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Review Article

Intramedullary Fixation Versus Plate Fixation of Distal Fibular Fractures: A Systematic Review and Meta-Analysis of Randomized Controlled Trials and Observational Studies

David B. Tas, BSc[1], Diederik P.J. Smeeing, MD, PhD[2,3], Benjamin L. Emmink, MD, PhD[2], Geertje A.M. Govaert, MD, FEBS[4], Falco Hietbrink, MD, PhD[4], Luke P.H. Leenen, MD, PhD[1], Roderick M. Houwert, MD, PhD[4,6]

[1] *Medical Student, Department of Trauma Surgery, University Medical Center Utrecht, Utrecht, The Netherlands*
[2] *Surgical Resident, Department of Trauma Surgery, University Medical Center Utrecht, Utrecht, The Netherlands*
[3] *Surgical Resident, Department of Trauma Surgery, Antonius Hospital Utrecht, Utrecht, The Netherlands*
[4] *Trauma Surgeon, Department of Trauma Surgery, University Medical Center Utrecht, Utrecht, The Netherlands*
[5] *Professor of Trauma, Department of Trauma Surgery, University Medical Center Utrecht, Utrecht, The Netherlands*
[6] *Trauma Surgeon, Utrecht Traumacenter, Utrecht, The Netherlands*

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ABSTRACT

Intramedullary fixation (IMF) has been described as a minimally invasive alternative to open reduction and internal fixation for operative treatment of distal fibular fractures in case of compromised soft tissue or severe comorbidities. The objective was to compare postoperative complications and functional outcomes of intramedullary versus plate fixation (PF) in distal fibular fractures. A systematic review and meta-analysis was performed. The PubMed/MEDLINE, Embase, Cochrane, and CINAHL databases were searched for both randomized controlled trials and observational studies. A total of 26 studies was included, reporting on 1710 patients with a mean age of 51.6 years. Meta-analysis was performed on 8 comparative studies, including subgroup and sensitivity analyses on all outcomes. IMF was associated with significantly fewer wound related complications (odds ratio [OR], 0.11; 95% confidence interval [CI], 0.04 to 0.25; $p < .01$), implant removals (OR, 0.54; 95% CI, 0.31 to 0.93; $p = .03$), and nonunions (OR, 0.31; 95% CI, 0.15 to 0.62; $p < .01$). No differences were found regarding malunion (OR, 0.45; 95% CI, 0.17 to 1.21; $p = .11$) and the Olerud Molander Ankle Score for long-term functional outcome (mean difference, 9.56; 95% CI, 1.24 to 20.37; $p = .08$). Results of this study apply to a select group of patients, in which the advantages of minimal soft tissue damage by IMF are preferable to optimal fracture reduction by PF. IMF of distal fibular fractures resulted in fewer wound-related complications, implant removals, and nonunions compared with PF. Especially in elderly patients, patients with chronic comorbidity, and patients with compromised soft tissue, IMF may be preferred over PF.

Ankle fractures are the most common type of fracture in the lower extremity, with an incidence varying from 100 to 180 fractures per 100,000 people each year in Europe and United States (1–4). The current standard for operative treatment of unstable distal fibular fractures is open reduction and internal fixation using a fibular plate. However, plate fixation (PF) is associated with a considerable risk of postoperative complications such as wound infection and implant failure (5,6). These complications may prolong hospital stay, increase costs, and even lead to death and are of special consideration in the elderly and in patients with chronic comorbidity.

Intramedullary fixation (IMF) has been described as a minimally invasive alternative to PF in cases where surgical fixation is deemed necessary but where large incisions may be undesirable owing to poor skin or soft tissue quality. In this selective group of patients, IMF has been proposed to reduce wound-related complications while maintaining functional outcome, although some concessions might be necessary to reduce anatomic fracture (7). This surgical technique avoids large incisions and extensive soft tissue dissection by using either intramedullary nails or compression screws, potentially resulting in a reduced risk of wound infection compared with PF (8). In addition, the low-profile intramedullary implants are supposed to cause fewer symptoms of metalwork prominence, which may reduce implant removal (9).

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Address correspondence to: David B. Tas, BSc, Department of Trauma Surgery, University Medical Center Utrecht, PO Box 85500, 3508 GA Utrecht, The Netherlands.
E-mail address: davidbtas@gmail.com (DavidB Tas).

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However, PF provides superior anatomic reconstruction of the fibular fracture.

There is a paucity of literature comparing IMF and PF in distal fibular fractures. Three previously published systematic reviews suggested that the effectiveness and safety of IMF are comparable to PF, with less wound infection and implant failure (7,9,10). Nevertheless, none of them could provide a definitive recommendation for implementation of IMF. Multiple comparative studies have been published since the publication of the reviews mentioned previously, allowing meta-analysis of a higher number of studies reporting on newer-generation IMF devices.

The aim of this systematic review and meta-analysis is to compare postoperative complications and functional outcomes of IMF versus PF for distal fibular fractures in skeletally mature patients.

Patients and Methods

A protocol for this systematic review has not been published. No institutional review board ethical approval was necessary for this review.

