Patients receiving surgery for advanced symptomatic DRUJ arthritis, with or without attritional extensor tendon rupture, aged 18–100 years at the time of surgery, were included

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in this study. The procedures were performed by two hand specialists. We excluded patients who received the Darrach procedure in acute traumatic settings, for infectious control, or as a part of tumor excision. The patients were invited for a clinical evaluation. Approval of this study was granted by the Institutional Ethics Committee of this hospital. Written informed consent was required from all participants.

## Surgical technique

The patients received surgery under general anesthesia. An incision was made on the dorsal side of the wrist, medial to the extensor carpi ulnaris (ECU). Anterior interosseous nerve (AIN) and posterior interosseous nerve (PIN) neurectomy were routinely performed, excising the distal 1–2 cm section. The extensor retinaculum, periosteum, and the distal part of the pronator quadratus (PQ) muscle were elevated to expose the distal ulna. Then ulnar osteotomy was made in a long-sloped shape, and parallel to the contour of the opposing radius. The edges of the ulnar cut were beveled with the saw. The detached distal part of the PQ muscle was transferred dorsally and sutured onto the periosteum sleeve of the ulnar stump, forming an interposition (Figure 2). In the cases with an attritional tear of the extensor tendons, the tendons were explored and reconstructed using the same incision.

For those who received extensor tendon repair and reconstruction, a short-arm splint was applied for 4 weeks postoperatively. Those who underwent only the Darrach procedure were immobilized for 2 weeks. Progressive physiotherapy was initiated after splint removal.

## Study variables and outcome assessment

Radiographs of the wrist were taken, including AP, lateral, and a modified "Scheker's view". The 2.2-kg weight proposed by Lees and Scheker [18] was decreased to 1 kg, as very few patients in our series were able to hold heavier than 1 kg. The space between the radius and ulna in the DRUJ remnant was measured. Radiographic convergence was defined by a decrease of radioulnar gap distance; radiographic impingement was defined by the absence of the gap between bones. The preoperative and immediate postoperative radiographs were reviewed. The length of the ulnar cut was measured from the distal margin of the ulnar head to the mid-point of the ulnar cut, using the volar rim of radial joint level as reference (Figure 3).

Ultrasonography was performed by the senior author (Y.C.H) with a portable ultrasound machine (Logiq e®; GE Healthcare, Chicago, Illinois, United States). The patients were placed in a position with full shoulder adduction, 90-degrees elbow flexion, and the forearm in a neutral rotation position. The examiner held the patient's hand in neutral rotation to ensure a standardized position. The probe was placed on the dorsal side of the distal forearm to acquire an axial view. The probe was then slid back and forth to locate the most-distal observable point of the ulnar tip.

