Hand Surgery and Rehabilitation 44 (2025) 102125

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Original article

Stability of the distal radioulnar joint before and after corrective osteotomy of the distal radius

Daniel Zobrist *, Andreas Schweizer, Lisa Reissner

Departement of Orthopedics, Hand Surgery Division, Balgrist University Hospital Zurich, Switzerland

ARTICLE INFO

Article history:
Received 7 December 2024
Received in revised form 4 March 2025
Accepted 6 March 2025
Available online 11 March 2025

Keywords:
Distal radioulnaur joint
Stability
Ultra-Sound
Radius malunion
Instability
Osteotomy
Sonography

ABSTRACT

Malunion of the distal radius with dorsal angulation reduces stability of the distal radioulnar joint. The aim of the study was to sonographically quantify the stability of the distal radioulnar joint in 20 patients following corrective osteotomy of the distal radius and to investigate the subjective and clinical results preoperatively, three and twelve months postoperatively. Sonographically measured dorsovolar ulnar head translation relative to the distal radius was significantly higher (3.6 mm) preoperatively compared to 2.9 mm three months postoperatively. Twelve months postoperatively the result was 3.2 mm, equal to the contralateral side (3.2 mm). Pain, Disability of the Arm, Shoulder and Hand questionnaire and Patient-Reported Wrist Evaluations, wrist flexion, radial and ulnar inclination, grip strength and pronation and supination torque improved significantly. Corrective osteotomy of the distal radius shows good subjective and clinical results and improves sonographically measured distal radioulnar joint stability.

Level of evidence: III.

Introduction

The stability of the distal radioulnar joint (DRUJ) is influenced by a complex interaction of osseous and ligamentous structures [1]. Saito et al. showed in seven cadaver specimens that DRUJ stability decreases with increasing dorsal tilt of the distal radius [2]. This was tested with the wrist is in a neutral position, as well as at 60 ° of pronation. These findings highlight the mechanical connection between dorsal angulation of the distal radius and DRUJ stability, which we aim to further investigate in our study through clinical data from patients with distal radius malunions.

Hess et al. developed a sonographic method to objectively measure DRUJ stability looking at the dorsovolar translation of the ulnar head relative to the distal radius [3]. They reported a mean dorsovolar translation of 2.5 mm in healthy volunteers. Using this method, Weber et al. further demonstrated that activation of the flexor carpi ulnaris (FCU) and extensor carpi ulnaris (ECU) significantly improves DRUJ stability, suggesting that dynamic muscle activity can counteract joint instability [4].

If the clinical examination shows instability of the DRUJ, it is not easy to decide whether to perform a triangular fibrocartilage complex (TFCC) refixation or reconstruction or just a corrective osteotomy of the distal radius.

We report our results of 20 patients following corrective osteotomy of the distal radius preoperatively, three and twelve months postoperatively with specific focus on the stability of the DRUJ.

Patients and methods

Patients with symptomatic, extra-articular malunions of the distal radius with varying degrees of dorsal angulation and impaction were recruited from our hand surgery clinic, between July 2021 and February 2023. Any cases with intra-articular malunions, were excluded.

The study was approved by the local ethics committee, and all patients provided written informed consent for their data to be used for this analysis (Kantonale Ethikkommission Zürich; 2021-00194).

Preoperative planning, surgical technique and rehabilitation protocol

The preoperative planning and the radial osteotomy was conducted in accordance with the protocol described by Roner et al. [5]. The Correctus plate (Intercus Schweiz GmbH, Aarau,

* Corresponding author.
E-mail addresses: d.zobrist@bluewin.ch (D. Zobrist).

https://doi.org/10.1016/j.hansur.2025.102125

Switzerland) was used in all patients. The surgical guide was custom designed with drill sleeves and frames to ensure an exact fit on the bone, featuring complex surface matching for secure placement. These guides were produced by Medacta International S.A. (Castel San Pietro, Switzerland). Bone grafts for the osteotomy gap, when necessary, were harvested from the iliac crest. Non-weightbearing mobilization was started two weeks postoperatively, while maintaining immobilization using a brace adjusted by occupational therapy. CT and X-Ray scans, along with clinical follow-ups, were conducted approximately at six weeks, three months and twelve months postoperatively. Progressive weight-bearing was initiated if satisfactory consolidation was observed six weeks after the operation.