Search Strategy and Selection Criteria

This study was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (11). Randomized controlled trials (RCT) and both prospective and retrospective observational studies reporting on IMF of distal fibular fractures were included. Two reviewers (D.T. and D.S.) independently conducted a search in PubMed/MEDLINE, Embase, CINAHL, and the Cochrane Library using the same search strategy. The last search was conducted on June 16, 2018. The search strategy was jointly created by 2 reviewers (D.T. and D.S.) and was checked by a clinical librarian. The created search syntax is provided in Appendix 1. The inclusion criteria were both comparative and noncomparative studies written in English, German, or French, reporting on IMF of all variants of distal fibular fractures, including Weber A, B, or C fractures, in skeletally mature patients (12). German- and French-language articles were included because the reviewers had a professional working proficiency in these languages. Excluded were studies involving fixation of associated tibial shaft fractures, augmented osteosynthesis with additional fibular PF, fixation by Kirschner wires, studies solely including Weber A fractures, reviews, biomechanical studies, surgical technique studies, case reports (n = 5), study protocols, letters, and studies on animals or cadavers. No minimum follow-up time, publication date, or other restrictions were applied on the search. All articles were screened by title and abstract, followed by full-text assessment for eligibility by both reviewers. Reference screening and citation tracking of the included articles and prior systematic reviews were performed. Eligibility disagreement was resolved by discussion with a third independent reviewer (R.H.).

Quality Assessment

Two reviewers (D.T. and D.S.) independently assessed the methodologic quality of all included studies using the Methodological Index for Non-Randomized Studies (MINORS) (13). The MINORS is a validated instrument for assessment of the methodological quality of both RCTs and observational studies. High study quality is associated with a high MINORS score, ranging from 0 to 24 for comparative studies and 0 to 16 for noncomparative studies. For this review, the criteria used in the MINORS quality scoring system were further specified based on the study objective (Appendix 2). Disagreement in critical appraisal was resolved by discussion with a third independent reviewer (R.H.).

Data Extraction

The following data were extracted by 1 reviewer (D.T.): first author, year of publication, country of study origin, study design, fracture type, treatment groups with type of plate or IMF material used, surgical technique used, sex and mean age of patient population, and length of follow-up. Additionally, all outcomes examined in this review, including range, standard deviation (SD), confidence interval (CI), and p values, were extracted. A second reviewer (D.S.) independently checked the extracted data.

No clear definition of minimally invasive surgical technique was found in the literature, although a skin incision of 1 to 2 cm was suggested as necessary for IMF (14). Therefore, the definition used in this study was closed reduction and internal fixation by a skin incision of 2 cm maximum length, which was assessed by the reviewers. Classification of fracture type was used as described in the methods section of the included articles.

Outcome Measures

Postoperative complications in this study were (1) wound healing disorders (any deviation in the postoperative course not requiring pharmacological or surgical intervention), (2) superficial wound infection (requiring oral antibiotic treatment), (3) deep wound infection (requiring wound debridement or implant removal), (4) implant removal (requiring elective reoperation without the indication of implant failure or signs of infection), (5) nonunion (radiographically confirmed unsuccessful bone healing after 6 months), (6) malunion (radiographically confirmed nonanatomic bone healing that caused symptoms), and (7) osteoarthritis (radiographically confirmed joint space narrowing, sclerosis, or osteophyte formation that caused symptoms).

The primary outcome measure was wound-related complications, including all wound healing disorders, and superficial and deep wound infections. Secondary outcome measures were implant removal, nonunion, malunion, osteoarthritis, and functional outcome with the Olerud Molander Ankle Score (OMAS) used in both the short term ($<$1 year) and long term ($\geq$1 year) (15). The results of other functional scores than the OMAS were also evaluated in a systematic review.

Statistical Analysis

Cochrane Review Manager software (RevMan, version 5.3.5; Cochrane, Copenhagen, Denmark) was used for data management and statistical analysis (16). When means, percentages, or SDs were not described, these were calculated from primary data provided in the article or appendices if possible. Meta-analysis was performed on outcomes reported by $\geq$2 studies that compared the 2 surgeries. Studies with zero events in both arms were excluded from meta-analysis. A narrative review was performed of studies reporting on outcomes that could not be pooled for meta-analysis.

Effect estimates were odds ratios (ORs) for dichotomous outcomes, and mean differences (MD) for continuous outcomes. A 95% CI was generated for all analyses, with the Mantel-Haenszel method used for dichotomous outcomes and the inverse variance method for continuous outcomes. A p value $<$.05 was deemed statistically significant in the overall effect Z test.

Heterogeneity was calculated using measures for quantifying inconsistency: T^2, I^2, and χ^2 testing, including the p value. A χ^2 with $p < .1$ or $I^2 >$25% was considered statistically significant heterogeneity (17). The random-effects model was used in meta-analyses of all outcomes, irrespective of heterogeneity.

