Is there a correlation between functional results and radiographic findings in patients with distal radius fracture A0 type A3 treated with volar locking plate or external fixator?

Trine Ludvigsen, MD\textsuperscript{a,b,*}, Kjell Matre, MD, PhD\textsuperscript{a,d}, Nils Vett, MD, PhD\textsuperscript{a,c}, Per Martin Kristoffersen, MD\textsuperscript{a,c}, Monika Kolskår Toppe, MD\textsuperscript{c}, Rakel Gudmundsdottir, MD\textsuperscript{d}, Yngvar Krukhaug, MD, PhD\textsuperscript{a,d}, Eva Dybvik, PhD\textsuperscript{e}, Jonas Meling Fevang, MD, PhD\textsuperscript{a,d}

\textbf{Purpose:} The aim of this study was to test the hypothesis that precise restoration of distal radius fractures is correlated to better patient-reported outcome.

\textbf{Methods:} The correlation between radiographic results and functional outcome was explored in 156 patients with extra-articular distal radius fractures included in a multicenter, randomized controlled trial comparing 2 surgical interventions, Volar Locking Plate or External Fixator. The primary functional outcome was the Patient Rated Wrist and Hand Evaluation score (PRWHE). Radiographically we assessed volar tilt, radial inclination, radial height, ulnar variance, and the presence of ulnar styloid fracture. The Pearson correlation analysis was used to estimate correlations between parameters.

\textbf{Results:} At 1-year follow-up the mean difference in radiographic findings compared with the uninjured side (min, max) was: reduced volar tilt 5.3\degree (\textminus15\degree, 25\degree), reduced radial inclination 2.3\degree (\textminus6\degree, 12\degree), radial height 1.3 mm (\textminus4 mm, 7 mm), and ulnar variance \textminus0.5 mm (\textminus6 mm, 3 mm). Overall, we found no correlation between radiographic parameters and the PRWHE at 1-year follow-up within the whole group, regardless of which treatment was chosen. At the time of injury 53\% (N = 80) had sustained an additional ulnar styloid fracture. After 1 year this fracture was still radiographically present in 31\% (N = 43) of the patients. No correlation between PRWHE score and the presence of an ulnar styloid fracture at 1-year follow-up was found.

\textbf{Conclusions:} We found no correlation between functional outcome (PRWHE) and radiographic findings after 1 year in patients operated on with a Volar Locking Plate or External Fixator. Patient-specific factors were more important than radiographic measurements in this study group.

\textbf{Level of evidence:} Therapeutic Level 2

\textbf{Trial registration:} Norway: National Committee for Medical and Health Research Ethics 213/555

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\textbf{Keywords:} displaced extra-articular fracture, distal radius fracture, external fixation, PRWHE, radiographic measurements, volar locking plate

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1. \textbf{Introduction}

A fracture of the distal radius (DRF) is the most common fracture in adults.\cite{1,2} Surgical fixation is recommended in severely displaced fractures.\cite{3} Volar locking plate (VLP) and external fixation (EF) are 2 of the most commonly used methods for treating DRF.\cite{4,5,6,7} The goal of the operation is to restore the normal anatomy and a mobile, pain-free wrist without functional limitations. The correlation between the degree of radiographic deformity and functional outcome of the fracture however is controversial.\cite{3,5,6,7,8,9,10,11} We therefore conducted a study alongside a RCT to assess the relationship between radiological findings and functional outcome.\cite{12}

2. \textbf{Methods and design}

2.1. Design

This was a prospective follow-up study. The patients included participated in a RCT comparing 2 surgical interventions in...
patients who had sustained an extra-articular distal radius fracture. Consecutive patients aged 18 to 70 years presenting to the orthopedic department with an isolated unilateral dorsally displaced unstable extra-articular fracture of the distal radius (OTA/AO 23 A3), according to the judgement of the surgeon on call, were eligible for inclusion into the trial. Patients were included in the study if they received treatment within 16 days of their injury. Patients had the meaning of the trial and the consequences explained to them, and all patients signed a consent form prior to inclusion.

