Internal versus external fixation for unstable distal radius fractures: an up-to-date meta-analysis

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Abstract

Purpose Our aim was to compare the effect of internal vs external fixation for unstable distal radius fractures regarding postoperative complications, clinical results and radiological outcomes.

Methods We selected PubMed; Cochrane Library; EMBASE; BIOSIS; Ovid and the relevant English orthopaedic journals and pooled data from ten eligible randomised controlled trials containing 738 patients to conduct a subgroup analysis according to different periods of follow-up. Our aim was to summarise the best available evidence.

Results Results showed that compared with external fixation, internal fixation led to significantly fewer total surgical complications [95% confidence interval (CI) 0.39–0.81, $P=0.002$] and reduced the incidence of pin-track infections (95% CI 0.08–0.46, $P=0.0002$) after a one year follow-up. For clinical results, grip strength (95% CI 1.59–8.25, $P=0.004$), supination (95% CI 13.99–48.83, $P=0.0004$) and pronation (95% CI 5.61–26.09, $P=0.002$) were superior in the internal fixation group six weeks postoperatively, and the same results were obtained three months postoperatively for grip strength (95% CI 3.21–13.47, $P=0.001$) and supination (95% CI 3.61–16.01, $P=0.002$).

Meanwhile, the Disabilities of the Arm, Shoulder and Hand (DASH) score was superior in the internal fixation group at three months (95% CI –20.62 to –2.07, $P=0.02$) and after one year (95% CI –14.37 to –2.32, $P=0.007$) follow-up.

Conclusions We suggest that the final results are significant and there is some evidence supporting the use of open reduction and internal fixation.

Introduction

Distal radius fractures are common orthopaedic injuries and account for approximately 1/6–1/4 [1] of clinical emergency fractures. Improper treatment results in chronic wrist pain and stiffness, seriously affecting hand function. When a distal radius fracture occurs, it contributes to considerable disability, increased dependence for the injured patient and causes a major challenge for health care systems. Therapeutic alternatives for distal radius fractures differ greatly throughout the world but mainly include internal (IF) and external (EF) fixation. Open reduction and internal fixation (ORIF) in our ten eligible randomised controlled trials [2–11] was performed with a precontoured, locked radial column or volar plate. However, in some trials, for the best possible stabilisation, some additional augmentation strategies were applied, including the use of additional Kirschner (K) wires, bone graft or bone substitute [2, 3, 5, 6, 8, 10, 11] in the IF group. In the trials studied, EF mainly consisted of bridging external fixator, also with the use of adjunctive K wires, bone graft or bone substitute for the best possible stabilisation [2–9]; fixators and percutaneous pins were removed between five and six weeks after surgery. However, whether IF or EF is more appropriate

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for distal radius fractures is still debated. IF offers a better reduction and can reduce the total complication and pin-track infection rates. However, some authors favour EF because it creates less surgical trauma and reduces operation time. Kateros et al. [12] believe the long-term clinical results between IF and EF are comparable. A number of clinical studies comparing IF with EF have been undertaken. They include randomised controlled trials (RCTs), observational studies and systematic reviews. Some other meta-analyses [13–15] have also been conducted to compare IF with EF. However, there are few RCTs included in these systematic reviews or that present results published after 2005. We addressed these issues by conducting an up-to-date meta-analysis of RCTs published to June 2010. The purpose was to evaluate clinical results comparing IF with EF, including comparison of complication rate, clinical results and radiological outcomes. It is hoped that the findings will improve our understanding of the treatment for unstable distal radius fractures.

Materials and methods

Inclusion and exclusion criteria

We included only studies meeting the following criteria: RCTs comparing IF with EF; Arbeitsgemeinschaft für Osteosynthesefragen (AO) type A-C3 fractures or Frykman type I–VIII fractures impossible to reduce or retain in an acceptable position in a cast after closed reduction; skeletally mature patients; patients with an unstable distal radius fracture of <14 days or axial compression >2 mm;

dorsal angulation >20°; reported clinical outcomes, such as complication, clinical results, radiological outcomes and Disabilities of the Arm, Shoulder and Hand (DASH) score; patients who had received oral and written information and signed an informed consent. All studies included patients having appropriate therapy for the first time. Trials were excluded if patients had the following conditions: fracture of the contralateral side or other fracture in need of treatment; open fracture; ongoing radiotherapy or chemotherapy; metabolic disease affecting the bone; medication affecting the bone.