After the primary analyses, subgroup analyses were performed for the effects of study design (both observational studies and RCTs) on all outcomes that were included for meta-analysis. In addition, sensitivity analyses were performed for the effects of study quality, mean age of patient population, and date of publication. In these sensitivity analyses, only the results of high-quality studies, studies with a mean age $>$65 years, and studies published after the year 2000 were used, respectively. In accordance to prior studies, MINORS scores $>$16 were arbitrarily considered as high quality (18,19).

Results

Search

The electronic searches identified a total of 6675 articles. After duplicate removal, 4403 articles were screened by title and abstract. Of the 30 articles that were selected for full-text assessment, 4 articles without distal fibular fracture (20–23) and 1 article reporting on IMF with additional PF of the distal fibula (24) were excluded. Reference screening and citation tracking resulted in 1 additional study (25). Ultimately, a total of 26 studies concerning all variants of distal fibular fractures was included in this systematic review (8,14,25–48), of which 8 were comparative studies (8,29,32,35,36,40,41,44). A flowchart summarizing the selection procedure of the included articles and reasons for exclusion is shown in Fig. 1.

Two studies by McLennan and Ungersma (34,35) possibly reported on the same patient cohort. Therefore, this particular cohort was only included in the article comparing IMF and PF (35).

Baseline Characteristics

Of the 26 included studies, 4 were RCTs (8,36,41,44), 4 were prospective cohort studies (27,34,35,42), and 18 were retrospective cohort studies (14,25,26,28–33,37–40,43,45–48). All included studies were written in English, except 1 article written in German (26). The included studies reported on a total of 1710 patients, with a mean age of 51.6 years and the majority being female (56.0%). The mean age of patient populations differed between studies published before and after the year 2000 (43.7 and 53.8 years, respectively). In total, 1085 patients were treated with intramedullary nails, 265 patients were treated with intramedullary screws, and 360 patients were treated with