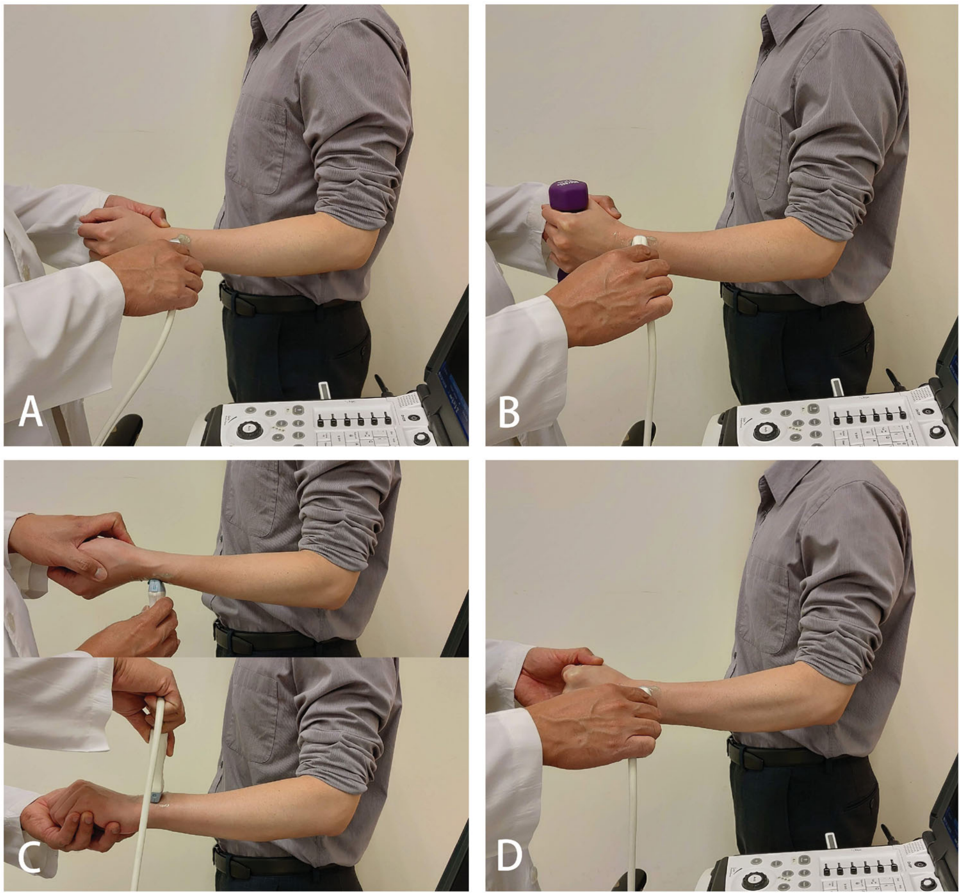



Figure 1. A diagram showing the process of our ultrasonography protocol. The patient was placed in full shoulder adduction, 90-degree elbow flexion, and the forearm in neutral rotation as a baseline (A). We paid special attention to keeping the rotation of the wrist steady while performing ultrasonography by holding the patient's hand in neutral rotation. The patients were then asked to hold a 1-kg weight (B) to perform full pronation followed by full supination (C) and to clench forcefully (D).

Three different maneuvers of the distal forearm were studied with ultrasonography. First, the patients were asked to hold a 1-kg weight (weight-stressed method, WS); second, they performed a forearm rotation from full pronation to full supination (pronation-supination method, PS); finally, they made a forceful clenched fist (fist-clenching method, FC) (Figure 1). The tendons of the dorsal compartment were assessed for gliding motion and noted for any abnormal catching or snapping. The images were recorded in videos and measured for radioulnar distance. We defined convergence as a decrease from the widest radioulnar distance, and impingement as radioulnar bony contact.

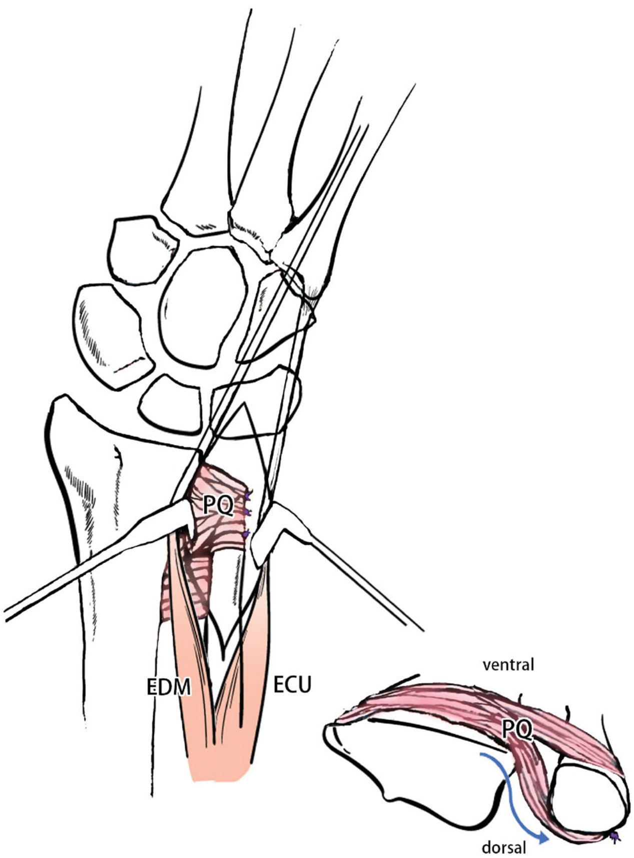



Figure 2. A diagram of the surgical procedure. The distal PQ was detached to the level of ulnar resection, transferred dorsally, and attached to the periosteum/joint capsule complex of the ulnar stump.

Grip strength was measured using a Jamar dynamometer (Baseline® Hydraulic Hand Dynamometers; Fabrication Enterprises, White Plains, NY, USA).

We assessed subjective outcomes *via* patient-reported evaluations, including the Quick Disability of the Arm, Shoulder and Hand (QDASH) score and objective pain in daily activities on a numeric rating scale (NRS) (from 0 to 10, with 0 denoting no pain at all, and 10 the worst possible pain).

Demographics, including age, sex, hand dominance, occupation, time from index procedure, etiologies of DRUJ arthritis, preoperative clinical scores, additional interventions, and post-operative complications, were collected from the medical charts.