Search strategy

According to guidelines from the Cochrane collaboration [16], we searched PubMed (1996 to June 2010); Cochrane Library (1996 to June 2010); EMBASE (1996 to June 2010); BIOSIS (1996 to June 2010); and Ovid. The following keywords were used: distal radial fracture, internal fixation, external fixation; the type of articles was limited to RCTs; publication language was restricted to English. We also examined the reference lists of eligible studies for potentially relevant reports and searched for references in the Cochrane Central Register of Controlled Trials.

Study review

Titles and abstracts were reviewed independently by two of the authors; all relevant articles were then retrieved and read to determine eligibility. A flow chart of the study selection process [17] is presented in Fig. 1.

Fig. 1 Flow chart of study selection process

Table 1 Eight-item modified Jadad scale

Item assessed	Response	Score
Was the study described as randomised?	Yes	+1
	No	0
	Not described	0
Was the method of randomisation appropriate?	Yes	+1
	No	-1
	Not described	0
Was the study described as blinded? ^a	Yes	+1
	No	0
	Not described	0
Was the method of blinding appropriate?	Yes	+1
	No	-1
	Not described	0
Was there a description of withdrawals and dropouts?	Yes	+1
	No	0
Was there a clear description of the inclusion/exclusion criteria?	Yes	+1
	No	0
Was the method used to assess adverse effects described?	Yes	+1
	No	0
Was the method of statistical analysis described?	Yes	+1
	No	0

^a Double-blind received one score; single-blind received 0.5 score

Data extraction

All relevant data that met the initial inclusion criteria were extracted independently by two of the authors. Disagreement was resolved by discussion. We sought the following summary data from each study: (1) information on general characteristics of participants; (2) postoperative complications (total complication rate, pin-track infection, rupture of extensor tendons, carpal tunnel syndromes, etc.); (3) clinical results (flexion, extension, pronation, supination, DASH score, etc.); (4) radiological outcomes (radial length, radial inclination, volar tilt, ulnar variance).

Statistical analysis

We used a fixed-effects model in the meta-analysis unless there was significant heterogeneity between studies, when we used the random-effects model of DerSimonian and Laird. Trial heterogeneity was estimated using the I^2 statistic, complying with Quality of Reporting of Meta-Analyses (QUOROM) guidelines [18], which describes the percentage of total variation across studies that is due to heterogeneity rather than chance. I^2 can be readily calculated from basic results obtained from a typical meta-analysis as $I^2 = 100\% \times (Q - df)/Q$, where Q is Cochran's

Table 2 Characteristics of the ten studies used in the meta-analysis

Authors	Year	Follow-up (months)	Numbers(IF/EF)	Age range	multicentre RCTs	Jadad scores
Xu et al [2]	2009	24	16/14	21–56	Single	4
Abramo et al [3]	2009	12	26/24	18–65	Single	4
Rozental et al [4]	2009	12	23/22	≥18	Both centres	5
Wei DH et al [5]	2009	12	12/22	≥18	Single	5
Leung et al [6]	2008	24	70/74	16–60	Multicentre	4
Egol K et al [7]	2008	12	39/38	18–87	Single	6
Kreder et al [8]	2005	24	91/88	16–75	Multicentre	5
Grewal [9] et al	2005	24	29/33	≤70	Single	4
Kapoor et al [10]	2000	48	29/28	Adults	Single	2
McQueen et al [11]	1996	12	30/30	16–86	Single	4

IF internal fixation, EF external fixation, RTC randomised controlled trial

Fig. 2 Total surgical complications reported after 1-year follow-up

heterogeneity statistic and df is the degrees of freedom [19]. Substantial heterogeneity exists when $I^2 > 50\%$. Dichotomous data are presented as relative risk (RR) and continuous variables as weighted mean difference (WMD), both with 95% confidence intervals (CI). Sub-group analyses were carried out according to the different postoperative times in order to assess clinical results and radiological outcomes between the IF and EF groups. Publication bias was tested by funnel plots. The meta-analysis was performed by RevMan5.0.25 software (Cochrane Collaboration, Oxford, UK) for outcome measures; a P value of <0.05 was considered statistically significant.