Exclusion criteria were previously fractured contra- or ipsilateral hand, open fractures, mental illness, dementia, and severe drug abuse.

During the inclusion period, 314 patients with A3 fractures between the age 18 and 70 years were assessed for eligibility. Out of these, 158 patients were excluded because of the following:

- Not meeting inclusion criteria (n=97)
  - Previous wrist fracture of either side (inclusive childhood fractures) (n=53)
  - Fracture >16 days (n=22)
  - Patients living outside catchment area (n=8)
  - Dementia (n=3)
  - Mental illness (n=7)
  - Drug abuse (n=4)
- Declined to participate (n=29)
- Unknown (n=32)

Of 156 primary included patients, 142 (91%) completed 1-year follow-up, among whom 73 were allocated to external fixator and 69 to volar plate. Patient characteristics are shown in Table 1. Forty different doctors were involved as primary surgeons, while the 1-year follow-up visit was performed by the authors. We analyzed the follow-up data 1 year after inclusion of the last patient.

2.2. Ethics

The study was conducted according to the Declaration of Helsinki and approved by the Regional Ethics Committee of Western Norway (ref 2013/555) and the local data protection officer. The trial was registered at ClinicalTrials.gov (NCT01904084). Written informed consent was obtained from all patients.

2.3. Intervention

Implants were standardized to either Hoffman Compact T2 external fixator or DVR/DePuy volar locking plate. All the surgeons involved (n=40) had experience with both procedures. They should have performed a minimum of 5 procedures of both techniques, independently or with experienced supervision, before participating in the study. All operations were performed with brachial plexus block or general anesthesia and fluoroscopic guidance. Operating techniques were standardized and all patients were admitted and treated as inpatients. The external fixator was removed after 6 weeks at the outpatient clinic. In the VLP group, a dorsal splint was applied until the patient had regained control of the arm after having the plexus block. The splint was removed before being discharged from the hospital. The patient was advised to move the wrist with a free range of motion but not to apply any weight for the first 6 weeks.

2.4. Outcome measures

2.4.1. Functional outcome measures.

The PRWHE (The Patient-Rated Wrist and Hand Evaluation), is a patient-reported outcome measuring wrist function in 2 (equally weighted) sections concerning the patients experience of pain and limitations in daily life activities, to give a score out of 100 (with 100 being the worst score).[16]

The PRWHE questionnaire has been cross-cultural validated to the Norwegian population.[17] The minimum clinically important difference for this score, in patients with distal radius fractures, is 11.5 points.[18] We defined patients reporting a difference in PRWHE score less than 11.5 points, compared with their preoperative score, as fully recovered.

2.4.2. Method of radiographic measurements.

Radiographs of the wrist were obtained according to standardized clinical procedures:

- Posterior-anterior (PA) views with the shoulder in 90° abduction, elbow in 90° flexion, and wrist in neutral position. Lateral views with the shoulder in adducted position and elbow in 90° flexion, and wrist in neutral position, if necessary the beam angled to visualize the radiocarpal joint.

All values for the involved side were compared with those for the contralateral side.

Radiographic findings were assessed as follows.

- The long axis of the radius was defined as the line between the midpoint of the radius at 3 and 6 cm proximal to the radiocarpal joint (Figs. 1 and 2).
- The volar tilt was defined as the angle between lines drawn perpendicular to the long axis of the radius and the distal joint surface of the radius using the lateral view. A positive angle denotes volar angulation and a negative angle dorsal angulation (Fig. 2).
- The ulnar variance was defined on the PA view as the distance between 2 parallel lines drawn along the distal ulnar aspects of the radius and the distal cortical rim of the ulna, perpendicular to the long axis of the radius (Fig. 1A).
- Radial height was measured on the PA view as the distance between 2 parallel lines drawn along the tip of the radial styloid and the distal cortical rim of the ulna, perpendicular to the long axis of radius (Fig. 1A).