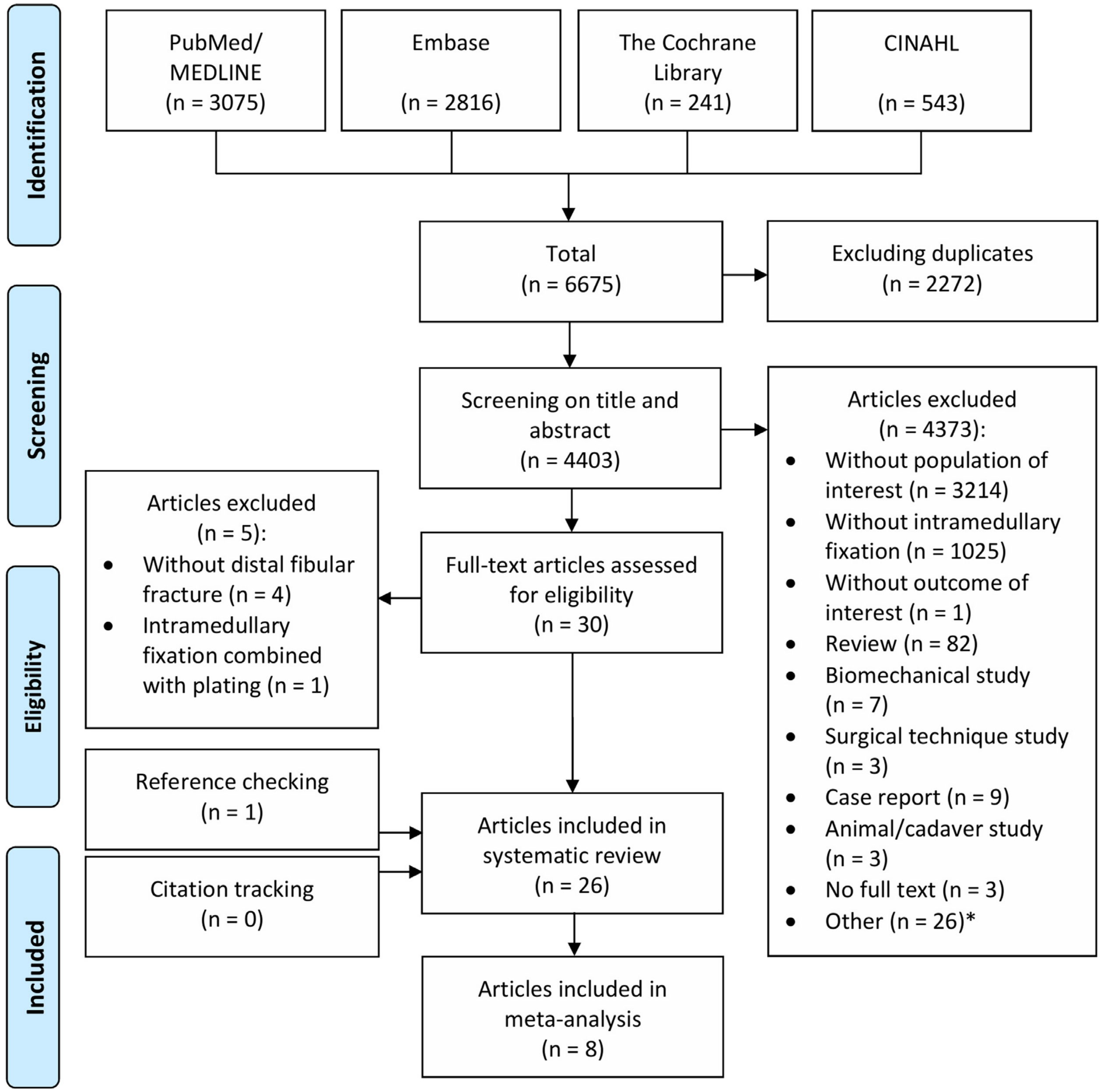

Fig. 1. Flowchart of the articles included in a systematic review of distal fibular fractures comparing intramedullary fixation and plate fixation. The *asterisk* indicates other languages, study protocols, errata, corrigenda, commentaries, letters, and opinions.

conventional PF. Eight different types of nails and 6 different types of screws were used. Most patients were included in the noncomparative studies (18 studies, patients n = 1007, mean age 52.2 years, percentage of females 58.7%), compared with the comparative studies (8 studies, patients n = 703, mean age 50.9 years, percentage of females 51.2%). The baseline characteristics of the included studies are presented in Table 1. The inclusion and exclusion criteria of all 8 comparative studies are provided in Appendix 3.

Quality Assessment

The quality scores of the included studies assigned during critical appraisal are listed in Appendix 4. The mean MINORS score of all studies was 9.5 ± 4.8 (range 4 to 20). The comparative studies had a mean score of 15.0 ± 4.8 (range 5 to 20), whereas this was 7.0 ± 1.9 (range 4 to 9) for noncomparative studies. Furthermore, the mean quality scores were 16.5 ± 4.0 (range 11 to 20) for RCTs, and 8.2 ± 3.8 (range 4 to 17) for observational studies.

Wound-Related Complications

All included studies except 1 (96%) reported wound-related complications, showing mean percentages of 1.7% (range 0% to 25%) of patients for IMF and 15.1% (range 5.3% to 28.1%) of patients for PF (Appendix 5) (28). Based on all 8 comparative studies, wound-related complications

Table 1
Baseline characteristics of all included studies in a systematic review of distal fibular fractures comparing intramedullary fixation and plate fixation (N = 26)