Study quality evaluation

Two reviewers independently graded each RCT using the modified Jadad scale [20], an eight-item scale designed to assess randomisation, blinding, withdrawals/dropouts, inclusion/exclusion criteria, adverse effects and statistical analysis and is presented in Table 1. The score for each article can range from 0 (lowest quality) to 8 (highest quality). Scores of 4–8 represent good to excellent (high quality) and 0 to 3 poor or low quality.

Sensitivity analysis

Sensitivity analysis was used to assess the robustness of results, whether decisions were uncertain or assumption about data and methods used [21]. To analyse the sensitivity of our study, some studies were excluded because they were of low quality (had a quality score of ≤ 3), as they might have weakened the conclusions.

Publication bias analysis

For the purpose of assessing publication bias, funnel plots based on studies was graphed. Egger's test [22] was performed by the SAS statistical software package (SAS Institute Inc, Cary, NC, USA version 9.1.3).

Results

Literature search

There were 1,556 potentially relevant papers. By screening the title then reading the abstract and the entire article, ten published studies with a total of 738 patients met all

Table 3 Other complications reported after 1-year follow-up

Surgical complication	Studies	Participants		RR	95% CI	P Value
		IF	EF			
Superficial wound infection	5	8/259	5/258	1.47	0.55–3.94	0.44
Rupture of extensor pollicis longus	3	5/160	1/156	2.94	0.6–14.29	0.18
Carpal tunnel syndrome	3	4/126	7/128	0.57	0.17–1.88	0.35
Abnormal union	4	13/165	19/166	0.69	0.38–1.26	0.22
Reflex sympathetic dystrophy	4	7/179	8/179	0.91	0.35–2.36	0.94

IF internal fixation, EF external fixation, RR relative risk, CI: confidence interval

Fig. 3 Pin-track infection reported after 1-year follow-up

inclusion criteria and proved eligible for this investigation [2–11]. Table 2 provides a summary of the studies, author, year of publication, patient age range, sample size, follow-up period, single or multiple centre study and Jadad scores.

Meta-analysis of complications

The ten eligible studies that reported a total of 738 patients provided information on total surgical complications after one year follow-up. Results are presented in Fig. 2. The pooled result showed a reduced risk of surgical complications with IF in comparison with EF, which was statistically significant (95% CI 0.39–0.81, $P=0.002$).

Table 3 shows that for all surgical complications except for pin-track infection, there were no statistically significant differences between IF and EF ($P>0.05$). Eight trials reported the number of patients with pin-track infection. For IF, there were 4/337 patients with pin-track infection; for EF, there were 28/337 patients. IF substantially reduced the risk of pin-track infection (95%

CI 0.08–0.46, $P=0.0002$), as shown in Fig. 3. However, there was an increased risk of extensor pollicis longus rupture and superficial wound infection for IF compared with EF, although the result was not statistically significant ($P>0.05$).

Meta-analysis of radiological outcomes

Table 4 shows radiological outcomes comparing IF with EF at six weeks, three months and one year postoperatively. Meta-analysis showed that radial inclination (95% CI 0.08–4.52, $P=0.04$) and ulnar variance were superior for IF than for EF three months postoperatively. However, there were no significant differences between groups at six weeks and after one year.