Subjective, clinical outcomes

Subjective evaluation utilized a numeric rating scale (NRS) for pain intensity (ranging from 0 to 10), the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire and the Patient-Related Wrist Evaluation (PRWE) score. Both scores indicate enhanced functionality as they decrease in value [6–8].

Range of motion (ROM) was measured with a goniometer. Grip strength was assessed using a JAMAR® hydraulic hand dynamometer, and the torque strength during pronation and supination was evaluated with a torque force device, first described by Reissner et al. in 2021 [9].

Ultrasound assessment

The ultrasound protocol for quantizing the instability of the DRUJ was primarily based on the technique established by Hess et al. in 2012, further assessed by Weber et al. in 2023 [3,4]. Participants were positioned accordingly with the pisiform bone resting on a specially designed pedestal, placed on a scale, to ensure a consistent pressure of either 0 kg (X1) or 5 kg (X2) during the measurement process (Fig. 1a). The ultrasound transducer was placed as described by Hess et al. [3] and two different measurements were taken: X1 representing the dorsovolar distance in an unloaded position (Fig. 1b), X2 representing the dorsovolar distance under maximal pressure force of 5 kg. Given those two measurements, the difference between X1 and X2 was calculated and used for statistical calculations (X1-X2).

All sonographic measurements were conducted using a high-resolution linear array transducer operating within a 15 MHz frequency range (GE Logiq P9 R3, GE Ultrasound Korea Ltd, 13204 Republic of Korea) by a hand surgeon with an expertise level of Grade three or above according to the criteria of Tang [10,11]. Measurements were taken during the preoperative consultation, as well as at three and twelve months postoperatively.

Statistics

All data were analyzed using SPSS (IBM SPSS Statistics; Version: 29.0.0.0). To assess normality, the Shapiro test was used due to the small study population of only 20 patients. For normally distributed data, an ANOVA test was conducted, followed by post-hoc t-testing with Bonferroni correction and paired t-testing. In cases of non-normal distribution, analysis was performed using the Friedman test with Bonferroni correction, followed by pairwise Wilcoxon testing. Subgroup analyses were conducted by excluding corrections of dorsal angulation below 30 ° or 20 °. Correlations were assessed using Pearson's test for normally distributed data and Spearman's test for non-normally distributed data. A p-value < 0.05 was considered statistically significant.

Results

Twenty patients, three males and 17 females, with a mean age of 54 years (SD 3 years) could be included. 18 patients were right-handed, 13 patients were operated on their dominant side.

Regarding the extent of correction according to the preoperative planning, there was a mean length correction of 4 mm (SD 0.3 mm; range 2 mm–7 mm), a mean volar correction of 18 ° angulation (SD 2.1 °; range 1 °–34 °). Four patients underwent previous wrist operation before corrective osteotomy, the remaining 16 patients initially received conservative treatment. The mean duration from trauma to corrective surgery was four years (range 1–28 years), with a median of one year.

Subjective and clinical results

The mean NRS for pain assessment showed a significant decrease in pain at rest ($p = 0.017$), as well as during load preoperatively compared to one year postoperatively ($p < 0.001$).

The PRWE and DASH score significantly decreased from preoperative 49 (SD 3.5) and 33 (SD 3.8) to 23 (SD 5.1) and 16 (SD 4) twelve months ($p < 0.001$) postoperatively (Table 1).

In terms of ROM and strength measurements, significant differences were observed from preoperative to twelve months postoperative assessments (Table 1). The average grip strength of the operated wrist was 84 % compared with the contralateral side, and force during pronation and supination was 84 % and 91 %, respectively. One patient had to be excluded from statistical analysis of pronation and supination torque due to missing data at twelve months postoperatively (Table 1).

Sonographic results

Sonographically measured dorsovolar ulnar head translation relative to the distal radius was significant higher with 3.6 mm (SD 0.4 mm) preoperative compared to 2.9 mm (SD 0.4 mm) three months postoperatively. Twelve months postoperatively the result was 3.2 mm (SD 0.4 mm), same as on the contralateral side with 3.2 mm (SD 0.3 mm) (Table 1).