### *Statistics*

Data are assessed for normality was using the Shapiro–Wilk test. Numeric variables were presented as means and standard deviations (SD) and while non-numeric data were presented as median values with the interquartile range (IQR). Comparisons were made between preoperative and postoperative outcomes. The paired *t*-test was used to compare numeric variables (grip strength) whereas Wilcoxon signed-rank test was used for variables with skewed distributions (pain on NRS scale). Results compare patients diagnosed with and without impingement *via* radiographic and ultrasonographic imaging with different wrist maneuver techniques. Mann–Whitney *U* test was used for the length of ulnar resection and the outcomes (QDASH score, PRWE score, grip strength, NRS pain scale) to compare groups diagnosed with and without impingement/convergence *via* different imaging modalities and methods. A *p*-value smaller than 0.05 was considered statistically significant.

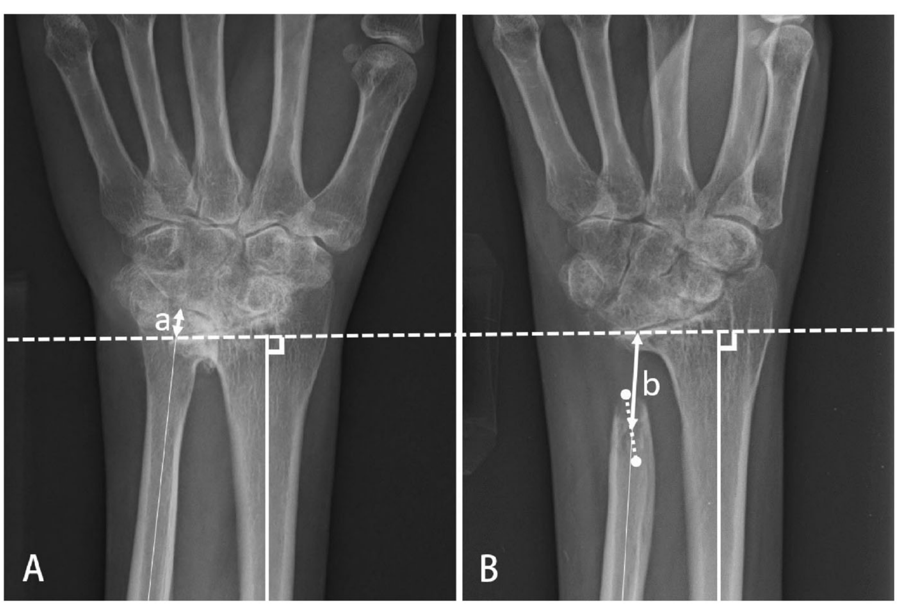



Figure 3. A diagram measuring the length of ulnar cut. A reference line (dashed line) was drawn from the ulnar side of the volar rim of the radial joint level, perpendicular to the radial intramedullary line. The length of the distal part (double arrow "a") was measured on the preoperative radiograph (A), along the intramedullary line, from the distal margin of the ulnar head to the reference line. The length of the proximal part (double arrow "b") was measured on the postoperative radiograph (B), along the intramedullary line, from the reference line to the mid-point of the ulnar cut (dotted line). The length of ulnar cut was the summation of "a" and "b".

## Results

Twenty-eight patients who received resection of the ulnar head in our hospital between 2010 and 2018 were identified. Three patients had already died, while two could not be reached, and three others refused participation due to personal reasons.

A total of 22 wrists from 20 patients (a follow-up rate of 71%), with an average age of 57.3 years (range 29–83) were available for the investigation. There were 3 men and 17 women. The etiologies of DRUJ destruction were RA in 19 wrists (17 patients), traumatic arthritis in 2, and osteoarthritis in 1 wrist. Sixteen wrists from 16 patients presented initially with an attritional tear of the extensor tendons, with rupture of three to four tendons. The mean ulnar cut length was 1.9 cm (range 1.2–3.1). The demographic information of the patients is summarized in Table 1.

Table 1. Demographic data of patients.

| Characteristic | Value |
|---|---|
| Sex (men:women ratio) | 3:17 |
| Age (years, mean and range) | 57.3 (29–83) |
| Dominant hand (number) | 16 |
| Occupation (number of patients) | |
| Service industry worker | 6 |
| Office worker | 4 |
| Manual labourer | 1 |
| Retired/unemployed | 9 |
| Etiology (number of patients) | |
| Rheumatoid arthritis | 19 |
| Traumatic arthritis | 2 |
| Osteoarthritis | 1 |
| Number of ruptured tendons in the affected wrist | |
| 4 | 4 |
| 3 | 12 |
| None | 6 |
| Time from index procedure (months, mean and range) | 55 (25–171) |

Table 2. Grip strength and patient-reported outcomes before and after operation.

| | Values | | |
|---|---|---|---|
| Outcomes | Pre-operation | Post-operation | *p*-value |
| Grip strength (lb.) | 35 ± 13 | 40 ± 12 | 0.13‡ |
| QDASH score | Not measured | 21.6 ± 9.2 | |
| PRWE score | Not measured | 24.1 ± 11.6 | |
| NRS pain scale | 5 (4–6) | 1 (0–2) | $<$0.001†* |

†Wilcoxon signed-rank test.
‡Paired *t*-test.
*Statistically significant.

