Article

AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY

Foot & Ankle Orthopaedics
2022, Vol. 7(4) 1–14

DOI: 10.1177/24730114221125447
journals.sagepub.com/home/fao

A Systematic Review of Outcomes Following Lisfranc Injury Fixation: Removal vs Retention of Metalwork

Amanda M. L. Rhodes, BSc, FRCS(Tr&Orth)[1], Louise McMenemy, PhD, MRCS[1], Richard Connell, MRCS[1], Robin Elliot, MA(Oxon) (Tr&Orth), FRCS[1], and Daniel Marsland, MSc, FRCS(Tr&Orth)[1]

Abstract

Background: Following Lisfranc injury fixation, no consensus exists on whether to routinely remove metalwork. The aim of this study was to evaluate functional outcomes and complications in patients following routine removal of metalwork and in those with retained metalwork.

Methods: A systematic review of literature (1999-2020) reporting results of metalwork removal vs retention following Lisfranc injury fixation, was undertaken. The primary outcome was functional outcomes at 1 year following index surgery. Secondary outcomes were rates of complications including unplanned removal of metalwork.

Results: No studies directly comparing routine metalwork removal vs retention were found. A total of 28 studies reporting on 1069 patients were included. Of these, 10 studies (317 patients) reported on retention and 18 (752 patients) on routine removal of metalwork. The difference in the American Orthopaedic Foot & Ankle Society (AOFAS) score between removal and retention groups was 3.38 (95% CI 6.3-0.48), $P = .02$ (removal 79.97 [±16.09; 71-96]; retention 76.59 [±20.36; 65.4-94]). No difference in reported rates of infection was found between the 2 groups (0%-12% for both groups). Of the 317 patients in the retention group, metalwork was removed in 198 cases, resulting in a 62.5% unplanned removal rate.

Conclusion: In conclusion, this systematic review found limited evidence comparing different strategies of metalwork management after Lisfranc injury fixation. A randomized controlled trial is necessary to elucidate if routine removal of metalwork confers any true benefit.

Level of Evidence: Level IV, systematic review including case series.

Keywords: Lisfranc, injury, fixation, metalwork retention, metalwork removal

Introduction

A Lisfranc injury describes a partial or complete injury to the tarsometatarsal joints that includes disruption of the Lisfranc ligamentous complex. These encompass both low- and high-energy injuries and often require surgical treatment, most commonly performed using internal fixation with screws and/or plates for joint-preserving fixation.[18,38] No consensus, however, exists as to whether metalwork should be routinely removed following fixation of Lisfranc injuries.[44,47]

Retaining metalwork in the long term could cause the tarsometatarsal joints to be stiff, as such simulating fusion and resulting in altered biomechanics of the midfoot. A number of reviews have compared primary arthrodesis vs open reduction and internal fixation—all limited by wide study heterogeneity with as yet no evidence of clinically relevant difference between the two.[36,42,47] The potential but unproven purported benefits of metalwork removal include

[1]Hampshire Hospitals NHS Foundation Trust, United Kingdom

Corresponding Author:
Amanda M. L. Rhodes, BSc, FRCS(Tr&Orth), Hampshire Hospitals NHS Foundation Trust, Aldermaston Road, Basingstoke, England, RG24 9NA, United Kingdom.
Email: amandarhodes@doctors.org.uk

optimization of midfoot biomechanics and function, reduced pain, lower risk of broken metalwork, and easier secondary surgery in the event of developing painful posttraumatic osteoarthritis. The disadvantages of routine metalwork removal include risks of surgery such as deep peroneal nerve injury,[21] a second anaesthesia, further time off work, rehabilitation delays, increased health care costs, and potentially no subjective benefit to the patient.[2,24,30,33,34]

To date, no studies have compared the outcomes of patients following routine removal or retention of Lisfranc metalwork for nonarthrodesis surgery. There is wide variation in current practice of removal or retention of Lisfranc metalwork, and a recent UK survey of 205 consultant surgeons demonstrated community clinical equipoise regarding metalwork management following fixation.[31]

In light of such uncertainty, the primary purpose of this systematic review was to assess the reported functional outcomes and complications of 2 postoperative strategies following Lisfranc injury fixation: planned metalwork removal vs long-term retention of metalwork. Based on the theory that removal of metalwork improves midfoot biomechanics, the primary hypothesis was that patient-reported outcomes are significantly better following routine removal of metalwork compared with planned retention.