Meta-analysis of clinical results

Figures 4 and 5 show forest plots of grip strength and DASH score at six weeks, three months and one year of follow-up;

Table 4 Radiological outcomes reported at 6 weeks, 3 months and 1 year follow-up

Time	Radiological results	Studies	Participants		WMD	95% CI	P Value
			IF	EF			
6 weeks	Radial length	1	12	22	1.10	(-1.22 to 3.42)	0.35
	Radial inclination	1	12	22	-1.30	(-5.65 to 3.05)	0.56
	Volar tilt	2	42	52	-3.38	(-17.88 to 11.12)	0.65
	Ulnar variance	1	12	22	-1.10	(-3.29 to 1.09)	0.32
3 months	Radial length	1	39	38	0.40	(-0.85 to 1.65)	0.53
	Radial inclination	1	39	38	2.30	(0.08 to 4.52)	0.04
	Volar tilt	1	39	38	1.10	(-2.05 to 4.45)	0.49
	Ulnar variance	1	39	38	-1.00	(-1.87 to -0.13)	0.02
1 year	Radial length	3	72	81	-0.57	(-0.83 to 0.43)	0.14
	Radial inclination	3	72	81	-1.39	(-3.44 to 0.65)	0.18
	Volar tilt	4	99	109	0.36	(-4.63 to 5.34)	0.89
	Ulnar variance	2	51	60	-0.86	(-1.82 to 0.10)	0.08

IF internal fixation, EF external fixation, WMD weighted mean difference, CI confidence interval

Fig. 4 Grip strength at 6 weeks, 3 months and 1-year follow-up

Fig. 5 Disabilities of the Arm, Shoulder and Hand (DASH) score 3 months and 1-year follow-up

other function recoveries are listed in Table 5. Grip strength (95% CI 1.59–8.25, $P=0.004$), supination (95% CI 13.99–48.83, $P=0.0004$), radial deviation (95% CI 4.08–11.57, $P<0.0001$), ulnar deviation (95% CI 5.71–16.89, $P<0.0001$) and pronation (95% CI 5.61–26.09, $P=0.002$) were superior in the IF group six weeks postoperatively, and similar results were obtained at three months for grip strength (95% CI 3.21–13.47, $P=0.001$), supination (95% CI 3.61–16.01, $P=0.002$) and pinch strength (95% CI 4.50–19.55, $P=0.002$). Meanwhile, the DASH score was superior in the IF group at three months (95% CI –20.62 to –2.07, $P=0.02$) and one year (95% CI –14.37 to –2.32, $P=0.007$).

Sensitivity analysis

Sensitivity analysis revealed that with low-quality (Jadad score <3) studies excluded, the summary OR, 95% CIs and P values for total complications and pin-track infections (as these were outcomes most studies included in the meta-analysis) were still similar to the results before they were excluded, as presented in Table 6, indicating that the results of our study are reliable and believable.

Publication bias analysis

Figure 6 shows the funnel plot based on studies with data on total complications (as this was the outcome that most studies included in their meta-analysis), which is symmetrical, and indicates that our study is not subject to this bias. Also Egger's test provides the same outcome ($P=0.8599$).

Discussion

Meta-analysis of RCTs is generally considered to provide the strongest evidence of clinical interventions [23] and has more advantages than observational research studies and single randomised trials. Observational research studies, regardless of the integrity and care with which they are conducted, are open to bias, and single randomised trials are often limited by relatively small sample sizes and resulting imprecision in the estimates of treatment effects. In our meta-analysis, we included the only ten eligible RCTs according to explicit inclusion criteria and believe our results to be valid. Nevertheless, there are limitations to meta-analysis. One is that of publication bias. Insofar as funnel plots could show, our study is not subject to this

Table 5 Other clinical results reported at 6 weeks, 3 months and 1-year follow-up