There were no significant strong correlations between the sonographically measured stability of the DRUJ and DASH score ($r = 0.191$, $p = 0.421$), PRWE score ($r = -0.129$, $p = 0.589$),

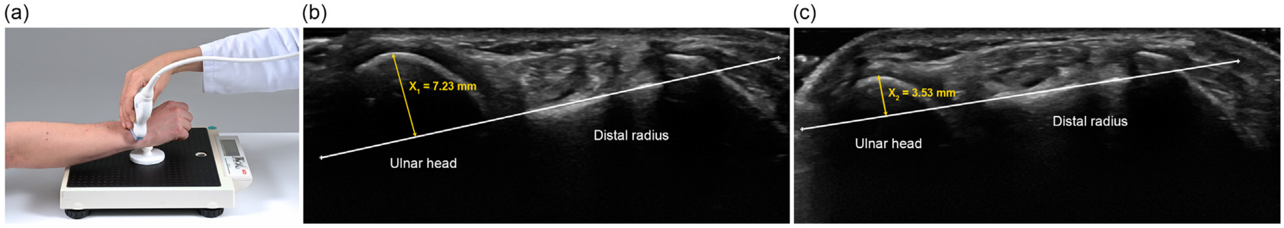

Fig. 1. (a) Sonography setup. (b) Sonography of the wrist showing the ulnar head and the Lister's tubercle, performed in a resting and unloaded position (×1). (c) Measurement while actively pressing the hand down with a maximal force of 5 kg (×2).

Table 1
Subjective, clinical and sonographic outcomes.

Mean values (SD)	Preoperative	3 months postoperative	12 months postoperative	p-values
NRS without / with load	2 (SD 0.4)/ 7 (SD 0.5)	2 (SD 0.5)/ 4 (SD 0.6)	2 (SD 0.5)/ 4 (SD 0.7)	p = 0.017 / p < 0.001 *
PRWE	49 (SD 3.5)	29 (SD 4.5)	23 (SD 5.1)	p < 0.001 *
DASH	33 (SD 3.8)	25 (SD 4.1)	16 (SD 4.0)	p < 0.001 *
Flexion (°)	47 (SD 4.1)	58 (SD 3.7)	64 (SD 3.1)	p = 0.001 *
Extension (°)	58 (SD 2.8)	54 (SD 2.1)	58 (SD 2.1)	p = 0.081 *
Pronation (°)	69 (SD 2.0)	71 (SD 1.7)	73 (SD 1.7)	p = 0.707 *
Supination (°)	72 (SD 4.0)	78 (SD 1.9)	81 (SD 2.2)	p = 0.098 *
Grip strength (kg)	21 (SD 1.3)	21 (SD 1.7)	25 (SD 2.3)	p = 0.008 *
Pronation strength (Nm)	3.5 (SD 0.3)	4.3 (SD 0.5)	5.3 (SD 0.6)	p = 0.006 *
Supination strength (Nm)	3.2 (SD 0.3)	4.0 (SD 0.3)	4.8 (SD 0.5)	p = 0.006 *
Sonography difference (X1-X2)	3.62 mm (SD 0.4)	2.92 mm (SD 0.4) **	3.15 mm (SD 0.4)	p = 0.030 **

NRS numeric rating scale, PRWE patient related wrist evaluation, DASH disability of arm, shoulder and hand. * p-values for preoperative vs. 12 months postoperative; ** p-value for preoperative vs. 3 months postoperative.

grip strength (r = -0.142, p = 0.549) or force during pronation (r = -0.0.19, p = 0.938) and supination (r = 0.455, p = 0.044).

Complete consolidation was observed between 13–36 weeks, with a mean consolidation time of 24 weeks. No major complications were observed in the forearm in the study population.

Discussion

The effects of deformities in the DRUJ on joint stability, are mostly based on biomechanical models [2,12–18]. In our study, we primarily attempted to quantify the effect of corrective osteotomies of the distal radius on malunited radius fractures in vivo using sonographic measurements. The sonographically measured dorsovolar ulnar head translation relative to the distal radius could show a significant decrease from 3.6 mm (SD 0.4 mm) preoperatively to 2.9 mm (SD 0.4 mm) at three months postoperative, with a translation of 3.2 mm (SD 0.4 mm) by twelve months postoperative, comparable to the contralateral side 3.2 mm (SD 0.4 mm). This result was associated with noticeable improvement in pain, Disability of the Arm, Shoulder, and Hand questionnaire scores and Patient-Reported Wrist Evaluations, as well as wrist flexion, grip strength, and pronation and supination torque. The DRUJ becomes enough stable after a corrective osteotomy of the distal radius. There is no need to attempt a TFCC refixation or reconstruction.

atients showed significant improvements twelve months postoperatively in both NRS without and with load, which is comparable to existing literature [19]. The postoperative DASH and PRWE scores were significant better compared to the results of Van Cauwelaert et al., and comparable with the results from Meesters et al. and. Mulders et al. [19–21].