| Table 1 |
|--------------------------------------------------|
| **Patient characteristics**                      |
| Number of patients included                      | 156 |
| Mean age (min–max)                               | 56 (20–70) |
| Sex                                               |
| Female                                           | 140 (90%) |
| Dominant side                                    |
| Right                                            | 138 (88%) |
| Dominant side injured                            | Yes |
| Volar locking plate                              | 75 (48%) |
| DVR/DePuy volar locking plate                    | 81 (52%) |
| PRWHE preinjury†                                  | 1.4±5.0 |
| Radiology†                                       |
| Volar tilt (°)†                                   | −21±11 |
| Radial inclination (°)†                           | 18±5.8 |
| Radial height (mm)†                               | 6.8±4.2 |
| Ulnar variance (mm)†                              | 2.6±2.4 |
| Ulna fracture (mm)†                               | 80 (52.2%) |

PRWHE = Patient Rated Wrist and Hand Evaluation score (0–100).
† Radiographic measurements of injured side prior to reduction.
The values are given as the mean with standard deviation.
Radial inclination was defined as the angle between a line drawn from the tip of the radial styloid to the medial edge of the articular corner of the radius and a line perpendicular to the long axis of the radius (Fig. 1B). An additional ulnar styloid fracture, if present, was registered (Fig. 1A).

All radiographs from 10 different randomly selected patients were reviewed independently by 3 radiologists and 1 orthopaedic surgeon. Previous studies have given a detailed description of these measurements. The results were assessed to check for comparability of the accuracy of measurements by calculating the intraclass correlation coefficient (ICC) according to guidelines given by Koo and Li. An ICC of 0 indicates no agreement and an ICC of 1 indicates perfect agreement. The ICC was interpreted as good or excellent (ICC 0.75–0.98) with the exception of radial inclination at 6 weeks and 1 year (moderate ICC 0.60–0.66). The radiographs for the remaining patients were split into 4 equally sized groups and reviewed by one of the same 4 interpreters.

Sample size was guided by a previous study on inter- and intra-observer reliability of assessment of distal radial fractures. However, no power analysis was undertaken.

2.5. Evaluation and follow-up

PRWHE was reported at the first examination after the injury according to wrist function prior to the injury and at 1-year follow-up.

Radiographs of both the injured and uninjured wrist were obtained at the first consultation after injury and radiographs of the injured wrist were obtained at 1-year follow-up.

2.6. Blinding

The interpreters of the radiographs were not the treating surgeon and were blinded to functional outcome but not to the method of treatment (as it would show on the radiographs).

2.7. Statistical analysis

Data from all the outcome measures were summarized using means and standard deviations (given in parenthesis). A Pearson correlation was calculated for radiological parameters and patient reported outcome (PRWHE). The strength of the correlations was interpreted as: negligible ($r = 0.00–0.3$), weak ($r = 0.31–0.5$), moderate ($r = 0.51–0.70$), strong ($r = 0.71–0.90$), and almost perfect ($r = 0.91–1.00$). A paired $t$ test was used to assess differences in the radiological parameters between uninjured side and 1-year follow-up. To compare the group of patients fully recovered with those not recovered after 1 year, continuous variables were analyzed using $t$ test and categorical variables using chi-square test. $P$ values less than 0.05 were considered statistically significant. The statistical analyses were performed in the statistical package IBM SPSS Statistics Version 26 (IBM Corp, Armonk, NY) and the statistical package R (http://CRAN.R-project.org).

3. Results

The mean patient reported PRWHE score prior to injury was $1.4 \pm 5$, while PRWHE score after 1 year was $7.6 \pm 13.5$. Radiographic results after 1 year differed significantly from the uninjured side. At the time of injury 53% ($N = 80$) had sustained an additional fracture of the ulna styloid. After 1 year the fracture was still radiographically present in 31% ($N = 43$) of the patients (Table 2).
Overall, we found no correlation between radiographic parameters and the PRWHE at 1-year follow-up within the whole group, regardless of which treatment was chosen (volar tilt $r = -0.005$, $P = 0.95$, radial inclination $r = -0.083$ $P = 0.34$, radial height $r = -0.043$, $P = 0.62$, and ulnar variance $r = 0.068$ $P = 0.43$). No correlation between PRWHE score and the presence of an ulnar styloid fracture at 1-year follow-up (mean difference [MD] $= 2.24$, $P = 0.37$) was found (Figs. 3–6).

