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Original article

Pulp-to-palm distance is associated with inferior short-term outcome after combined plating for distal radius fractures



La distance pulpe-paume est associée à un résultat inférieur à court terme après ostéosynthèse par plaque des fractures de l'extrémité distale du radius

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ABSTRACT

Distal radius fractures (DRF) are the most common fracture in adults. A tool is needed to identify patients who may need extra attention from the physical therapist during the rehabilitation process. The purpose of the study was to examine if pulp-to-palm distance (PTP) 4 weeks postoperatively is associated with wrist function 3 months postoperatively in patients undergoing combined plating for a complex DRF. This prospective study involved 53 patients. PTP was assessed by a physical therapist at the second visit, 4 weeks postoperatively. The 3-month follow-up visit consisted of evaluating the following outcomes: PRWE (Patient-Rated Wrist Evaluation), QuickDASH (Disabilities of the Arm, Shoulder and Hand), VAS pain scores, hand grip strength and wrist range of motion. All patients received the same amount of hand therapy. Patients with zero PTP at 4 weeks postoperative had a significantly better range of motion in wrist extension, flexion, radial deviation, ulnar deviation, hand grip strength and QuickDASH scores compared to patients with a PTP > 0 cm. VAS pain scores did not differ between the two groups. Patients with zero PTP at 4 weeks postoperative were more likely to have a better wrist function at 3 months postoperative compared to patients with measurable PTP. Based on this study's findings, measuring the PTP distance at 4 weeks postoperative could be useful for identifying patients in need of support during the rehabilitation process after DRF surgery. This could potentially improve the allocation of hand rehabilitation resources; screening patients postoperatively could help to begin relevant interventions. © 2019 SFCM. Published by Elsevier Masson SAS. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

R É S U M É

La fracture de l'extrémité distale du radius (EDR) est la plus commune des fractures de l'adulte. Il est nécessaire d'avoir un outil pour identifier les patients qui peuvent nécessiter une attention particulière par le kinésithérapeute dans le processus de rééducation. Le but de l'étude était d'examiner si la distance pulpe-paume (DPP) à 4 semaines postopératoires est associée à la fonction de poignet à 3 mois postopératoires chez les patients après ostéosynthèse par plaque d'une fracture complexe de l'EDR. Cette étude prospective a impliqué 53 patients. La DPP a été évaluée par le kinésithérapeute au deuxième rendez-vous, à quatre semaines postopératoires. Le suivi à trois mois incluait les valeurs des résultats suivants : scores PRWE (Patient-Rated Wrist Evaluation) et QuickDASH (Disabilities of the Arm, Shoulder and Hand), douleur évaluée sur une échelle visuelle analogique (EVA), force de poigne et mobilités du poignet. Tous les patients recevaient le même nombre de séances de kinésithérapie de la main. Les patients à DPP nulle à 4 semaines postopératoires montraient une meilleure mobilité en extension, flexion, inclinaison radiale et ulnaire, une meilleure force de poigne et de meilleurs scores QuickDASH comparés à ceux des patients présentant une DPP > 0 cm. Les scores douleur ne différiaient pas entre les deux groupes. Les patients à DPP nulle à 4 semaines postopératoires sont plus susceptibles d'avoir une

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meilleure fonction de poignet à trois mois postopératoire en comparaison aux patients avec une DPP > 0. Les résultats présentés dans cette étude indiquent que la mesure de DPP à quatre semaines postopératoires pourrait éventuellement être utile pour identifier les patients nécessitant un soutien pendant la rééducation après chirurgie d'une fracture de l'EDR. Cela pourrait potentiellement améliorer l'allocation des ressources de rééducation des mains, le dépitage postopératoire des patients pourrait donc être bénéfique afin d'initier des mesures pertinentes.

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1. Introduction

The Distal radius fracture (DRF) is the most common fracture in adults and constitutes 18% of all fractures in an orthopedic trauma unit [1]. The annual incidence in Sweden has been reported to be 26 per 10,000 inhabitants [2]. Fractures with minor displacement are commonly treated non-operatively with a cast [3]. Intra-articular fractures with displacement are often considered for operative treatment [4]. Interventions like pinning, non-locking plates or external fixation have gradually been replaced by volar locking plates [5]. This shift has taken place with a low level of evidence [6]. Combined volar and dorsal plating is a common alternative to manage complex, unstable, intra-articular fractures. Ring et al. [7,8] have reported good results for combined plating of DRFs using a volar T-plate and a dorsal Pi-plate.

