

Functional outcomes of distal radius fractures with and without ulnar styloid fractures: a meta-analysis

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Abstract

The aim of this meta-analysis was to compare the functional outcomes of patients with a distal radius fracture with and without a concomitant fracture of the ulnar styloid process. A systematic literature search was performed to identify all studies comparing patients with a distal radius fracture with and without an ulnar styloid process fracture. The initial search revealed 511 articles, of which 12 articles with a total of 2243 patients were included; 1196 patients with and 1047 patients without an ulnar styloid process fracture. A statistically significant mean difference of 3.40 points (95% CI 1.33–5.48) in the Disability of the Arm, Shoulder, and Hand score was found in favour of patients without an ulnar styloid process fracture. This difference is less than 10 and therefore not clinically important. No significant difference was found in Patient-Rated Wrist Evaluation scores, range of motion, grip strength, visual analogue scale pain scores, ulnar-sided wrist pain and distal radio-ulnar joint instability between patients with and without an ulnar styloid process fracture after 1 year of follow-up. Moreover, no significant differences were found between ulnar styloid base and nonbase fractures.

Level of evidence: I

Keywords

Ulnar styloid process, distal radius, fracture, functional outcome

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Introduction

Distal radius fractures are often accompanied by a fracture of the ulnar styloid process (Krämer et al., 2013; Lindau et al., 1997; Oskarsson et al., 1997; Wijffels et al., 2014). The effect of a concomitant ulnar styloid process fracture on functional outcomes is unclear. Some studies state that a fracture of the ulnar styloid process does not significantly affect functional outcome after a distal radius fracture in terms of patient-reported outcomes, range of motion and grip strength (Chen et al., 2013; Gogna et al., 2014; Kim et al., 2010; Reichl et al., 2011; Zenke et al., 2009). Other studies show a negative effect of a concomitant ulnar styloid process fracture on functional outcomes (Amorosa et al., 2011; Ayalon et al., 2016; Belloti et al., 2010; Daneshvar et al., 2014; Oskarsson et al., 1997; Sammer et al., 2009; Souer et al., 2009; Zyluk et al., 2014). Moreover, attached to the ulnar styloid process is the triangular fibrocartilage complex (TFCC) (Sachar, 2012).

A fracture of the ulnar styloid process may result in disruption of the TFCC, potentially causing ulnar-sided wrist pain and distal radio-ulnar joint (DRUJ) instability (Daneshvar et al., 2014; Haugstvedt et al., 2006; May et al., 2002; Sachar, 2012).

A concise understanding of the effect of ulnar styloid process fractures on clinical outcome in patients experiencing a distal radius fracture could aid surgeons on treatment decisions and prognosis. Therefore, the aim of this meta-analysis was to

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evaluate the clinical relevance of ulnar styloid process fractures in patients with distal radius fractures by comparing functional outcomes in patients with and without this injury.

Methods

This meta-analysis was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) Guidelines (Moher et al., 2009).

Literature search and study selection

With the assistance of a clinical librarian, a systematic literature search was performed in Medline (Pubmed), EMBASE, Cochrane Library and Web of Science, on 21 January 2016. The search for each database is depicted in online Table S1. No limitations on publication date were applied.

Two authors (MAMM and LJFS) independently screened the title and abstract of all articles on eligibility, using the inclusion and exclusion criteria mentioned below. After abstract screening, full texts were retrieved. If the full text of articles could not be found, authors were contacted. Disagreement was addressed by discussion until consensus was reached. Additionally, a cross-reference check was performed.

Eligible criteria

All studies comparing patients with a distal radius fracture with and without an ulnar styloid process fracture were assessed for inclusion in this study. Studies were included if they reported on non-operatively treated ulnar styloid process fractures, functional outcomes measured with the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, the QuickDASH or the Patient-Rated Wrist Evaluation (PRWE) questionnaire and had an average follow-up of at least 12 months. Only English or German studies were included.