Postoperative clinical outcomes were evaluated at a mean of 55 months (ranging from 25 to 171) from the index procedure.

The pain on the NRS scale was 5 (IQR 4–6) preoperatively and improved to 1 (IQR 0–2) postoperatively. The grip strength did not improve significantly. The QDASH and PRWE scores were not recorded before the surgery, but averaged 21.6 and 24.1, respectively, at the time of this investigation (Table 2). There were 10 patients (50%) able to return to their original job, and the other 10 patients were either retired or remained unemployed after surgery. One patient with tendon re-rupture but was satisfied with the current condition.

### Radiographic findings and outcomes

Upon a 1-kg weight stress test, radiographic convergence was observed in 20 of the 22 wrists (91%), while radiographic impingement was observed in 12 wrists (55%). The impingement identified *via* radiography was not found associated with the length of the ulnar cut. No association was found between radiographic impingement and the QDASH score, PRWE score, grip strength, or pain (Table 3).

### Ultrasonographic findings and outcomes

Both WS methods of dynamic ultrasonography and radiography employed a weight-loaded wrist by holding a 1-kg object. The WS method-related convergence was found in all wrists. Of the 12 wrists diagnosed with radiographic impingement, only 2 wrists (9%) presented impingement under WS method of ultrasonography (Table 4, Figure 4, and Video 1). In the 10 wrists with radiographic impingement but not sonographic impingement, a thin gap formed by the interposed PQ muscle could be observed by ultrasonographic imaging (Figure 5 and Video 2). However, WS impingement is not associated with the length of the ulnar cut. No association was found between WS impingement and the QDASH score, PRWE score, grip strength, or pain (Table 3).

With the PS method, convergence was found in all wrists, with 4 wrists (18%) presenting impingement (Figure 6 and Video 3). Two of the wrists with PS impingement also presented radiographic impingement, but not WS impingement (Table 4). An association was found between PS impingement and a higher QDASH score, PRWE score, and pain on NRS scale, but not the grip strength or length of ulnar resection (Table 3).

Upon forceful fist clenching, radioulnar convergence was found in 9 wrists (41%). No impingement was observed with the FC

Table 3. Radiographic and ultrasonographic results and the corresponding length of ulnar cut and outcomes.

| | Number of wrists (%) | Length of Ulnar cut (cm) | *p*-value | QDASH score (0-100) | *p*-value | PRWE score (0-100) | *p*-value | Grip strength (lb) | *p*-value | NRS pain (0-10) | *p*-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Radiography | | | | | | | | | | | |
| Impingement | 12 (55%) | 1.5 (1.3–1.8) | 0.06 | 23 (21–30) | 0.31 | 26 (16–27) | 0.80 | 40 (28–45) | 0.16 | 1 (0–2) | 0.89 |
| No impingement | 10 (45%) | 2.2 (1.6–2.8) | | 11 (6–26) | | 22 (13–29) | | 42 (34–56) | | 1 (0.5–2.5) | |
| Ultrasonography | | | | | | | | | | | |
| WS, impingement | 2 (9%) | 1.3 (1.2–1.5) | 0.48 | 31 (30–33) | 0.16 | 18 (13–18) | 0.45 | 45 (37–54) | 0.61 | 1.5 (1–2) | 0.12 |
| WS, no impingement | 20 (91%) | 1.8 (1.3–2.0) | | 23 (16–23) | | 26 (13–27) | | 45 (33–48) | | 1 (0–2) | |
| PS, impingement | 4 (18%) | 1.9 (1.8–2.0) | 0.26 | 23 (18–30) | 0.04* | 26 (16–28) | 0.048* | 47 (45–48) | 0.052 | 2.5 (1.5–3.5) | 0.02* |
| PS, no impingement | 18 (82%) | 1.5 (1.3–2.2) | | 14 (5–23) | | 20 (13–26) | | 35 (31–45) | | 1 (0–1.5) | |
| FC, convergence | 9 (41%) | 2.1 (1.8–2.8) | 0.001* | 20 (11–23) | 0.31 | 26 (21–40) | 0.12 | 39 (27–55) | 0.75 | 2 (1–3) | 0.18 |
| FC, no convergence | 13 (59%) | 1.3 (1.2–1.7) | | 26 (18–30) | | 21 (13–27) | | 40 (35–45) | | 1 (0–1) | |

Data are presented as median (interquartile range).
All comparisons were made using Mann–Whitney *U* test.
*Statistically significant, $p < 0.05$.