First Author	Year	Country of Study Origin	Study Design	Fracture Type	Groups	Implant Type (with surgical technique used)	Included Patients (n)	Sex (M:F)	Age (mean, years) (± SD)	Follow-Up (months)
Appleton (42)	2006	UK	PC	44-B/C	Nail (locked)	Acumed nail (MI)	37	8:29	67 (range 42 to 93)	13 (range 7 to 0)
Ashman (43)	2016	Canada & UK	RC	44-B/C	Nail (locked)	Acumed nail (MI)	24	6:18	67 (range 36 to 87)	12 (range 7 to 38)
Asloum (44)	2014	France	RCT	Lauge Hansen SE/PE	Nail (locked)	Epifisa nail (NR)	29	16:13	54.8 (range 22 to 81) (± 17.9)	12
					Plate	Synthes plate (ORIF)	42	21:21	52.2 (range 18 to 90) (± 20.5)	
Bankston (45)	1994	USA	RC	44-B/C	Screw	Woodruff screw (ORIF)	44	19:25	39.5 (range 16 to 93) (± 16.3)	7
Bugler (46)	2012	UK	RC	NR	Nail (locked)	Acumed nail (MI)	105	19:86	64.8 (range 22 to 95)	NR
Challagundla (47)	2017	UK	RC	Lauge Hansen SA/SE/PE	Nail (locked)	Acumed nail (NR)	15	3:12	74 (range 61 to 90)	12 (range 8 to 25)
Coifman (48)	2017	Israel	RC	44-B/C	Nail (locked)	Acumed nail (MI)	39	19:20	50 (range 18 to 97)	10 (range 2 to 35)
Ebraheim (40)	2018	USA	RC	44-B/C	Screw	Cannulated screw (MI)	44	59:51	49.3 (range 15 to 94) (± 18)	6
					Plate	Plate NFS (ORIF)	66			
Förch (26)	2017	Germany	RC	44-B/C	Nail (locked)	Acumed nail (MI)	18	6:12	78	6
Gehr (27)	2004	Germany	PC	44-B/C	Nail (locked)	XS nail (ORIF)	194	78:116	51.2 (range 14 to 91)	15
Kara (28)	1999	Turkey	RC	44-B/C	Nail (locked)	ANK nail (ORIF)	128	72:56	range 19 to 70	37 (range 12 to 84)
Latif (25)	2013	UAE	RC	44-B/C	Screw	Synthes steel screw (MI)	46	30:16	39.5 (range 18 to 67)	15
Lee 2009 (29)	2009	Taiwan	RC	44-B2	Nail (unlocked)	Knowles pin (ORIF)	25	15:10	40.1	29 (range 12 to 63)
					Plate	Tubular plate (ORIF)	22	16:6	36.9	
Lee 2010 (30)	2010	Taiwan	RC	44-B2	Screw	Acutrak plus compression screw (ORIF)	23	13:10	37.4	12 (range 10 to 15)
Lee 2005 (31)	2005	Taiwan	RC	44-A1/B1/B2/C1	Nail (unlocked)	Knowles pin (ORIF)	168	89:79	44 (range 18 to 87)	37 (range 32 to 84)
Lee 2007 (32)	2007	Taiwan	RC	44-B2	Nail (unlocked)	Knowles pin (ORIF)	45	20:25	62.7	35 (range 12 to 80)
					Plate	Tubular plate (ORIF)	30	12:18	60.0	33 (range 12 to 77)
Li (41)	2018	China	RCT	44-A/B/C	Screw	Cannulated screw (NR)	50	30:20	36.4 (± 3.9)	12
					Plate	NR (ORIF)	50	35:15	34.0 (± 2.6)	
Loukachov (33)	2017	The Netherlands	RC	44-B2/B3	Screw	Synthes titanium screw (MI)	11	6:5	59 (range 23 to 83) (± 19.3)	12 (minimum)
McLennan 1988 (34)	1988	USA	PC	Lauge Hansen SA/SE/PE	Nail (unlocked)	Inyo nail (ORIF)	75	27:48	42	24 (minimum)
McLennan 1986 (35)	1986	USA	PC	Lauge Hansen SA/SE/PE	Nail (unlocked)	Inyo nail (ORIF)	75	NR	37	NR
					Plate	Plate NFS (ORIF)	75	NR	37	
Pritchett (36)	1993	USA	RCT	Lauge Hansen SE	Nail (unlocked)	Rush rod (NR)	25	10:15	74 (range 65 to 84)	36 (range 24 to 72)
					Plate	Plate NFS (NR)	25	11:14	73 (range 65 to 83)	34 (range 26 to 74)
Rajeev (14)	2011	UK	RC	NR	Nail (locked)	SST nail (MI)	24	2:22	79 (range 71 to 91)	7
Ramasamy (37)	2001	UK	RC	44-B2/B3	Nail (locked)	SST nail (MI)	9	2:7	67.2 (range 50 to 79) (± 10.1)	26 (range 6 to 51)
Ray (38)	1994	USA	RC	44-B/C	Screw	Woodruff screw (MI)	24	13:11	37 (range 15 to 78) (± 17.3)	12 (range 0 to 28)
Smith (39)	2017	UK	RC	NR	Screw	Cancellous screw (MI)	23	4:19	70 (range 29 to 89)	42 (range 8 to 110)
White (8)	2016	UK	RCT	NR	Nail (locked)	Acumed nail (MI)	50	14:36	74 (range 65 to 88)	12
					Plate	Tubular plate (ORIF)	50	11:39	74 (range 65 to 93)	

Abbreviations: MI, minimally invasive; NFS, not further specified; NR, not reported; ORIF, open reduction and internal fixation; PE, pronation external rotation; PC, prospective cohort study; RC, retrospective cohort study; RCT, randomized controlled trial; SA, supination adduction; SD, standard deviation; SE, supination external rotation; UAE, United Arab Emirates; UK, United Kingdom; USA, United States of America.

Study or Subgroup	IMF Events	IMF Total	plate Events	plate Total	Weight	Odds Ratio M-H, Random, 95% CI
1.1.1 Wound healing disorders						
Asloum et al. 2014	0	28	9	32	9.0%	0.04 [0.00, 0.79]
Lee et al. 2007	0	45	1	30	7.2%	0.22 [0.01, 5.49]
Lee et al. 2009	0	25	2	22	7.9%	0.16 [0.01, 3.54]
Subtotal (95% CI)		**98**		**84**	**24.1%**	**0.11 [0.02, 0.63]**
Total events	0		12			
Heterogeneity: Tau² = 0.00; Chi² = 0.66, df = 2 (P = 0.72); I² = 0%						
Test for overall effect: Z = 2.47 (P = 0.01)						
1.1.2 Superficial wound infection						
Lee et al. 2007	0	45	2	30	8.0%	0.13 [0.01, 2.70]
Lee et al. 2009	0	25	2	22	7.9%	0.16 [0.01, 3.54]
Pritchett et al. 1993	0	25	0	25		Not estimable
White et al. 2016	0	50	8	50	9.1%	0.05 [0.00, 0.88]
Subtotal (95% CI)		**145**		**127**	**25.0%**	**0.10 [0.02, 0.55]**
Total events	0		12			
Heterogeneity: Tau² = 0.00; Chi² = 0.36, df = 2 (P = 0.84); I² = 0%						
Test for overall effect: Z = 2.63 (P = 0.008)						
1.1.3 Deep wound infection						
Lee et al. 2007	0	45	0	30		Not estimable
Lee et al. 2009	0	25	0	22		Not estimable
Pritchett et al. 1993	0	25	2	25	7.9%	0.18 [0.01, 4.04]
White et al. 2016	0	50	2	50	8.0%	0.19 [0.01, 4.10]
Subtotal (95% CI)		**145**		**127**	**15.9%**	**0.19 [0.02, 1.66]**
Total events	0		4			
Heterogeneity: Tau² = 0.00; Chi² = 0.00, df = 1 (P = 0.99); I² = 0%						
Test for overall effect: Z = 1.51 (P = 0.13)						
1.1.4 Wound infection not further specified						
Ebraheim et al. 2018	1	44	18	66	17.8%	0.06 [0.01, 0.48]
Li et al. 2018	0	50	3	50	8.4%	0.13 [0.01, 2.67]
McLennan et al. 1986	0	75	4	75	8.7%	0.11 [0.01, 1.99]
Subtotal (95% CI)		**169**		**191**	**35.0%**	**0.09 [0.02, 0.37]**
Total events	1		25			
Heterogeneity: Tau² = 0.00; Chi² = 0.20, df = 2 (P = 0.90); I² = 0%						
Test for overall effect: Z = 3.29 (P = 0.001)						
Total (95% CI)		**557**		**529**	**100.0%**	**0.11 [0.04, 0.25]**
Total events	1		53			
Heterogeneity: Tau² = 0.00; Chi² = 1.58, df = 10 (P = 1.00); I² = 0%						
Test for overall effect: Z = 5.07 (P < 0.00001)						
Test for subgroup differences: Chi² = 0.36, df = 3 (P = 0.95), I² = 0%						