We excluded studies that were not available in full text, studies that compared functional outcomes based on union and non-union of the ulnar styloid process fracture and case series. Studies for which the required data for this meta-analysis could not be retrieved from the published or raw data were excluded as well.

Outcome measures

The primary outcome used for this meta-analysis was functional outcome as reported by the DASH,

QuickDASH or PRWE questionnaire after an average of at least 12 months of follow-up. The DASH questionnaire comprises 30 items and focuses on two components, disability and symptoms of the upper extremity. It is scored from zero (good status) to 100 (poor status) (Calfee and Adams, 2012; Changulani et al., 2008; Hoang-Kim et al., 2011). The 11-question QuickDASH is a modified version of the DASH questionnaire and can be used instead of the DASH questionnaire with similar precision (Gummesson et al., 2006). The minimal clinically important difference is 10 for the DASH and 14 for the QuickDASH (Sorensen et al., 2013). The PRWE is a 15-item questionnaire that focuses on measurement of wrist pain and disability in activities of daily living. It is scored from zero (minimum pain and disability) to 100 (maximum pain and disability) (Changulani et al., 2008; MacDermid et al., 1998). The minimal clinically important difference of the PRWE is 11.5 (Walenkamp et al., 2015).

Secondary outcomes were range of motion, grip strength, wrist pain measured on a visual analogue scale (VAS), the presence of ulnar-sided wrist pain and DRUJ instability. Range of motion included flexion, extension, radial deviation, ulnar deviation, pronation and supination, and was reported in degrees. Grip strength was reported in kilograms. Wrist pain was scored, using the VAS, from zero (no pain) to 10 (maximum pain).

In addition, we determined the difference in DASH and PRWE scores between patients with an ulnar styloid process base and nonbase fracture. A nonbase fracture was classified as a fracture located at the distal portion of the ulnar styloid process, and a base fracture as a fracture located at the styloid base or in the foveal head.

Data collection

Data collected included publication details, the number of patients subdivided into patients with and without an ulnar styloid process fracture, patient characteristics, details regarding distal radius fracture treatment, the follow-up in months and our primary and secondary outcomes. Moreover, in case a distinction was made between base and nonbase ulnar styloid process fractures, this was recorded.

For this meta-analysis, we collected the mean and standard deviation (SD) of the DASH, QuickDASH or PRWE score, as well as the range of motion, grip strength and VAS pain scores. In case the standard error of a mean (SEM) was provided, the SD was obtained by multiplying the SEM by the square root of the sample size, according to the *Cochrane Handbook*. In case range of motion was given in

other measures than degrees (e.g. relative deficit), authors were contacted for original data. Additionally, we determined the presence of ulnar-sided wrist pain and DRUJ instability between patients with and without an ulnar styloid process fracture per study. For every outcome variable, a subset of the articles was used, depending on the data available. In case of missing data, original authors were contacted.

Quality assessment

For the quality assessment, the methodological index for non-randomized studies (MINORS) was used (Slim et al., 2003). The MINORS checklist rates each study on the potential risk of bias on 12 domains. Each of the 12 domains was scored with zero (not reported in the article), one (reported but inadequately) or two (reported adequately) points. Two reviewers (MAMM and LJFS) independently assessed the potential risk of bias of each of the included studies. Disagreement between the reviewers was discussed until consensus was reached.

Meta-analysis of the primary and secondary outcomes

The mean differences of the primary and secondary outcomes between patients with and without an ulnar styloid process fracture were calculated using a 95% confidence interval (CI). The same applied to the difference in DASH and PRWE scores between patients with an ulnar styloid process base and nonbase fracture.

As the DASH and QuickDASH scores address the same questions and both range from zero to 100, their results were reported together. For the secondary outcomes, ulnar-sided wrist pain and DRUJ instability, risk ratios were calculated with corresponding 95% CI. For all outcomes, an inverse variance method and random effect model were applied (Mahid et al., 2006).