Table 4. Demographics of the patients and presentation of radiographic and sonographic impingement.

| | | | Radiography | | Sonography | | |
|---|---|---|---|---|---|---|---|
| Case | Age/sex | Hand | Convergence | Impingement | WS impingement | PS impingement | FC converge |
| 1 | 62/F | Left | + | − | − | − | − |
| 2 | 48/F | Left | + | + | − | + | + |
| 3 | 48/F | Right | + | + | − | − | − |
| 4 | 53/F | Left | + | + | − | − | − |
| 5 | 63/F | Right | + | + | + | − | − |
| 6 | 58/F | Right | + | + | − | − | − |
| 7 | 60/F | Left | + | − | − | + | − |
| 8 | 49/M | Right | + | − | − | − | + |
| 9 | 68/F | Left | − | − | − | − | + |
| 10 | 29/F | Right | + | + | − | − | + |
| 11 | 83/F | Right | + | − | − | − | + |
| 12 | 52/F | Left | + | − | − | − | − |
| 13 | 62/F | Left | + | − | − | + | − |
| 14 | 55/M | Right | + | − | − | − | + |
| 15 | 53/F | Left | + | + | − | − | − |
| 16 | 61/F | Right | + | + | + | − | − |
| 17 | 58/F | Right | + | + | − | − | − |
| 18 | 37/F | Right | + | + | − | − | + |
| 19 | 75/F | Right | + | − | − | − | + |
| 20 | 53/F | Left | + | + | − | + | + |
| 21 | 53/F | Right | + | + | − | − | − |
| 22 | 62/F | Left | − | − | − | − | − |

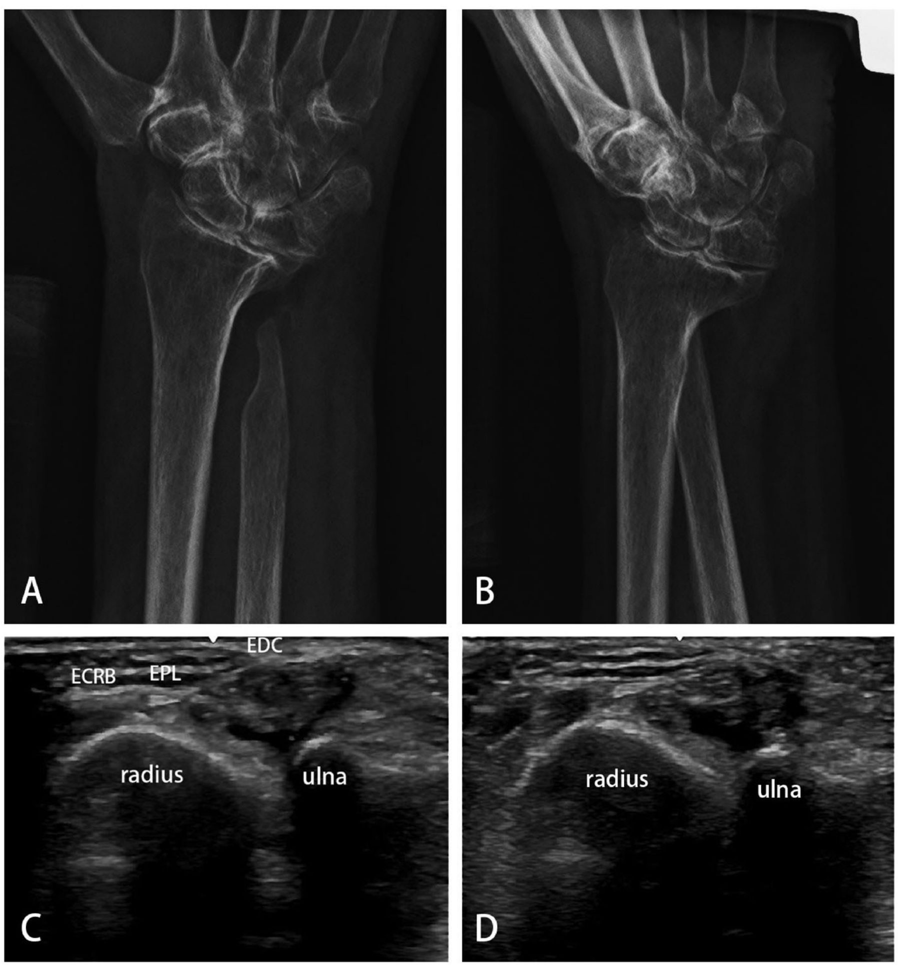



Figure 4. AP (A) and Scheker's (B) view of a 67-year-old female 4 years after the Darrach procedure. The radiographs showed dynamic ulnar impingement. The finding was confirmed with ultrasonography changes from baseline (C) to holding a 1-kg weight (D, WS impingement).