During the recovery phase after a DRF, many factors play an important role in predicting the outcome such as age, sex, injury compensation, education, radial shortening and intra-articular involvement [9]. A previous study has demonstrated a moderate correlation between pulp-to-palm distance (PTP) and total finger flexion [10]. We hypothesized that patients with an increased PTP distance after surgical management of a DRF will have a worse functional outcome. The aim of the present study was to assess whether pulp-to-palm distance at 4 weeks postoperatively corresponds to hand function 3 months after surgical treatment of DRFs.

2. Patients and methods

2.1. Patients

The Regional Ethical Review Board (Reference No 2016/455) approved this prospective cohort study. Patients undergoing open reduction and internal fixation for intra-articular DRF with combined plating using a volar locking T-plate and a dorsal locking Pi-shaped plate (TriMed, Inc. Santa Clarita, CA, USA) between February 1st, 2017 and July 31st, 2018 at the University Hospital in Örebro, Sweden were enrolled. Verbal and written informed consent was obtained from all patients in accordance with the Helsinki declaration. Fractures were classified according to the AO classification [11]. Inclusion criteria included unstable intra-articular DRFs (AO type C) with an articular displacement of > 2 mm and a dorsal angulation of > 20°. Patients aged 18–80 with a DRF at our hospital operated with combined plating during the study period were enrolled in the study, and all procedures were performed by fellowship-trained orthopedic hand surgeons. Exclusion criteria included patients under the age of 18 or over 80 years, dementia, substance abuse, patients with impaired autonomy or patients unable to comprehend the study information, patients unable to understand Swedish, fractures older than 12 days, a previous fracture in the same wrist, another fracture in the ipsilateral arm, carpal ligament injury and bilateral cases. A total of 53 patients with a DRF met the inclusion criteria, were recruited into the study and underwent surgery with combined plating.

2.2. Surgical technique

All surgical procedures were performed in accordance with the instructions given by the manufacturer of the implants and all surgeons used the same technique. A central volar incision including a carpal tunnel release was performed to view the volar part of the radius. The interval between the finger flexors and the median nerve was used for exposure. Following volar reduction and application of the locking T-plate, the dorsal side was exposed using a longitudinal incision over Lister's tubercle. The fracture was viewed using a Z-shaped opening of the fourth extensor compartment. The brachioradialis insertion was released. Impacted articular fragments were reduced and gathered into a single unit using the dorsal plate as a reduction tool, by applying the screws proximally to distally and using the volar plate as a fulcrum. The reduced fracture fragments were then stabilized with locking screws. Surgical time was defined as the tourniquet time.

2.3. Postoperative rehabilitation

All patients were seen by an experienced hand therapist and given instructions focused on edema control, pain reduction, as well as shoulder and finger motions before being discharged from the hospital on the day following surgery. A volar forearm cast was used for 2 weeks postoperatively. Mobilization of the wrist with a prefabricated removable brace was started under the guidance of a hand therapist. The brace was removed during the range of motion exercises and was used for the first 4 to 6 weeks postoperatively. The patients were given instructions to use the operated hand in light daily activities. Range of motion exercises were to be performed for 45 minutes per day divided into 4–5 sessions. Loading of the wrist was to be increased gradually. The aim was to make the patient independent and confident in order to regain optimal wrist function. Lifting heavy objects was discouraged for the first 10–12 weeks postoperatively. All patients were thus given the same rehabilitation protocol before being discharged from the hospital and at 2 weeks, 4 weeks and 3 months postoperatively.

2.4. Outcome measures

The following outcome measures were evaluated at 4 weeks postoperative by a hand therapist at our facility: pain (visual analog scale (VAS) at rest and during activity), range of motion (ROM) (flexion, extension, radial deviation, ulnar deviation, pronation, and supination) and pulp-to-palm (PTP) distance. At 3 months postoperative, hand grip strength (kg), Patient-Rated Wrist Evaluation score (PRWE) and the quick Disabilities of the Arm Shoulder and Hand score (QuickDASH) were determined in addition to pain at rest and during activity and range of motion. All patients rated their wrist pain on VAS (0 = no pain, 10 = worst imaginable pain), both at rest and during activity. Grip strength measurements were done by a physical therapist using a calibrated hand dynamometer (E-LINK Hand Kit, Biometrics Ltd, Newport UK). The patients were evaluated seated with 90° elbow flexion and the forearm in neutral rotation. The unaffected side was evaluated first; three attempts were made on both sides and the