We found no significant difference in radiographic findings between the 2 surgical methods considering volar tilt (MD $= 0.908$, $P = 0.34$), radial inclination (MD $= -0.97$, $P = 0.10$) and radial height (MD $= 0.468$, $P = 0.30$). However, the ulnar variance was significantly smaller in the VLP group (MD $= -0.819$, $P = 0.01$).

At 1 year, we found that 80% had regained full recovery. However, at the same time we found that 20% had PRWHE scores higher than 11.5 points compared with their preoperatively score, indicating persisting major disability (Table 3). When comparing the 2 groups we found no difference in results influenced by age, gender, injury of dominant hand, injury energy level, or manual work. Further, type of implant, time until surgery, type of anesthesia, operation time, and duration of postoperative stay had no influence on results at 1 year in either group. However, we found that patients with high PRWHE scores at 1 year were more likely to have had an injury indoor, being unemployed or receiving disability benefits. Radiologically, we found that the patients with high PRWHE score at 1 year had significantly larger initial displacement after injury considering radial inclination ($P = 0.004$) and radial height ($P = 0.047$), but this was not the findings regarding volar tilt, ulnar variance, and the presence of an ulnar styloid fracture. At 1 year, no radiological difference was found affecting the functional results. Neither a dorsal displacement $>10^\circ$ ($P = 0.975$) nor an ulnar variance $>2$ mm ($P = 0.838$) compared with the uninjured side after 1 year was found to affect the functional outcome.

### Table 2

| Radiographic outcomes 1 year |
|-----------------------------|
|                            | Uninjured side |          | P value |       |
|                            | Injured side  |          |         |       |
| Radiographic measurements  |              |          |         |       |
| Volar tilt (°)             | 5±5.6        | 10.5±3.9 | <0.000  |       |
| Radial inclination (°)     | 24±3.5       | 25.8±2.9 | <0.000  |       |
| Radial height (mm)         | 10.3±2.6     | 11.6±2.1 | <0.000  |       |
| Ulnar variance (mm)        | 1.2±1.8      | 0.7±1.6  | =0.001  |       |
| Ulna fracture (N)          | 43 (30.9%)   | Nil      |         |       |

* The values are given as the mean (standard deviation).

4. Discussion

In our study, we found no correlation between radiographic measurements and wrist function at 1-year follow-up in patients with extra-articular (A0 type A3) distal radius fractures operated with a VLP or EF. Furthermore, with the exception of significantly smaller ulnar variance in the VLP group no difference in radiographic findings was found between the 2 surgical methods. Still, there were 20% reporting persisting disability after 1 year, but no correlation to radiological outcomes were found.

The possible correlation between radiological findings and the PRWHE score has been studied previously. Synn et al,[11] in a study of 53 patients, demonstrated no associations between radiographic findings and the PRWHE score at 6 months postinjury in older patients above the age of 53. Among patients included in that study, 51% (n=27) received surgical treatment that included pin fixation or volar plating. Karnezis et al[23] demonstrated a moderate correlation ($r = -0.53$) with PRWHE and the degree of radial height 12 months postinjury. Their study
was smaller (n = 30) and the mean age was lower than in our study with mean age 46 versus 56 in our study. Furthermore, all included patients received surgical treatment with closed reduction and pin fixation, and the radial shortening was found to be 2.0 mm compared with our findings with radial shortening 1.6 mm. Plant et al\(^{[24]} \) (n = 45) only presented radiological results according to volar tilt and ulnar variance, and the patients, which resembled ours in terms of mean age (56), all received surgical fixation with percutaneous pinning or volar plate. A weak correlation between volar tilt \(^{r = 0.20}\), but no correlation

![Figure 4. Result radial inclination at 1 year.](image)

![Figure 5. Result radial height at 1 year.](image)
between ulnar variance (r = 0.03) and the PRWHE score at 12 months, was reported in their study. Volar tilt was found to be 3.5° and ulnar variance 1.4 mm, which differed somewhat to our findings of 5° and 1.2 mm, respectively.