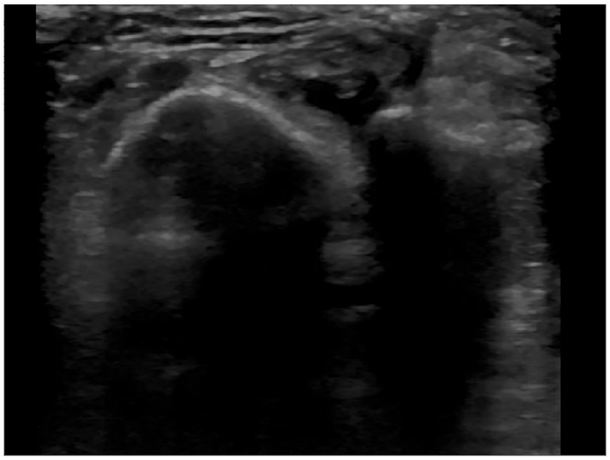
method. No association was found between FC convergence and patient-reported outcomes. The length of ulnar resection was found to be statistically longer in wrists with FC convergence in comparison with those without (Table 3).

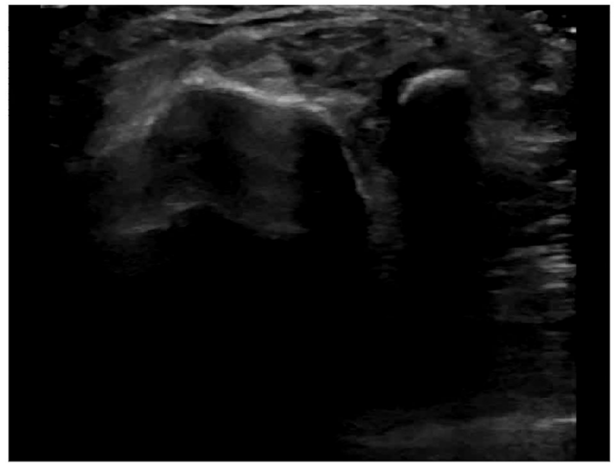
No abnormal catching or snapping of the tendon was observed with ultrasonography in any of these three dynamic test methods.

## Discussion

In this study, 22 wrists of 20 patients were examined by a mean of 55 months after the Darrach procedure. Three methods of sonographic measurements were tested: the weight-stressed (WS) method, the pronation-supination (PS) method, and the fist-clenching (FC) method. Radiographic impingement was found in 12 wrists (55%), while ultrasonography revealed true bone contact in only 2 (9%) and 4 (18%) of the wrists with the WS and PS method, respectively. Impingement found with the PS method was associated with worse functional outcomes and more pain in daily activities.

The WS method resembles the conventional Scheker's view of radiograph, placing stress across the DRUJ by holding a weight. Previous studies with Scheker's view showed that weight-loaded