mean value was recorded. The results are presented as kilograms and percentage of the uninjured side. ROM for wrist flexion, extension, radial deviation, ulnar deviation, pronation and supination was recorded by a physical therapist using a goniometer. The measurements were done according to the guidelines from the Swedish national quality registry for hand surgery [12]. The PTP distance was assessed according to the process described by Macey et al. [13] where a ruler was used to measure the distance between the nail-to-distal nail fold junction and the distal palmar crease. The baseline PTP distance was not registered. However, there were no signs of congenital malformations or old finger injuries limiting the ability to make a full fist preoperatively. Patients completed the validated Swedish translation of the PRWE questionnaire [14]. The psychometrics of the PRWE questionnaire are well described [15,16]. This is a 15-item questionnaire rating pain and disability in functional activities. A score out of 100 is calculated where zero represents no pain or disability. A shorter version of the original DASH, the 11-item QuickDASH [17] measures physical function and symptoms in people with musculoskeletal disorders of the upper limb. The scores range from zero (no disability) to 100 (most severe disability).

2.5. Statistical analysis

Due to the range of motion and grip-strength variables being normally distributed, data are presented as mean and standard deviation. The patients were separated into two groups: patients with zero PTP distance (thus, the fingertips could reach the palm) and patients with a PTP distance > 0 cm. The difference between the groups in the age, operating time, days to surgery, ROM, hand grip strength and sick leave was assessed using an unpaired *t*-test. Due to a non-normal distribution of the pain, PRWE and QuickDASH data (Shapiro-Wilks test, data not shown), the Mann-Whitney U-test was used to determine statistically significant differences between the two groups. A *P*-value of less than 0.05 was considered statistically significant.

3. Results

All 53 patients completed the 3-month follow-up. The patients had a mean age of 59 years (standard deviation 15); there were 40 females (mean age 62, range 25–80) and 13 males (mean age 50, range 19–73). There were no perioperative complications. There was one early deep infection, treated with surgical debridement and antibiotics. This patient was operated with combined plating and had zero pulp-to-palm distance 4 weeks postoperatively. The infection healed uneventfully. The group of patients with a PTP-distance > 0 cm at 4 weeks postoperative had a somewhat higher age, longer operating time and longer time to surgery than the group with zero PTP distance, although these differences were not significant. There was no difference between the groups in the length of sick leave (Table 1). The patients with a PTP distance > 0 cm at 4 weeks postoperatively had significantly lower mean wrist extension, flexion, radial and ulnar deviation than the group of patients with zero PTP distance. The group with a PTP distance > 0 cm also had higher VAS pain scores at rest and during activity; however, this difference was not significant (Table 2).

At the 3-month follow-up visit, the group with a PTP distance > 0 cm at 4 weeks postoperative still had a significantly less range of motion in wrist extension, flexion, radial and ulnar deviation (Table 3). Grip strength was also significantly lower in the PTP distance > 0 cm group with 13 kg compared to 18 kg for the group with zero PTP distance. The grip strength for the patients

with a PTP distance > 0 cm was 46% compared to the uninjured side whereas the patients with zero PTP distance had a grip strength of 60% compared to the uninjured side (Table 4). These differences in hand grip strength were significant. VAS pain scores did not differ between the groups. The group with PTP distance > 0 cm at 4 weeks postoperatively had a median QuickDASH score of 34, which was significantly worse (*P* = 0.016) than the score of 25 for the group with zero PTP distance. There was no significant difference in the PRWE scores between the two groups.

4. Discussion

Our study found significantly better ROM, grip strength and QuickDASH score at 3 months postoperative for the group of patients with zero PTP distance at 4 weeks postoperative compared to the group of patients with PTP distance > 0 cm. The optimal physical therapy program for patients after DRF is debated and available data are somewhat diverging. Some studies [18,19] have found a significant difference in wrist motion for patients receiving supervised physical therapy while others [20,21] have reported findings that favor independent exercises through home instructions. A recent systematic review [22] concluded there is insufficient evidence to support a home program or therapist supervised clinic-based program as a superior treatment method for adults following a DRF. Lucado [23] stressed the importance of clinicians relying on past experience and clinical judgment when deciding whether a patient would benefit from supervised therapy versus a home exercise program. Our study indicates that a PTP distance > 0 cm at 4 weeks postoperative could be an indicator of worse outcomes 3 months postoperatively. This could assist the hand therapist in allocating rehabilitation resources.