Time	Function	Studies	Participants		WMD	95% CI	P Value
			IF	EF			
6 weeks	Supination	2	35	44	31.41	(13.99–48.83)	0.0004
	Pronation	2	35	44	15.85	(5.61–26.09)	0.002
	Extension	3	65	74	16.93	(–6.19 to 40.05)	0.15
	Flexion	3	65	74	8.10	(–9.91 to 26.12)	0.38
	Radial deviation	2	35	44	7.82	(4.08–11.57)	$P<0.0001$
	Ulnar deviation	2	35	44	11.30	(5.71–16.89)	$P<0.0001$
	Pinch strength	2	35	44	10.27	(–1.50 to 22.04)	0.09
3 months	Supination	3	74	82	9.81	(3.61–16.01)	0.002
	Pronation	3	74	82	2.73	(–10.54 to 15.99)	0.69
	Extension	4	102	111	4.61	(–4.81 to 14.04)	0.34
	Flexion	4	102	111	–0.30	(–8.12 to 7.52)	0.94
	Radial deviation	3	74	82	12.38	(–8.66 to 33.43)	0.25
	Ulnar deviation	3	74	82	2.61	(–0.35 to 5.58)	0.08
	Pinch strength	2	35	44	12.03	(4.50 to 19.55)	0.002
1 year	Supination	4	96	103	5.30	(–2.92, 13.52)	0.21
	Pronation	4	96	103	9.78	(–0.68 to 20.24)	0.07
	Extension	4	99	109	–3.77	(–7.93 to 0.38)	0.08
	Flexion	4	99	109	–3.79	(–9.88 to 2.30)	0.22
	Radial deviation	3	72	81	0.76	(–5.61 to 7.12)	0.82
	Ulnar deviation	3	72	81	2.23	(–5.41 to 9.86)	0.57
	Pinch strength	2	33	44	0.29	(–5.26 to 5.83)	0.92

IF internal fixation, EF external fixation, WMD weighted mean difference, CI confidence interval

bias. Another issue is study heterogeneity, both in the nature of the studies themselves and in the statistical heterogeneity of individual RR. Various epidemiological studies have shown an increasing incidence of unstable distal radius fractures with age, starting at around 40 years, in women. A prospective survey [24] of patients aged ≥ 35 years with Colles' fracture at six centres in the UK for a period of one year reported the overall incidence of this fracture to be 9/10,000 in men and 37/10,000 in women. Therefore, although there may be effect modification due to mean age and proportion of women, we could not determine this from available data.

According to the best estimates from our meta-analysis, IF reduced the incidence of total surgical complications and pin-track infections after one year of follow-up. Pin-track infection in the IF group results from the use of adjunctive K wires to attain the best possible stabilisation [8]. Infections are often associated with open pin sites [14]. Pin loosening also was responsible for the higher risk of pin-track infection. The number of complications for the palmar locking-plate fixation ranged from 0% to 10% [25, 26]. Schmelzer-Schmied [27] also considered it was better than that of external fixation. However, the incidence of extensor pollicis longus rupture was higher after IF, possibly because the hardware lies in direct contact with the extensor tendons [28–30]. Dobretz [31] reported this complication in up to 12% of cases when using the palmar locking plate.

With regard to grip strength, we used a fixed-effects model in the meta-analysis. There was no significant heterogeneity between studies ($I^2 < 50\%$), as shown in Fig. 4. Our pooled results showed that grip strength, values of which are given as the percentage of the value for the uninjured side, was superior in the IF group at six weeks and three months postoperatively. For DASH score, the random-effects model was used, and significant heterogeneity existed ($I^2 > 50\%$), as shown in Fig. 5. DASH score was superior in the IF group at three months and one year follow-up. The better clinical results with IF in our study may be due to the higher rigidity of the fixation, which

Fig. 6 Funnel plot based on studies with data on total complications

enables faster rehabilitation. Regardless of the method of reduction and stabilisation, early restoration of wrist function is the goal of treatment for distal radius fractures [32].

Radiographic outcomes, the given values of which were compared with those for the contralateral extremity, may affect functional outcome [33, 34]. It is the surgeon's goal to restore the distal radius to its normal anatomical alignment and congruity. How accurately this is achieved can be measured from radiographs by comparing volar tilt angle, radial inclination etc. with published normal values [34–37]. In our study, radial inclination and ulnar variance were superior in the IF group three months postoperatively.