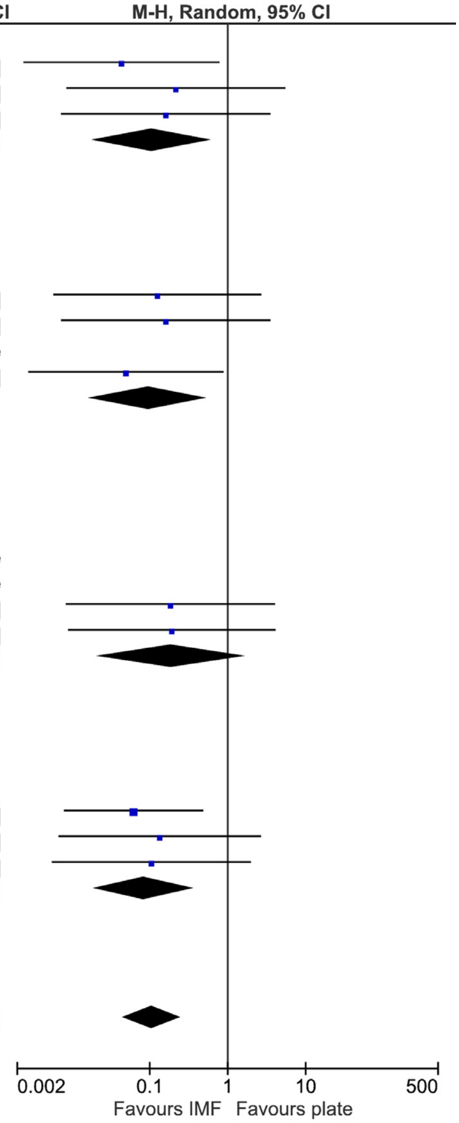

Fig. 2. Wound-related complications in a systematic review of distal fibular fractures comparing intramedullary fixation and plate fixation. IMF, intramedullary fixation.

occurred significantly less after IMF compared with PF, with an OR of 0.11 (95% CI, 0.04 to 0.25; $p < .01$) (Fig. 2).

Wound healing disorders occurred significantly less after IMF (1.7%) compared with PF (14.3%), with an OR of 0.11 (95% CI, 0.02 to 0.63; $p = 0.01$). Superficial wound infection was observed in 1.0% of patients after IMF and in 9.4% of patients after PF. This difference favoring IMF was statistically significant (OR, 0.10; 95% CI, 0.02 to 0.55; $p < .01$). The mean percentages of patients with deep wound infection did not significantly differ between IMF and PF (OR, 0.19; 95% CI, 0.02 to 1.66; $p = .13$), being 0.3% and 3.1%, respectively.

Implant Removal

Nineteen studies (73%) reported on elective implant removal (8,25,28–32,34–36,38–40,42,43,45–48). The mean percentage of patients with implant removal was 24.2% (range 0% to 88%) for IMF and 34.7% (range 12% to 95.5%) for PF. Based on 6 comparative studies, IMF resulted in significantly less elective implant removal compared with PF, with an OR of 0.54 (95% CI, 0.31 to 0.93; $p = .03$) (Appendix 6) (8,29,32,35,36,40).

Nonunion

Twenty (77%) studies described the number of nonunions (14,25,26,29–36,38–41,44–48). The mean percentages of patients with nonunion after IMF and PF were 1.7% (range 0% to 20.5%) and 13.7% (range 0% to 39.4%), respectively. Statistical analysis showed a significant difference favoring IMF (OR, 0.31; 95% CI, 0.15-0.62; $p < .01$) (Appendix 7).