The group of patients with a PTP distance > 0 cm had a higher mean age and a longer operating time, compared to the patients with zero PTP distance, although the differences were not significant. A previous study by Jiang et al. [24] found that patients with a complication had a significantly longer surgical time. In addition, Jiang et al. found no difference in complication rates of intra-articular versus extra-articular fractures. It seems plausible that intra-articular fractures would represent a group of more complex fractures compared to extra-articular fractures, thus resulting in a longer surgical time. In our study, all patients had intra-articular AO-type C fractures, meaning that all fractures were complex. Thus, the influence of operating time on outcome is somewhat difficult to interpret given that Jiang's study used other outcome measures. PTP distance has been shown to have a moderate correlation to finger flexion measures [10]. Studies addressing the role of PTP distance in DRF rehabilitation are scarce. A study by Valdes et al. [25] assessing patients with DRFs treated by volar plate fixation identified finger flexion to the distal palmar crease at baseline as a predictor of total range of motion and PRWE score 6 months postoperatively. This finding is in line with our results.

Grip strength at 3 months postoperative (injured/uninjured side) was 46% for the group with a PTP distance > 0 cm and 60% for the group with a PTP distance of zero. This is somewhat lower than in a study by Landgren et al. [26], who found a grip strength of 69% at 3 months postoperative. However, these patients were treated with volar locking plates or fragment-specific plates using a modified Henry approach for the volar incision; hence the cohorts are not entirely comparable to our patients treated with combined plating and a volar central incision. Our patients treated with combined plating had load-bearing restrictions during the first 10–12 weeks postoperatively; this is likely to have had an impact

Table 1
Demographics.

	Pulp-to-palm distance > 0 cm	Pulp-to-palm distance = 0 cm
Number of patients	20	33
Mean age, years	62	57
Operating time (min)	97	87
Sex (male/female)	5/15	8/25
Fracture type AO C1	4	9
Fracture type AO C2	7	13
Fracture type AO C3	9	11
Days to surgery	8.5	7.3
Right/left-handed	20/0	30/3
Dominant/non-dominant side injured	9/11	12/21
Number of patients requiring sick leave	8/20	17/33
Manual laborer	3/8	12/17
Number of days sick leave (median, interquartile range)	96.5 (53, 109)	96 (93,101)

There was no significant difference between the groups for age, operating time, days to surgery or number of days sick leave (assessed by independent *t* test).

Table 2
Wrist function at 4 weeks postoperative.

Outcome measure	Pulp-to-palm distance > 0 cm	Pulp-to-palm distance = 0 cm	<i>P</i> -value
Pronation	60° (21)	67° (18)	0.23
Supination	44° (21)	52° (18)	0.16
Extension	13° (11)	23° (10)	0.002
Flexion	25° (7)	35° (8)	< 0.001
Radial deviation	7° (7)	11° (5)	0.04
Ulnar deviation	15° (6)	20° (6)	0.004
VAS pain at rest	0.8 (0, 2.8)	0 (0, 1.5)	0.24
VAS pain during activity	4.5 (1.9, 6.4)	3 (2.5, 5)	0.24

The values are presented as mean (standard deviation) except for VAS pain scores where median (interquartile range) was used. Statistical significance was assessed using an independent *t* test except for VAS pain scores where the Mann-Whitney U-test was used. VAS: Visual Analog Scale.

on the grip strength. In addition, studies have shown that grip strength improves during the first year postoperative [27]; this is likely the case in our study as well. The grip strength in the dominant hand is usually 10% higher. Whether the individual is left or right handed can also be a factor [28] as well as sex and age [29]. In order to neutralize these factors, the relative grip strength was calculated as an additional outcome measure.

The group with a PTP distance > 0 cm had higher QuickDASH and PRWE scores than the group with zero PTP distance indicating a worse functional outcome. The difference between groups was significant for the QuickDASH score but not for the PRWE score. A previous study of 68 DRFs treated surgically found a moderate statistical correlation between the PRWE and DASH scores [30]. One reason the PRWE score did not reach statistical significance in our study may be that half of the PRWE score corresponds to pain. The VAS pain scores in our study were low and

similar in both groups of patients. Another reason may be that the number of patients in our study was too small to detect a significant difference for the PRWE score. The PRWE scores in our patients are in line with the findings by MacDermid et al. [31] who found a PRWE score of 23 at 3 months postoperative. However, MacDermid's patients included cases with extra-articular, partial articular and complete articular fractures. Our patients all had intra-articular fractures treated with combined plating. We thus believe the outcome regarding the patients' self-assessed function (PRWE score) after combined plating is encouraging.

The patients were not screened for depression. Depression is known to be associated with an inferior outcome after surgery [32] and this is a limitation of the study.

The range of motion was measured as degrees and percentage of the uninjured side, measuring the percentage of the uninjured side is common but the method has some limitations [33].

Table 3
Wrist function at 3 months postoperative.