If studies reported results per anatomical region (i.e. tip, middle and base of the ulnar styloid process), data were pooled using a weighted mean and SD according to the *Cochrane Handbook*. In case multiple follow-up moments were used, only the data of the follow-up moment closest to 12 months post-injury were derived from the article. Differences in outcome were considered statistically significant if the p -value was less than 0.05. Heterogeneity was determined using I^2 statistics (Higgins and Thompson, 2002). In addition, sensitivity analyses were performed for our primary outcome based on the inclusion criteria and the meta-analytic model.

Meta-analyses were conducted using Review Manager (Cochrane Collaboration, version 5.2, London, UK).

Results

Literature search and study selection

The initial search found 511 articles, of which 278 remained after excluding the duplicates (Appendix S1). After title and abstract screening, 33 articles were considered for inclusion. Of two articles, the full text was not available despite contacting the authors (Casale et al., 2013; Rotter, 2010). After full-text screening, 13 articles met our inclusion criteria. However, one article reported insufficient data, even after contacting the authors, and could not be included in the meta-analysis (Yilmaz et al., 2015). This left 12 articles for the meta-analysis. The study selection is displayed in Figure S1.

Characteristics of the included studies

The included studies were published between 2009 and 2016. A total of 2243 patients were included, consisting of 1196 patients with an ulnar styloid process fracture and 1047 patients without a ulnar styloid process fracture (Table S2). In seven studies, all distal radius fractures were treated operatively. One study reported non-operative treatment only. The four remaining studies reported both operative and non-operative treatments of the distal radius fracture. The risk of bias is depicted per study in Figure S2.

DASH, QuickDASH and PRWE questionnaires

The DASH questionnaire was used in nine studies and the QuickDASH in one study. Four studies showed a significant difference in DASH score in favour of no fracture of the ulnar styloid process (Amorosa et al., 2011; Ayalon et al., 2016; Belloti et al., 2010; Krämer et al., 2013). A significant difference was found in the study of Amorosa et al. (2011) [26 (SD 23) versus 13 (SD 18), $p = 0.04$], Ayalon et al. (2016) at [17 (SD 19) versus 9 (SD 14), $p = 0.001$], Belloti et al. (2010) [13 (SD 14) versus 6 (SD 15), $p = 0.04$] and in the study of Krämer et al. (2013) [21 and 22 versus 14, $p = 0.045$].

Three of the included studies used the PRWE questionnaire. One study (Daneshvar et al., 2014) found a significant higher PRWE score for ulnar styloid process-base fractures after 12 months. Moreover, Finsen et al. (2013) found a significant

correlation between an ulnar styloid process fracture and both the PRWE and the QuickDASH score (Spearman correlation 0.189 and 0.163, respectively, $p < 0.001$).

In the meta-analysis, two studies (Gogna et al., 2014; Krämer et al., 2013) provided insufficient data on the DASH score, and could therefore not be added to the meta-analysis. We found a significant mean difference of 3.40 points [95% CI 1.33–5.48] in DASH score in favour of no ulnar styloid process fracture (Figure 1(a)). The heterogeneity was 52%, which might embody moderate to substantial heterogeneity. No significant difference was found in PRWE scores (Figure 1(b)).

A sensitivity analysis was performed for the DASH score based on the age of the included patients. Only the article of Amorosa et al. (2011) included patients aged 70 years and older, where all other articles included patients of all ages. We found that by excluding the article of Amorosa et al. (2011), the outcome was still statistically significant (mean difference: 3.04 points [95% CI 1.12, 4.97], $p = 0.002$ and $I^2 = 47%$). In addition, the meta-analytic model was changed. This also did not change the significance of our results.