Malunion

Three comparative studies reported on malunion, showing comparable results between IMF and PF (OR, 0.45; 95% CI, 0.17-1.21; $p = 0.11$)

Table 2
Subgroup and sensitivity analyses on study design, quality, mean age, and publication date in a systematic review of distal fibular fractures comparing intramedullary fixation and plate fixation

Outcomes	Results Primary Analysis	Subgroup Analysis Observational	RCT	Sensitivity Analyses Study Quality	Mean Age	Date of Publication
Wound-related complications*	0.11 (0.04 to 0.25)	0.11 (0.04 to 0.35)	0.10 (0.03 to 0.37)	0.10 (0.03 to 0.37)	0.12 (0.02 to 0.66)	0.10 (0.04 to 0.26)
Wound healing disorders*	0.11 (0.02 to 0.63)	0.19 (0.02 to 1.73)	0.04 (0.00 to 0.79)†	0.08 (0.01 to 0.66)	‡	0.11 (0.02 to 0.63)
Superficial infection*	0.10 (0.02 to 0.55)	0.14 (0.02 to 1.25)	0.05 (0.00 to 0.88)†	0.09 (0.01 to 0.70)	0.05 (0.00 to 0.88)†	0.10 (0.02 to 0.55)
Deep infection*	0.19 (0.02 to 1.66)	‡	0.19 (0.02 to 1.66)	0.19 (0.01 to 4.10)†	0.19 (0.02 to 1.66)	0.19 (0.01 to 4.10)
Implant removal*	0.54 (0.31 to 0.93)	0.47 (0.22 to 1.02)	0.78 (0.29 to 2.09)	0.67 (0.22 to 2.04)	0.78 (0.29 to 2.09)	0.75 (0.43 to 1.30)
Nonunion*	0.31 (0.15 to 0.62)	0.37 (0.16 to 0.88)	0.19 (0.05 to 0.70)	0.21 (0.01 to 4.65)†	0.18 (0.01 to 4.04)†	0.32 (0.15 to 0.69)
Malunion*	0.45 (0.17 to 1.21)	0.42 (0.14 to 1.26)†	0.62 (0.07 to 5.13)	1.00 (0.06 to 16.44)†	0.62 (0.07 to 5.13)	1.00 (0.06 to 16.44)†
Long-term OMAS§	9.56 (−1.24 to 20.37)	‡	9.56 (−1.24 to 20.37)	9.56 (−1.24 to 20.37)	3.60 (−4.15 to 11.35)†	9.56 (−1.24 to 20.37)

Abbreviations: OMAS, Olerud Molander Ankle Score; RCT, randomized controlled trial.
* Effect estimates are odds ratios (95% confidence interval)
† Analysis based on 1 comparative study.
‡ Analysis not performed because there was <1 comparative study in the subgroup.
§ Effect estimates are mean differences (95% confidence interval).

(Appendix 8) (8,35,36). Malunion was observed in 3.6% (range 0% to 6.7%) of patients after IMF and in 8.7% (range 2% to 14.7%) of patients after PF.

Osteoarthritis

Five (19%) studies reported on osteoarthritis (28,29,31,35,37). The mean percentages of patients with osteoarthritis after IMF and PF were 3.7% (range 0% to 22.2%) and 11.3% (range 0% to 14.7%), respectively. Only 2 comparative studies described osteoarthritis, of which 1 study had no events in both patient groups, not allowing meta-analysis (29,35).

Functional Scores

Only 1 study described short-term OMAS with comparable scores for IMF (58.8) and PF (57.5), not allowing meta-analysis (8).

Six studies (23%) reported on long-term OMAS, of which 2 were comparative studies (8,14,42,44,46). The mean long-term OMAS were 71.7 for IMF and 70.8 for PF. Statistical analysis showed no significant differences in long-term OMAS between IMF and PF (MD, 9.56; 95% CI, −1.24 to 20.37; $p = 0.08$) (Appendix 9). Six comparative studies described long-term outcomes with other functional scoring systems, with all favoring IMF (Appendix 5) (29,32,36,41,44).

Subgroup and Sensitivity Analyses

Subgroup analysis using only the results of observational studies showed that differences in wound healing disorders, superficial infection, and implant removal became insignificant (Table 2). Similarly, the results of implant removal were no longer significant after subgroup analysis using only RCTs. After sensitivity analysis, differences in implant removal and nonunion became insignificant for high-quality studies, whereas implant removal only was no longer significant for recently published studies. In addition, differences in implant removal and nonunion became insignificant using only the results of high-quality studies. Results for all other outcomes remained unchanged.

Discussion

This systematic review and meta-analysis including both RCTs and observational studies focused on the surgical techniques for stabilization of distal fibular fractures. Results of this study showed that the average age of patients included in meta-analysis was 50.9 years and demonstrated fewer wound-related complications, implant removals, and nonunions after IMF compared with PF.