As expected, we observed significantly better wrist flexion after corrective osteotomy of a distal radius fracture healed in malalignment with dorsal angulation. No significant improvement of wrist extension was seen with normal values preoperative.

We observed a significant increase in grip strength from 21 kg preoperatively to 25 kg postoperatively comparable to Weihrauch et al. with a grip strength increase from 17 kg to 27 kg postoperative [22].

We demonstrate sonographically a significant decrease in dorsovolar translation from preoperative to three months postoperative, comparing unloaded and loaded conditions at the wrist. From preoperative to twelve months postoperative, while there was an overall reduction, it as expected did not reach statistical significance, showing comparable results with the contralateral side. There is no need to attempt a TFCC reconstruction even in cases of instability. The DRUJ becomes enough stable after a corrective osteotomy of the distal radius. We have seen patients who have undergone TFCC reconstruction, which over time has failed and only corrective osteotomy of the distal radius has led to the desired stability in the DRUJ. The result of the study proves that correct osteotomy of the distal radius should be treated as a priority before TFCC reconstruction.

Onishi et al. showed on cadaveric specimens that dorsovolar translation of the DRUJ in a neutral forearm position ranges from 8 to 10 mm, depending on whether the carpal bones are being stabilized [23]. Compared to that, Nagata et al. found a dorsovolar translation of 5.5 mm with a variance of 1 mm in vivo [24]. Hess et al. showed an average dorsovolar translation of 2.5 mm in a healthy population. No significant differences between the dominant and nondominant side were shown [3]. Weber et al. could show an average dorsovolar translation of 4.1 mm without additional forearm muscle activation, but could show that voluntary activation of the ECU and FCU muscle resulted in 70% less dorsovolar ulnar head translation [4]. Our postoperative values of 3.2 mm lie in between and are therefore comparable with these two studies. However, Hess et al. was able to show differences of more than 2 mm amplitude compared to the opposite side as soon as there was a TFCC lesion. We have not seen a difference in amplitude between the healthy and pathological side of more than 2 mm. This is also consistent with the results of Saito et al., there were a clearly more unstable situations in the distal radioulnar joint after sectioning the radioulnar ligament at the DRUJ [3]. Saito et al. found a significant decrease of DRUJ stability with 10 ° and 20 ° of dorsal tilt of the radius in pronation. In our study only 7 patients had a correction over 20 °, and 15 over 10 °. However, subgroup analyses, even when excluding minor corrections of dorsal tilt lower than 20 °, did not provide further significance between pre and twelve months postoperatively. The statistical difference in the study of Saito et al. was only found in 60 ° pronation, not in neutral position [2]. Our study was measured in 30 ° pronation and may therefore not produce a significant result. Saito et al. fixed the ulna and moved the radius on cadavers, whereas we fixed the radius and moved the ulna in vivo [2].

This study has several limitations. First, the sample size is small, second patients had different correction of angulation of the distal radius and third, we tested sonographically the stability of the DRUJ only in pronation and not in supination. In addition, stability and instability cannot be reduced to this single displacement. Shortening, translation and soft tissue lesions are always associated.

Conclusion

In summary, three months after corrective osteotomy for malunited distal radius fractures, the DRUJ stability improved significantly according to sonographic evaluation in dorsovolar translation. As expected, this stability diminishes over time, leading to non-significant changes at twelve months postoperatively, but stability remains superior to preoperative levels and is similar to the contralateral side. These findings were consistent across subjectively satisfied patients with good ROM and grip strength and force during pronation and supination. Therefore, corrective osteotomy of the distal radius appears to be an useful procedure for improving the stability of the DRUJ in malunited fractures of the distal radius.

CRediT authorship contribution statement

Confirmation of authorship, contributorship and acknowledgements attached.

Informed consent

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Approval from our local ethic committee (Kantonale Ethikkommission Zürich) was given with the reference number: 2021-00194.

Informed consent was obtained from all individual participants included in the study.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used chatGPT in order to translate certain words and phrases from German to English and to check, for grammatical errors. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Funding

No funding for this project.

Declaration of competing interest

No conflict of interest to declare

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