In summary, we suggest that the final results are significant and that there is some evidence supporting the use of ORIF, although not enough for use in most decisions necessary in managing distal radius fractures. Limitations remain, and results need to be further verified by more high-quality trials. For better results, we need to more carefully consider issues of long-term outcomes and intraoperative and preoperative factors and report them in a reliable, consistent and standardised manner.

Table 6 Sensitivity analysis

Excluded	Outcomes	Studies			
		No.	Patients	RR (95% CI)	P value
No studies excluded	Total complications	10	738	0.70(0.56,0.88)	0.002
	Pin-track infection	8	674	0.19(0.08,0.45)	0.0002
Exclude studies of low-quality(Jadad score <3)	Total complications	9	681	0.68(0.54,0.86)	0.001
	Pin-track infection	7	617	0.19(0.08,0.45)	0.0002

RR relative risk, CI confidence interval

References

- Kotnis R, Waites TD, Fayomi O, Dega R (2005) The use of a template to improve the management of distal radial fractures. *Emerg Med J* 22:544–547
- Xu GG, Chan SP, Puhaindran ME, Chew WY (2009) Prospective randomised study of intra-articular fractures of the distal radius: comparison between external fixation and plate fixation. *Ann Acad Med Singapore* 38:600–606
- Abramo A, Kopylov P, Geijer M, Tagil M (2009) Open reduction and internal fixation compared to closed reduction and external fixation in distal radius fractures: A randomized study of 50 patients. *Acta Orthop* 80:478–485
- Rozental TD, Blazar PE, Franko OI, Chacko AT, Earp BE, Day CS (2009) Functional outcomes for unstable distal fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation: a prospective randomized trial. *J Bone Joint Surg Am* 91:1837–1846
- Wei DH, Raizman NM, Bottino CJ, Jobin CM, Strauch RJ, Rosenwasser MP (2009) Unstable distal radial fractures treated with external fixation, a radial column plate, or a volar plate. A prospective randomized trial. *J Bone Joint Surg Am* 91:1568–1577
- Leung F, Tu Y, Chew WY, Chow SP (2008) Comparison of external and percutaneous pin fixation with plate fixation for intra-articular distal radius fractures: a randomized study. *J Bone Joint Am* 90:16–22
- Egol K, Walsh M, Tejwani N, McLaurin T, Wynn C, Paksima N (2008) Bridging external fixation and supplementary kirschner-wire fixation versus volar locked plating for unstable fractures of the distal radius: a randomized, prospective trial. *J Bone Joint Surg Br* 90:1214–1221
- Kreder HJ, Hanel DP, Agel J et al (2005) Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius. *J Bone Joint Surg Br* 87:829–836
- Grewal R, Perey B, Wilmsink M, Stothers K (2005) A randomized prospective study on the treatment of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating versus Mini open reduction, percutaneous fixation, and external fixation. *J Hand Surg Am* 30:764–772
- Kapoor H, Agarwal A, Dhaon BK (2000) Displaced intra-articular fractures of distal radius: a comparative evaluation of results following closed reduction, external fixation and open reduction with internal fixation. *Injury* 31:75–79
- McQueen MM, Hajducka C, Court-Brown CM (1996) Redisplaced unstable fractures of the distal radius: a prospective randomized comparison of four methods of treatment. *J Bone Joint Surg Br* 78:404–409
- Kateros K, Macheras G, Galanakis SP, Sofianos I, Papakostas I, Papadakis SA (2010) External fixation versus “T” plate for distal radius fractures. *J Trauma* 68:166–172
- Handoll HH, Madhok R (2009) WITHDRAWN: Surgical interventions for treating distal radial fractures in adults. *Cochrane Database Syst Rev* CD003209
- Margaliot Z, Haase SC, Kotsis SV, Kim HM, Chung KC (2005) A meta-analysis of outcomes of external fixation versus plate osteosynthesis for unstable distal radius fractures. *J Hand Surg Am* 30:1185–1199