At 1 year, most patients had good scores and there was no statistically significant difference at a group level. When comparing the patients with poor results to those who had gained full recovery, they were more likely to be unemployed or disabled. This may indicate that patients with poorer functional results have other health issues. Roh et al.[25] found that preoperative anxiety and catastrophic pain ideation were associated with delayed recovery after DRF and Yeoh et al.[26] found depression to be the strongest predictor of worse functional score after 1 year. Our patients with poor outcome were also more likely to have sustained a low-energy indoor trauma and they had more loss of radial inclination and radial height, indicating osteoporosis. Fitzpatrick et al.[27] found that postmenopausal osteoporotic women had worse functional outcomes than women without osteoporosis sustaining similar injuries at 1 year. No significant difference in ROM or radiographic data between the groups were found. Roh et al.[28] also identified osteoporosis to be a risk factor delaying long-term functional recovery after DRF. This indicates that factors that can predict long-term results after surgical treatment of DRF are influenced by other issues than radiologic findings alone.

Our study included more patients than previous studies, which makes it less probable that our failure to detect a correlation between radiographic findings and functional outcomes is due to an underpowered study.

Previous studies have indicated that radiographic and functional outcomes are more closely correlated in younger patients.[29,30] This was not supported by our study, where all patients were under the age of 70.

With the exception of the failure of EF to maintain ulnar variance to the same extent as VLP, we found no significant difference in radiographic parameters between the 2 surgical treatments. Similar results have been found in other studies.[31–36]

Some studies have reported that more than 40% of distal radius fractures have an associated ulnar styloid fracture.[37–39] This is consistent with our study (53% ulnar styloid fracture).

The frequency of ulnar styloid nonunion has previously been found to be between 26%.[40] and 63%,[37] and functional outcome scores for such patients were not worse than for patients with healed fractures.[37,41–43] In our study, there were 31% nonunions and we found no correlation to the PRWHE score after 1 year.

The major strengths of our study were a large sample size (n = 142), a uniform type of fractures and a high follow-up rate (91%). We used validated radiographic measurements, and the use of the PRWHE, the most sensitive outcome measure for patients sustaining wrist injuries, also strengthens our results.[16] The patients were recruited from the trauma unit in 2 hospitals, and a large number of surgeons were involved in the primary treatment. This renders external validity of the results although one could also argue that this also raise a concern regarding the level of experience the surgeons had with management of this type of injury.

However, the study was limited to patients having surgical fixation of their fractures. For this reason, the results cannot be extrapolated to patients treated conservatively, but should be interpreted in the context of the studied age group, type of fracture and the applied treatment methods. Further, our results do not translate into intra-articular deformity or severe degrees of extra-articular deformity, since no patients in this study had either of those 2 findings. Follow-up was limited to 1 year, thereby it is not possible to identify patients who will develop long-term symptoms and disability consequent to the injury.
In conclusion, for extra-articular fractures, healing within a close range to normal values, there is little effect of radiographic alignment on functional outcome.

Future studies should focus on the limits of radiographic deviations, which might influence the patients’ outcome.