These results indicate that the use of IMF is a solid alternative for PF. However, results of this meta-analysis apply to a select group of patients. Based on the literature describing the IMF technique, there are specific indications concerning fibular fractures that suggest either IMF or PF for surgical treatment. Because PF provides optimal anatomic reconstruction by compression of the fibular fracture, this technique is currently favored in most patients, especially the young athletics. However, IMF may be preferred over PF in elderly patients (32,36). PF can be difficult in osteoporotic fractures and is associated with a complication rate of up to 40% in patients >65 years old (49). In addition, IMF may be superior in patients with chronic comorbidity, such as diabetes, neuropathy, and peripheral vascular disease because these patient populations are more prone to wound complications (50). Because IMF avoids large skin incisions and extensive soft tissue dissection, this technique is superior to PF in fractures in elderly patients, as well as in patients with chronic comorbidity or compromised soft tissue. For every patient, the optimal surgical technique for fibular fracture fixation should be determined on the basis of patient-specific factors, considering the advantages of minimal wound-related complications by IMF and optimal fracture reduction by PF.

Skin incision length necessary for IMF ranges from 1 to 2 cm, whereas PF demands a minimum of 8 cm (14,32). Although the small incisions used in IMF may be disadvantageous in soft tissue interposition, this potentially reduces wound-related complications. Of all comparative studies reporting on wound infection, only White et al (8) and Ebraheim et al (40) described the use of a minimally invasive surgical technique. As a potential result, these studies showed the highest difference in wound infection favoring IMF. This corroborates the hypothesis that the minimal incisional soft tissue damage in IMF causes the lower associated risk of wound infection compared with that in PF.

The advantages of IMF were also described in previous studies. A systematic review performed by Jain et al (7) included 17 studies consisting of 1008 patients, in which excellent union rates and satisfactory functional outcome after IMF were observed. They observed a relatively high mean complication rate of 10.3% after IMF, which was explained as a result of a learning curve. However, these results of IMF could not be compared with PF because of a lack of comparative studies, solely allowing a narrative review. Another systematic review by Jordan et al (10) showed similar results for IMF based on 2 comparative and 8 noncomparative studies included in 2015. Contrarily, our study was able to include 26 studies by searching 4 databases in 2018, allowing meta-analysis of more-recent studies reporting on newer-generation IMF devices.

In addition, a systematic review and meta-analysis by Rehman et al (9) included 4 studies reporting on 375 fibular fractures, showing significantly less wound infection and implant removal after IMF. These results were similar to our study. In contrast to the prior study by Rehman et al (9), this systematic review and meta-analysis included 26 studies, of which 4 are recently published comparative studies (8,40,41,44). In addition, in contrast to Rehman et al (9), wound healing disorders were evaluated and both subgroup and sensitivity analyses were performed.

Although more comparable studies were available for inclusion compared with previous systematic reviews, the results of locked and unlocked nailing were not separately described in this study because of the small number of studies on this subject. Another review suggested that interlocking nailing devices provide better stability and rotational control, resulting in a reduced risk of nail migration and loss of fixation compared with unlocked nailing (7). These advantages may predominantly be present in newer-generation locking devices such as the Acumed Fibular Rod System (Acumed, Hillsboro, Oregon). Bugler et al (46) described their learning curve with this fibular interlocking nail, ultimately preferring a distal anterior-to-posterior locking screw for stabilization of the distal fracture fragment, combined with a proximal transsyndesmotic locking screw to avoid nail migration and rotation. A biomechanical evaluation in cadaveric Weber B fibular fractures showed that this nailing construct provides superior rotational strength compared with standard PF, potentially allowing earlier postoperative weightbearing (51). In summary, the fibular interlocking nail may provide superior stabilization compared with unlocked nail types.

Several limitations of this study should be mentioned. First of all, the included studies were of low methodologic quality, resulting in a high risk of bias. In addition, differences between the included studies were observed in definitions of outcomes, fracture type, mean age of patient population, surgical technique, and type of implant used. Additionally, definitions of wound-related complications were inadequately or not described by most of the included studies. The studies before the year 2000 included a considerably younger patient population compared with more recent studies as a result of different inclusion criteria, focusing on a general population rather than selected patients. This was observed for implant removal, in which heterogeneity was caused by 2 studies describing relatively low rates of implant removal, potentially as a result of younger patient populations (29,35). Although Weber A fibular fractures are mostly treated conservatively, studies that also included Weber A fractures were not excluded to avoid selection bias. Finally, the differences observed in meta-analysis relate to the use of a nail rather than a screw for IMF, because only 2 of the 8 included comparative studies reported on intramedullary screw fixation (40,41). Future research should be focused on more adequately powered, randomized comparative studies.

In conclusion, this systematic review and meta-analysis shows that in a patient population of relatively high age, IMF of distal fibular fractures results in fewer wound-related complications, implant removals, and nonunions. In addition, subdivision of wound-related complications showed fewer wound healing disorders and superficial wound infections. No differences between IMF and PF were observed for deep wound infection, malunion, or long-term functional outcome. Especially in elderly patients, patients with chronic comorbidity, and patients with compromised soft tissue, the advantages of minimal soft tissue damage by IMF may be preferred over optimal fracture reduction by PF.

Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jfas.2018.08.028.

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