Range of motion and grip strength

Data on range of motion was available in nine studies. Krämer et al. (2013) and Belloti et al. (2010) reported loss of motion instead of range of motion. Moreover, Kim et al. (2010) reported the full arc of

flexion–extension and forearm rotation, and Ayalon et al. (2016) reported the range of motion as a percentage of the uninjured side. Their results could not be used in the meta-analysis. A significant mean difference in radial deviation was found in favour of no ulnar styloid process fracture (mean difference: 1.17° [95% CI 0.14, 2.20], $p = 0.03$ and $I^2 = 0%$) and in supination in favour of an ulnar styloid process fracture (mean difference: -1.46° [95% CI $-2.64, -0.28$], $p = 0.02$ and $I^2 = 0%$). Overall the range of motion was not significantly different (Figure S3a).

Grip strength was measured in 10 of the included studies. A significant difference between patients with and without a fracture of the ulnar styloid process was only found in the study of Krämer et al. (2013) (68% healed ulnar styloid process fracture and 69% non-united ulnar styloid process fracture versus 91% no ulnar styloid process fracture, $p = 0.001$). For the meta-analysis, data on grip strength were available in six studies. No significant difference in grip strength was found (Figure S3b).

Wrist pain and ulnar-sided wrist pain

Data on wrist pain at 12 months was available in five studies, of which three studies reported significantly higher pain scores in patients with an ulnar styloid process fracture. Both Ayalon et al. (2016) and Belloti et al. (2010) reported a significant difference in mean VAS scores in favour of patients without an ulnar styloid process fracture. Krämer et al. (2013) assessed three different aspects of wrist pain: during radial

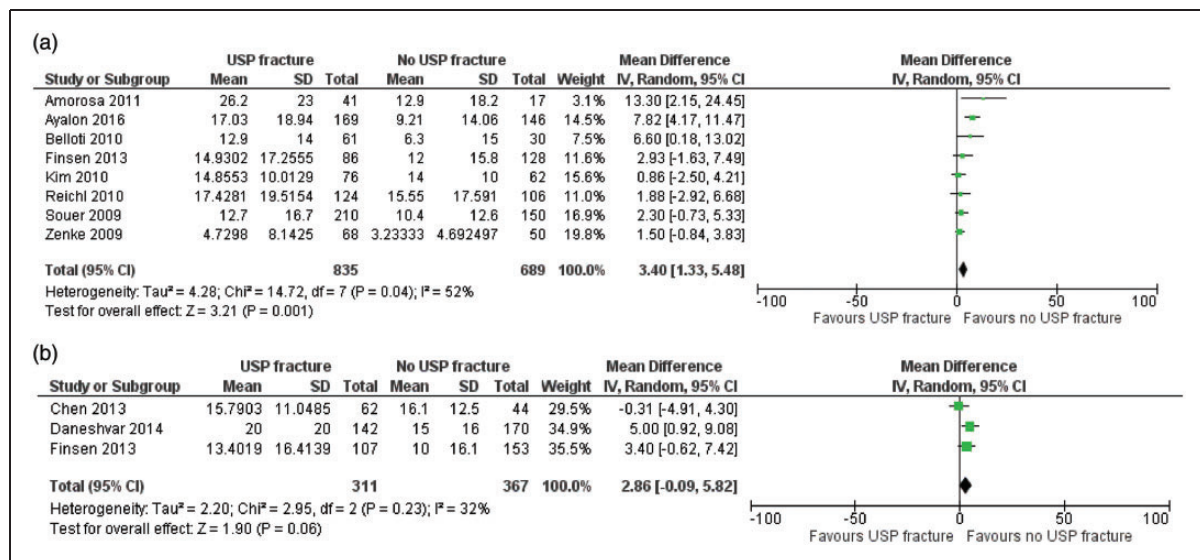


Figure 1. (a) Forest plot of comparison functional outcome ulnar styloid process fracture versus no ulnar styloid process fracture measured with DASH score. (b) Forest plot of comparison functional outcome ulnar styloid process fracture versus no ulnar styloid process fracture measured with PRWE score. USP: ulnar styloid process; CI: confidence interval; SD: standard deviation.

and ulnar deviation and related to translation of the DRUJ. All three VAS pain scores were significantly higher in patients with an ulnar styloid process fracture.