References

1. Hove LM, Fjeldsgaard K, Reitan R, et al. Fractures of the distal radius in a Norwegian city. Scand J Plast Reconstr Surg Hand Surg. 1995;29:263–267.
2. Lofthus CM, Frihagen F, Meyer HE, et al. Epidemiology of distal forearm fractures in Oslo, Norway. Osteoporos Int. 2008;19:781–786.
3. Ng CY, McQueen MM. What are the radiological predictors of functional outcome following fractures of the distal radius? J Bone Joint Surg Br. 2011;93:145–150.
4. Downing ND, Karantana A. A revolution in the management of fractures of the distal radius? J Bone Joint Surg Br. 2008;90:1271–1275.
5. Koval KJ, Harrast JJ, Anglen JO, et al. Fractures of the distal part of the radius. The evolution of practice over time. Where’s the evidence? J Bone Joint Surg Am. 2008;90:1853–1861.
6. Mellstrand-Navarro C, Pettersson HJ, Tornqvist H, et al. The operative treatment of fractures of the distal radius is increasing: results from a nationwide Swedish study. Bone Joint J. 2014;96-B:963–969.
7. Kvernmo HD, Krukhaug Y. Treatment of distal radius fractures. Tidsskr Nor Laegeforen. 2013;133:405–411.
8. Kvernmo HD, Otterdal P, Balteskard L. Treatment of wrist fractures and clinical outcome after distal radius (Colles’) fracture. J Hand Surg Eur Vol. 2013;38:116–126.
9. Batra S, Gupta A. The effect of fracture-related factors on the functional outcome following fractures of the distal radius. Injury. 2002;33:499–502.
10. Finsen V, Rod O, Rod K, et al. The relationship between displacement and clinical outcome after distal radius (Colles’) fracture. J Hand Surg Eur Vol. 2013;38:116–126.
11. Synn AJ, Makhni EC, Makhni MC, et al. Distal radius fractures in older patients: is anatomic reduction necessary? Clin Orthop Relat Res. 2009;467:1612–1620.
12. Tsukazaki T, Takagi K, Iwasaki K. Poor correlation between functional results and radiographic findings in Colles’ fracture. J Hand Surg. 1993;18:588–591.
13. Villar RN, Marsh D, Rushon N, et al. Three years after Colles’ fracture. A prospective review. J Bone Joint Surg Br. 1987;69:635–638.
14. Ludvigsen T, Matre K, Gudmundsdottir RS, et al. Surgical treatment of distal radial fractures with external fixation versus volar locking plate: a
multicenter randomized controlled trial. J Bone Joint Surg Am. 2021;103:405–414.
15. Meenig EG, Agel J, Roberts CS, et al. Fracture and dislocation classification compendium-2018. J Orthop Trauma. 2018;32 (suppl 1): S1–S170.
16. MacDermid JC, Turgeon T, Richards RS, et al. Patient rating of wrist pain and disability: a reliable and valid measurement tool. J Orthop Trauma. 1998;12:577–586.
17. Reigstad O, Vaksvik T, Lutken T, et al. The PRWHIE form in Norwegian—a assessment of hand and wrist afflications. Tidsskr Nor Laegeforen. 2013;133:2125–2126.
18. Walenkamp MM, de Muinck Keizer RJ, Goslings JC, et al. The minimum clinically important difference of the patient-rated wrist evaluation score for patients with distal radius fractures. Clin Orthop Relat Res. 2015;473:3235–3241.
19. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15:155–163.
20. Plant CE, Hickson C, Hedley H, et al. Is it time to revisit the AO classification of fractures of the distal radius? Inter- and intra-observer reliability of the AO classification. Bone Joint J. 2015;97-b:818–823.
21. Hinkle DE, Wiersma W, Jurs SG. Applied statistics for the behavioral sciences. 2003;Houghton Mifflin College Division,
22. 2007;Wilcke MKT, Abbaszadegan H, Adolphson Per Y. Patient-perceived outcome after displaced distal radius fractures: a comparison between radiological parameters, objective physical variables, and the DASH score. 20:290–298.
23. Karnezis IA, Panagiotopoulos E, Tyllianakis M, et al. Correlation between radiological parameters and patient-perated wrist dysfunction following fractures of the distal radius. Injury. 2005;36:1435–1439.