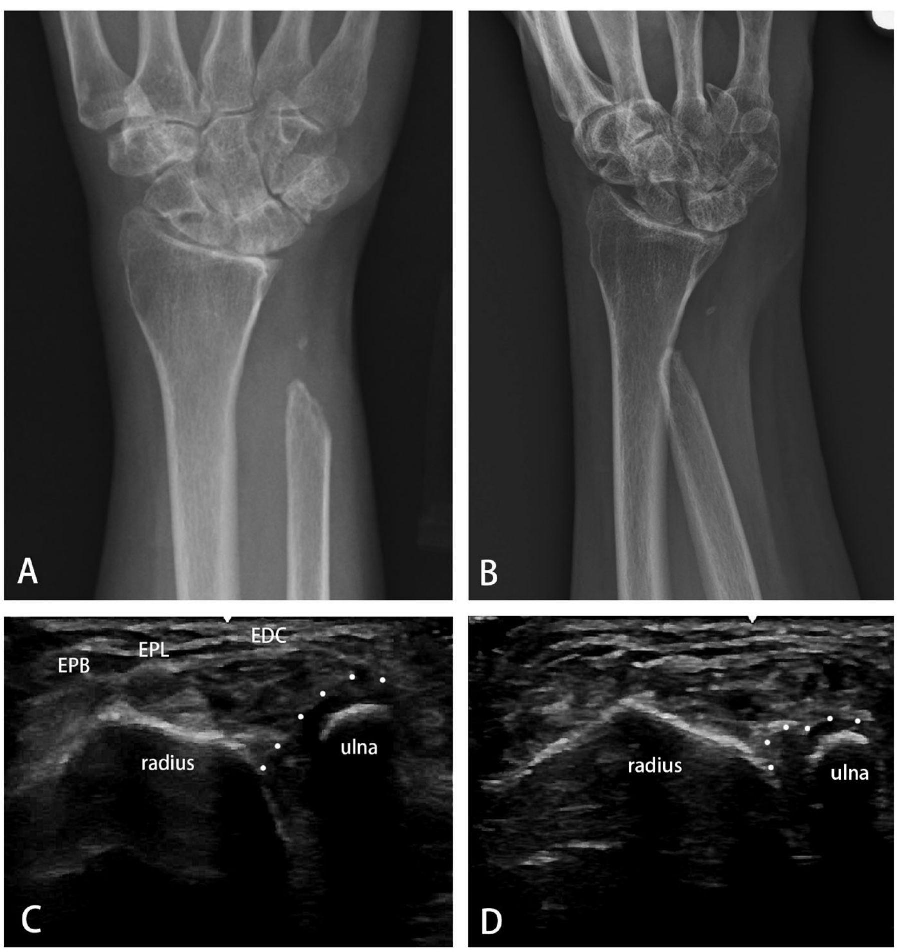



Figure 5. AP (A) and Scheker's (B) view of a 62-year-old female 4 years after the Darrach procedure. Dynamic ulnar impingement would have been diagnosed with the radiographs. However, ultrasonography transitioning from baseline (C) to holding a 1-kg weight (D) revealed the PQ (dotted) interposed between the radius and ulna, forming a gap measured 1 mm.

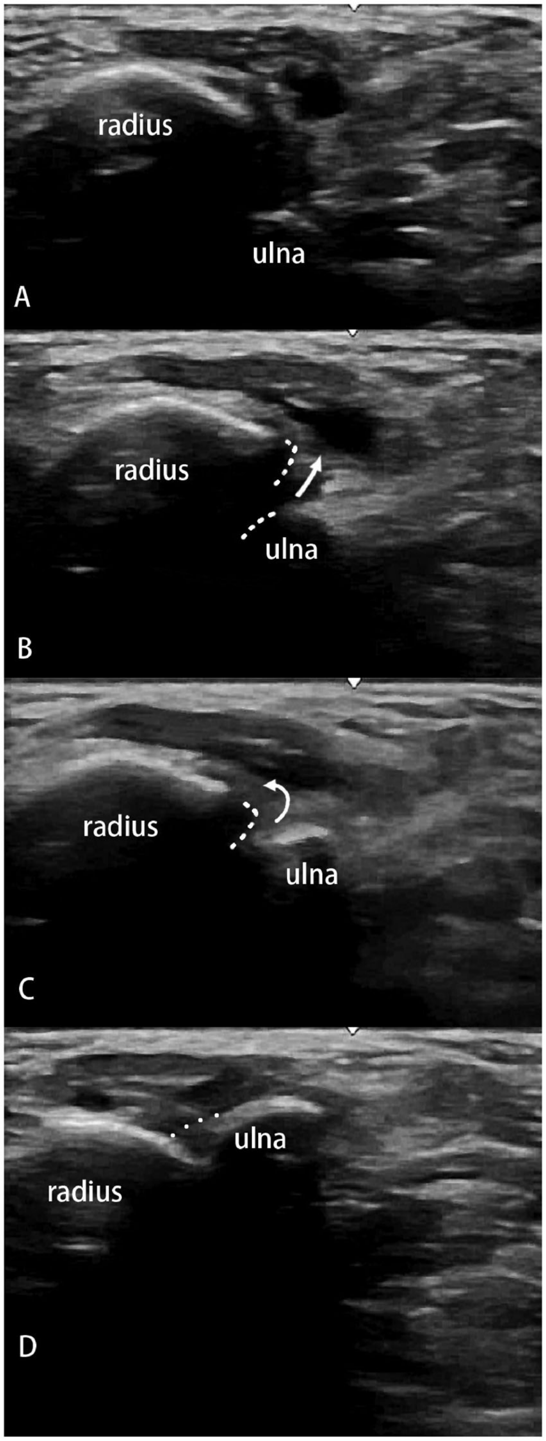
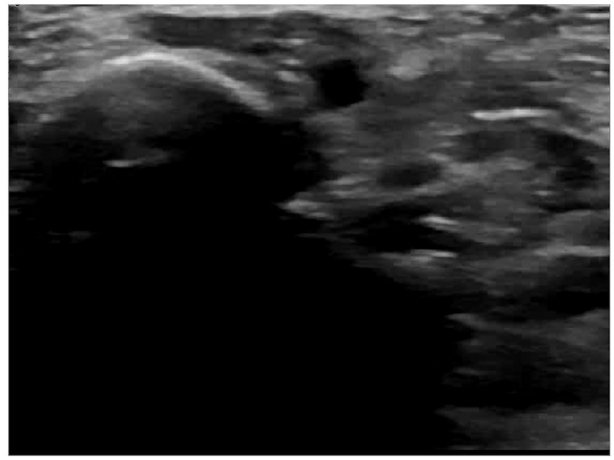