- Paksima N, Panchal A, Posner MA, Green SM, Mehlman CT, Hiebert R (2004) A Meta-analysis of the literature on distal radius fractures: review of 615 articles. *Bull Hosp Jt Dis* 62:40–46
- Higgins J, Green S (2006) *Cochrane handbook for systematic reviews of interventions* 4.2.6. In the Cochrane library Wiley: Chichester 301. (Updated September 2006)
- Moher D, Cook DJ, Eastwood S, Olkin I, Rennie D, Stroup DF (1999) Improving the quality of reports of Meta-analyses of randomized controlled trials: the QUOROM statement. Quality of Reporting of Meta-analyses. *Lancet* 354:1896–1900
- Liberati A, Altman DG, Tetzlaff J et al (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Ann Intern Med* 18:151–154
- Higgins JP, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analysis. *BMJ* 327:557–560
- Oremus M, Wolfson C, Perrault A, Demers L, Momoli F, Moride Y (2001) Interrater reliability of the modified Jadad quality scale for systematic reviews of Alzheimer’s disease drug trials. *Dement Geriatr Cogn Disord* 12:232–236
- Breierova L, Choudhary M (1996) An introduction to sensitivity analysis. *MIT Pr* 41–107
- Egger M, Davey SG, Altman DG (2001) *Systematic reviews in health care: Meta-analysis in context*. BMJ books, London
- Greenhalgh T (2001) *How to read a paper*. BMJ Books, The basics of evidence based medicine. London
- O’Neill TW, Cooper C, Finn JD et al (2001) Incidence of distal forearm fracture in British men and women. *Osteoporosis International* 12:555–558
- Sakhaii M, Groenewold U, Klönz A, Reilmann H (2003) Results after palmar plate-osteosynthesis with angularly stable T-plate in 100 distal radius fractures: a prospective study. *Unfallchirurg* 106:272–280
- Thielke KH, Wagner T, Bartsch S, Echtermeyer V (2003) Angularly stable radius plate: progress in treatment of problematic distal radius fracture? *Chirurg* 74:1057–1063
- Schmelzer-Schmied N, Widloch P, Martini AK, Daecke W (2009) Comparison of external fixation, locking and non-locking palmar plating for unstable distal radius fractures in the elderly. *Int Orthop* 33:773–778
- Axelrod TS, McMurtry RY (1996) Open reduction and internal fixation of comminuted, intraarticular fractures of the distal radius. *J Hand Surg Am* 15:1–11
- Kambouroglou GK, Axelrod TS (1998) Complications of the AO/ASIF Titanium distal radius plate system (pi plate) in internal fixation of the distal radius: a brief report. *J Bone Surg Am* 23:737–741
- Orbay JL, Fernandez DL (2002) Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. *J Hand Surg Am* 27:205–215
- Dobretz H, Kutscha-Lissberg E (2003) Osteosynthesis of distal radial fractures with a volar locking screw plate system. *Int Orthop* 27:1–6
- Trumble TE, Schmitt SR, Vedder NB (1995) Factors affecting functional outcome of displaced intra-articular distal radius fractures. *J hand Surg Am* 19:325–340
- Anderson DD, Bell AL, Gaffney MB, Imbriglia JE (1996) Contact stress distributions in malreduced intra-articular distal radius fractures. *J Orthop Trauma* 10:331–337
- Knirk JL, Jupiter JB (1986) Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am* 68:647–659
- Kreder HJ, Hanel DP, McKee M, Jupiter J, McGilivray G, Swiontkowski MF (1996) X-ray film measurements for healed distal radius fractures. *J Hand Surg Am* 21:31–39
- Schuidt F, Alemzadeh S, Stallenberg B, Burny F (1996) Does the normal contralateral wrist provide the best reference for X-ray film measurements of the pathologic wrist? *J Hand Surg Am* 21:24–30
- van der Linden W, Ericson R (1981) Colles’ fracture. How should its displacement be measured and how should it be immobilized? *J Bone Surg Am* 63:1285–1288