24. Plant CE, Parsons NR, Costa ML. Do radiological and functional outcomes correlate for fractures of the distal radius? Bone Joint J. 2017;99-B:376–382.
25. Roh YH, Lee BK, Noh JH, et al. Effect of anxiety and catastrophic pain ideation on early recovery after surgery for distal radius fractures. J Hand Surg. 2014;39:2238.e2–2264.e2.
26. Yeeh JC, Pike JM, Slobogean GP, et al. Role of depression in outcomes of low-energy distal radius fractures in patients older than 55 years. J Orthop Trauma. 2016;30:228–233.
27. Fitzpatrick SK, Casemyr NE, Zurakowski D, et al. The effect of osteoporosis on outcomes of operatively treated distal radius fractures. J Hand Surg. 2012;37:2027–2034.
28. Roh YH, Lee BK, Noh JH, et al. Factors delaying recovery after volar plate fixation of distal radius fractures. J Hand Surg. 2014;39:1465–1470.
29. Kumar S, Penematla S, Sadri M, et al. Can radiological results be surrogate markers of functional outcome in distal radial extra-articular fractures? Int Orthop. 2008;32:505–509.
30. Mackenney PJ, McQueen MM, Elton R. Prediction of instability in distal radial fractures. J Bone Joint Surg Am. 2006;88:1944–1951.
31. Hammer OL, Clementsen S, Hast J, et al. Volar locking plates versus augmented external fixation of intra-articular distal radial fractures: functional results from a randomized controlled trial. J Bone Joint Surg Am. 2019;101:311–321.
32. Karantana A, Downing ND, Forward DP, et al. Surgical treatment of distal radial fractures with a volar locking plate versus conventional percutaneous methods: a randomized controlled trial. J Bone Joint Surg Am. 2013;95:1737–1744.
33. Wilcke MK, Abbaszadegan H, Adolphson PY. Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year. Acta Orthop. 2011;82:76–81.
34. Williensen JH, Frihagen F, Hellund JC, et al. Volar locking plate versus external fixation and adjuvant pin fixation in unstable distal radius fractures: a randomized, controlled study. J Hand Surg. 2013;38:1469–1476.
35. Mellstränd Navarro C, Ahrengart L, Tornqvist H, et al. Volar locking plate or external fixation with optional addition of K-wires for dorsally displaced distal radius fractures: a randomized controlled study. J Orthopa Trauma. 2016;30:217–224.
36. Williensen JH, Husby T, Hellund JC, et al. External fixation and adjuvant pins versus volar locking plate fixation in unstable distal radius fractures: a randomized, controlled study with a 5-year follow-up. J Hand Surg. 2015;40:1333–1340.
37. Catalano LW3rd, Cole RJ, Gelberman RH, et al. Displaced intra-articular fractures of the distal aspect of the radius. Long-term results in young adults after open reduction and internal fixation. J Bone Joint Surg Am. 1997;79:1290–1302.
38. May MM, Lawton JN, Blazar PE. Ulnar styloid fractures associated with distal radius fractures: incidence and implications for distal radioulnar joint instability. J Hand Surg. 2002;27:965–971.
39. Oskarsson GV, Aaser P, Hjal J. Do we underestimate the predictive value of the ulnar styloid affection in Colles fractures? Arch Orthop Trauma Surg. 1997;116:341–344.
40. Bocorn KR, Kurtzke JF. Colles’ fracture; a study of two thousand cases from the New York State Workmen’s Compensation Board. J Bone Joint Surg Am. 1953;35-A:643–658.
41. Zenke Y, Sakai A, Oshige T, et al. The effect of an associated ulnar styloid fracture on the outcome after fixation of a fracture of the distal radius. J Bone Joint Surg Br. 2009;91:102–107.
42. Bujiege GA, Ring D. Clinical impact of united versus nonunited fractures of the proximal half of the ulnar styloid following volar plate fixation of the distal radius. J Hand Surg Am. 2010;35:223–227.
43. Kim JK, Koh YD, Do NH. Should an ulnar styloid fracture be fixed following volar plate fixation of a distal radial fracture? JBone Joint Surg Am. 2010;92:1–6.