**Figure 6.** Ultrasonography of a 53-year-old female 5 years after the Darrach procedure. Impingement was observed as the patient rotated her forearm from supination (A) to pronation (D). The serial images show the ulna impinged and glided on the radial surface (B), with a “click” generated as the ulnar leaped out from the radial border (dashed line) (C to D). An interposing PQ emerged in view with the wrist in full pronation (dotted) (D).

impingements were rarely symptomatic [15–17]. In our investigation using ultrasonography with WS method, we found that in the 12 wrists with radiographic impingement, an interposed PQ muscle could be identified in 10 wrists. The thin layer of soft tissue indiscernible in radiographs, buffers direct bone contact, which may be a reason why radiographic impingements were not associated with pain. This highlights the inconsistency between radiographic findings and actual impingement.



In the rest two cases with sonographic WS impingement, the wrist pain and functions were not found to be worse. A review by Garcia-Elias [20], emphasized that ulnar cut in long-slope shape may be helpful in preventing painful weight-stressed impingements. Besides, we routinely perform AIN and PIN neurectomy, which has been shown to achieve high satisfaction rate, reducing pain scores from 4.0 to 2.2 [21]. However, further studies with more cases may be required to identify the exact etiologies.

The PS method is intended to detect radioulnar contact during forearm rotation. The 4 wrists with PS impingement were associated with worse function and pain. Rotational impingement has been described as “clicking” in previous studies on the Darrach procedure, with a prevalence of 0–30% [3,9,16,17,22–26]. It has been either a subjective symptom or physical finding and has rarely been demonstrated with images. Studies have reported a painful clicking wrist as a debilitating complication, which requires further stabilization procedures [4,9,16,24]. Nevertheless, Nanchahal et al. reported the clicking may diminish with time [25].

Rana and Taylor (1973) found that clicking can be avoided by excising <2 cm of the distal ulna. In our series, the median length of ulnar resection in rotationally impinged wrists was 1.9 cm (IQR 1.8–2.0) compared to 1.5 cm (IQR 1.3–2.2) in the others. However, the difference was not found to be significant. Snapping of the ECU tendon has been suggested as a possible etiology of a clicking wrist [3,22]. The symptoms and conditions were not observed in our cohort. However, if such etiology is present, dynamic ultrasonography can also serve as a powerful tool for detection.

In our study, as ultrasonographies were recorded in video, convergence was more readily detectable and found in all patients with WS and PS methods, while it was 91% with Scheker’s radiographic views. Nevertheless, neither radiographic nor sonographic convergence was found to be associated with a poor outcome. It may represent normal radio-ulnar motion after the Darrach procedure and carries little clinical significance.

McKee and Richards demonstrated in their series of 25 operated wrists that a forceful fist clenching induced dynamic radioulnar convergence in 14 wrists and impingement in 5 wrists [16]. We therefore also tested the effect of forceful fist-clenching under ultrasonography. A 41% rate of FC convergence was observed, but no case of impingement was found. Also, no association was found between FC convergence and patient-reported outcomes. Thus, the FC method may not be the optimal way of detecting dynamic impingement.

There are a couple of drawbacks, however, in ultrasonography. First, it is sometimes difficult to identify the very distal part of the ulna observable in ultrasonography. Also, it requires practice to adhere the probe to the same point on the wrist during the pronation-supination motion of the PS method.

The limitations of our study are, firstly, the small number of patients. Secondly, the cross-sectional nature of this study, which failed to demonstrate the chronological change. Thirdly, the QDASH and PRWE scores had not been evaluated before surgery for comparison. However, most cases presented initially with an attritional tear of extensor tendons, and had been repaired concomitantly. This would have attributed to the change in the patient-reported outcomes. Fourth, in this study, the etiologies leading to advanced DRUJ arthritis were RA in most cases. The outcomes may not apply to all patients receiving the Darrach procedure. Fifth, the 2.2 kg adopted in the standard Scheker's stress-loaded view was modified to 1 kg in this study, since few patients in our series were able to hold only 1-kg weight but not heavier. Finally, we utilized partial PQ interposition to enhance radio-ulnar stability. The imaging features of PQ interposition may not apply to ones following Darrach procedures modified with flexor or extensor tenodesis.

In summary, we describe three methods of dynamic sonography, of which the impingement detected by PS method is associated with greater pain and degraded function. The method is simple and readily available in outpatient settings. The addition of this dynamic ultrasonography may be valuable in follow-up evaluations after the Darrach procedure.

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## Ethics approval

Approval of this study was granted by the Institutional Ethics Committee of the hospital (Ethics approval number: 2020-02-007AC Date: 2020/01/30). All authors agreed with the content and gave explicit consent to submit. No funding was received for conducting this study.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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