Outcome measure	Pulp-to-palm distance > 0 cm	Pulp-to-palm distance = 0 cm	<i>P</i> -value
Pronation	71° (11)	71° (11)	0.82
Supination	64° (17)	69° (13)	0.22
Extension	29° (16)	41° (13)	0.004
Flexion	36° (11)	48° (12)	< 0.001
Radial deviation	10° (5)	15° (4)	< 0.001
Ulnar deviation	20° (5)	25° (7)	0.001
Grip strength (kg)	13 (6)	18 (6)	0.008
VAS Pain at rest	0 (0.0–1.4)	0 (0.0–0.0)	0.16
VAS Pain during activity	3 (2.3–5.0)	3 (2.0–4.0)	0.24
PRWE	28 (19, 49)	23 (14, 32)	0.1
QuickDASH	34 (23, 54)	25 (16, 33)	0.016

The values are presented as mean (standard deviation) except for VAS pain scores, PRWE and QuickDASH where median (interquartile range) was used. Statistical significance was assessed using an independent *t* test except for VAS pain scores, PRWE and QuickDASH where the Mann-Whitney U-test was used. kg: kilograms; VAS: Visual Analog Scale; PRWE: Patient-Rated Wrist Evaluation; QuickDASH: quick Disabilities of the Arm, Shoulder and Hand.

Table 4

Wrist function at 3 months postoperative in the operated side as percentage of the uninjured side.

Outcome measure	Pulp-to-palm distance > 0 cm (%)	Pulp-to-palm distance = 0 cm (%)	P-value
Pronation	87	93	NS
Supination	77	84	NS
Extension	42	60	0.01
Flexion	53	67	<0.05
Radial deviation	46	70	<0.001
Ulnar deviation	56	75	0.005
Grip strength (kg)	46	60	0.005

Grip strength and wrist range of motion expressed as the percentage operated/uninjured side; statistical significance was assessed using an independent *t* test. NS: non-significant; kg: kilograms.

There was no significant difference in VAS pain scores between both groups and the pain scores were relatively low. This is encouraging as pain is an important outcome measure. Souer et al. identified pain to be the most important predictor of disability [20]. Another study by Birch et al. assessed the importance of different factors in the success of wrist surgery and found that pain is the most important factor [34]. Our study is limited by a relatively short follow-up. On the other hand, a longer follow-up could also mean that the difference between the patient groups diminishes over time, as both groups are likely to continue improving in their hand grip strength, range of motion and self-assessed function (QuickDASH score). In addition, with a larger number of patients in the study, the group of patients with a PTP distance > 0 cm could have been further divided into subgroups to assess whether patients with a large PTP distance have worse outcomes compared to patients with a small PTP distance.

The length of sick leave did not differ between the groups. However, the total number of patients requiring sick leave was low and may have made it impossible to demonstrate a difference statistically. Educational level was not registered, and this may be a limitation. The patients were not blinded to the physical therapists who performed the evaluation 3 months postoperatively. However, the patients' PTP values were not available to the physical therapist at the time of the evaluation 3 months postoperatively. This may have reduced bias. MacDermid et al. [9] proposed that hand therapy is indicated in the rehabilitation of DRFs in cases of moderate tendon adhesions or tendinitis. Surgeon skill and fracture severity may also need to be considered when determining who needs therapy and who does not [9]. However, all patients in our study had the same type of fracture, were operated by fellowship-trained orthopedic hand surgeons using the same type of incisions and hardware and had the same postoperative cast immobilization and rehabilitation. This suggests that the cohort of patients is uniform, making it a strength of the study. To our knowledge, no study has previously investigated PTP distance and the relationship with hand function in the context of DRF. Measuring the PTP distance is convenient and can provide a visual goal for the patient in the rehabilitation setting after a DRF.

5. Conclusion

Our study indicates that PTP distance at 4 weeks postoperative could be useful as an adjunct to identify patients in need of support during the rehabilitation after DRF surgery. This could potentially improve the allocation of hand rehabilitation resources. Screening patients postoperatively could thus be beneficial in order to begin relevant interventions. To clarify which interventions are optimal and whether additional hand therapy would be reimbursable, further studies are warranted. Randomized controlled trials where patients with a PTP distance > 0 cm are randomized to either a regular rehabilitation program or additional hand therapy under the supervision of a certified hand therapist would be optimal.

Study design

Prospective cohort single-center study.

Ethical review committee statement

The study was approved Nov 16th 2016 by the regional ethical committee reference number 2016/455.

Disclosure of interest

The authors declare that they have no competing interest.

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