The presence of ulnar-sided wrist pain was described in four studies, of which only Krämer et al. (2013) reported a significant higher VAS score for patients with an ulnar styloid process fracture ($p=0.011$).

For the meta-analysis, data on wrist pain and ulnar-sided wrist pain were available for four and three studies, respectively. No significant differences between an ulnar styloid process fracture and no ulnar styloid process fracture for both outcomes were found (Table 1).

DRUJ instability

Five of the included studies reported on DRUJ instability. Only Krämer et al. (2013) found a significant higher rate of DRUJ instability in patients with an ulnar styloid process fracture ($p=0.032$). The meta-analysis found no significant difference in DRUJ instability between a fracture of the ulnar styloid process and no ulnar styloid process fracture (Table 1).

Level of the ulnar styloid process fracture

Four studies using the DASH questionnaire and three studies using the PRWE questionnaire distinguished results based on the level of the ulnar styloid

process. No significant differences were found between ulnar styloid process base and nonbase fractures for either the DASH and the PRWE scores (Table 2).

Discussion

Meta-analysis of the currently available data suggests that a concomitant fracture of the ulnar styloid process does not significantly affect PRWE scores, range of motion, grip strength or pain in patients with a distal radius fracture. Although DASH scores show a statistically significant difference in favour of no ulnar styloid process fracture, this difference is well below the minimal clinically important difference of the DASH score. In addition, the level of the ulnar styloid process fracture seems not to lead to a difference in functional outcomes.

Today, patient-reported outcome measures, such as the DASH and PRWE questionnaire, are becoming more important due to the fact that these questionnaires not only focus on the functional outcomes, but also take into consideration patient-related factors. Consequently, it is not only important to understand significant differences but also clinically important differences. This meta-analysis shows that there is neither a significant nor a clinically meaningful difference for the PRWE questionnaire. For the DASH questionnaire, a significant mean difference of 3.40 (95% CI 1.33–5.48) in favour of no fracture of the ulnar styloid process was found. Though, this

Table 1. Results of the meta-analysis for (ulnar sided) wrist pain and DRUJ instability.

Outcome measurement	Included studies	N USP fractures	N No USP fractures	I ² (%)	Mean difference*/ Risk ratio** [95% CI]	p-value
Wrist pain	a, b, c, h	502	370	93	0.16 [−0.70, 1.02]*	0.71
Ulnar-sided wrist pain	c, e, i	158	113	0	1.01 [0.96, 1.07]**	0.61
DRUJ instability	c, d, e, f, g	409	394	29	1.00 [0.96, 1.03]**	0.81

(a) Ayalon et al., 2016; (b) Belotti et al., 2010; (c) Chen et al., 2013; (d) Daneshvar et al., 2014; (e) Gogna et al., 2014; (f) Kim et al., 2010; (g) Krämer et al., 2013; (h) Souer et al., 2009; (i) Zenke et al., 2009.

USP: ulnar styloid process; CI: confidence interval; DRUJ: distal radio-ulnar joint.

Table 2. Results of the meta-analysis for the level of the USP fracture.

Outcome measurement	Included studies	N USP base fractures	N USP nonbase fractures	I ² (%)	Mean difference [95% CI]	p-value
DASH	c, d, e, f	142	212	0	−1.92 [−4.51, 0.68]	0.15
PRWE	a, b, c	138	173	64	2.02 [−4.47, 8.52]	0.54

(a) Chen et al., 2013, (b) Daneshvar et al., 2014, (c) Finsen et al., 2013, (d) Kim et al., 2010, (e) Reichl et al., 2011, (f) Zenke et al., 2009. USP: ulnar styloid process; CI: confidence interval; DASH: disabilities of the arm, shoulder, and hand; PRWE: patient-rated wrist evaluation

difference is not clinically meaningful. Only Amorosa et al. (2011) found both a significant and clinically meaningful difference of 13.3 [95% CI 2.15–24.45]. However, they had the smallest study sample of all included studies (58 patients).

We found no difference in range of motion and grip strength between a concomitant fracture of the ulnar styloid process and no fracture. The mean difference found in radial deviation in favour of no ulnar styloid process fracture and in supination in favour of an ulnar styloid process fracture was small, 1.2° and 1.5°, respectively. These differences are not clinically meaningful.

Lindau et al. (1997) found a correlation between ulnar styloid process fractures and TFCC injuries. The anatomical insertion of the TFCC is based on the ulnar fovea at the base of the ulnar styloid process (Hauck et al., 1996). Therefore, an ulnar styloid process base fracture with significant displacement may compromise TFCC integrity, and thereby compromising the congruency of the DRUJ (Hauck et al., 1996; May et al., 2002; Reichl et al., 2011). In contrast, with an ulnar styloid process nonbase fracture the TFCC remains intact, and therefore the DRUJ will remain stable (Hauck et al., 1996). Nonetheless, in this meta-analysis we found no difference in DRUJ instability and ulnar-sided wrist pain between a ulnar styloid process fracture and no ulnar styloid process fracture. This was confirmed by Fujitani et al. (2011) who found that a ulnar styloid process fracture is not a reliable predictor of DRUJ instability. Moreover, both magnetic resonance imaging (MRI) scans and wrist arthroscopy have shown that there is no association between a rupture of the TFCC and an ulnar styloid process fracture (Richards et al., 1997; Spence et al., 1998). It has been suggested that ulnar-sided wrist pain and DRUJ instability is not solely dependent on the TFCC, but also on secondary stabilizers (Sachar, 2012; Wijffels et al., 2014), which could explain why no difference was found in this meta-analysis. Moreover, we found no difference in DASH and PRWE scores and the level of the ulnar styloid process fracture. This was confirmed by Souer et al. (2009) who determined the difference between no ulnar styloid process fractures and ulnar styloid process base fractures solely. They concluded that an unrepaired ulnar styloid process base fracture does not influence the functional outcome, even when the ulnar styloid process fracture was displaced more than 2 mm. However, in this meta-analysis we did not determine the effect of the level of the ulnar styloid process fracture on DRUJ instability, since this was not addressed in the included articles.

This study has some limitations. First, the included studies comprised patients with different ages, treatment modalities for the distal radius fracture, levels of the ulnar styloid process fracture, and durations and follow-up moments. Also, we made no distinction in the treatment for the distal radius fracture. Four studies that included both operatively and non-operatively treated distal radius fractures were included in this meta-analysis. Two of these studies found a significant higher percentage of ulnar styloid process fractures in the operative treated group (Ayalon et al., 2016; Krämer et al., 2013). However, the study of Krämer et al. (2013) was only included in the meta-analysis of the DRUJ instability and did therefore not contribute to the results of the other functional outcomes. Second, only patients with non-operatively treated ulnar styloid process fractures were included. This could have introduced bias by assuming that the more problematic ulnar styloid process fractures were treated operatively. Souer et al. (2009) found no difference in functional outcomes between patients with a displacement of the ulnar styloid process base fracture of more than 2 mm and those with less displacement. However, the question remains if ulnar styloid process fractures accompanied by an unstable DRUJ can be left untreated. Third, we did not distinguish between united and non-united ulnar styloid process fractures. Moreover, although we looked at a mean follow-up of at least 12 months, some included studies had a wide range. This means that a few patients with a follow-up shorter or longer than 12 months were reviewed. Lastly, the quality of the included studies in the meta-analysis was not optimal, and although an effort was made to retrieve the raw data, not all data for all outcome variables were complete. As a consequence, not all desired data could be used in our meta-analysis.

This meta-analysis indicates that patients with a distal radius fracture and a fracture of the ulnar styloid process have the same functional outcome compared with patients without a fracture of the ulnar styloid process after 1 year of follow-up. Moreover, the level of the ulnar styloid process fracture seems not to contribute to a difference in functional outcomes.

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