Methods

A systematic review was registered prospectively with PROSPERO[32] and the review process carried out according to PRISMA guidelines. In May 2020, a comprehensive search of OVID Medline, Embase, and CINAHL databases was conducted (date restricted 1999-2020) to identify studies reporting comparative results of metalwork removal or retention after Lisfranc injury fixation.

The search strategy included the following terms: *lisfranc*, *hardware*, *metalwork*, *removal*, *early weight bearing*, *enhanced recovery*, *early motion*, *posttraumatic arthritis*, *osteoarthritis*, *fracture*, *fracture dislocation*, *ligamentous*, *tarsometatarsal joint* (see Appendix 1 for full electronic search strategy).

Duplicate studies were removed, and all titles and abstracts screened for eligibility by 2 independent reviewers (A.R., R.C.) and where no consensus was reached, the senior author (D.M.) made the final decision. Data were extracted by 2 reviewers (A.R., L.M.). The references of all the selected studies were subsequently screened for additional publications.

Specific study characteristics used as criteria for eligibility, and inclusion and exclusion criteria are detailed in Appendix 2, along with rationale. Eligible studies included those reporting outcomes of surgical internal fixation for unstable Lisfranc injuries in adult patients (aged >18 years). Included injuries were tarsometatarsal fracture dislocations and unstable ligamentous Lisfranc injuries. Both retrospective and prospective observational studies, cohort, case-control, case series, and randomized controlled studies were included. Only English-language articles were included.

Exclusion criteria were as follows: Lisfranc injuries not treated with internal fixation (nonoperative treatment / external fixation / partial fusion / fusion); outcomes not reported; follow-up of <1 year; open Lisfranc injuries; fixation method not stated; case reports; expert reviews; surgical technique articles; letters to the editor; and pediatric patients.

Data were extracted using a predetermined datasheet (Appendix 3). For cohort and randomized studies comparing open reduction and internal fixation (ORIF) vs arthrodesis outcomes, only the ORIF groups were included. Studies were grouped according to group A, intended retention of metalwork; and group B, planned or routine elective removal of metalwork.

Primary and Secondary Outcomes

The primary outcome was functional outcomes at 1 year following primary surgery. Commonly used functional outcome measures considered included the American Orthopaedic Foot & Ankle Society (AOFAS) Score, the Foot Function Index, the Manchester-Oxford Foot Questionnaire, general health scores such as Short Form-36 (SF-36) or EuroQuol-5 domains (EQ-5D) and the visual analog scale (VAS) for pain.

Secondary outcomes were complication rates: infection, nerve damage, broken metalwork, rates of secondary osteoarthritis, and rates of unplanned additional surgery. Unplanned additional surgery included the removal of metalwork in patients where retention was intended.

Assessment of Bias

Two anonymized independent reviewers (L.M., R.C.) assessed the methodologic quality of each study. The Methodological Index for Non-Randomized Studies (MINORS) criteria[37] was used to assess the risk of bias (of the study, as opposed to the outcome level) for both noncomparative (criteria 1-8) and comparative (criteria 9-12) studies (Appendix 4). This index produced an overall rating for each study of high (<50%), moderate (50%-75%), or low (>75%) risk of bias. The level of evidence of each study was recorded as defined by the Oxford Centre for Evidence Based Medicine definitions.[26]

Statistical Analysis

The mean and SD were recorded for studies that reported functional scores as the primary outcome. For studies that only reported mean, range, and sample size, the SD was

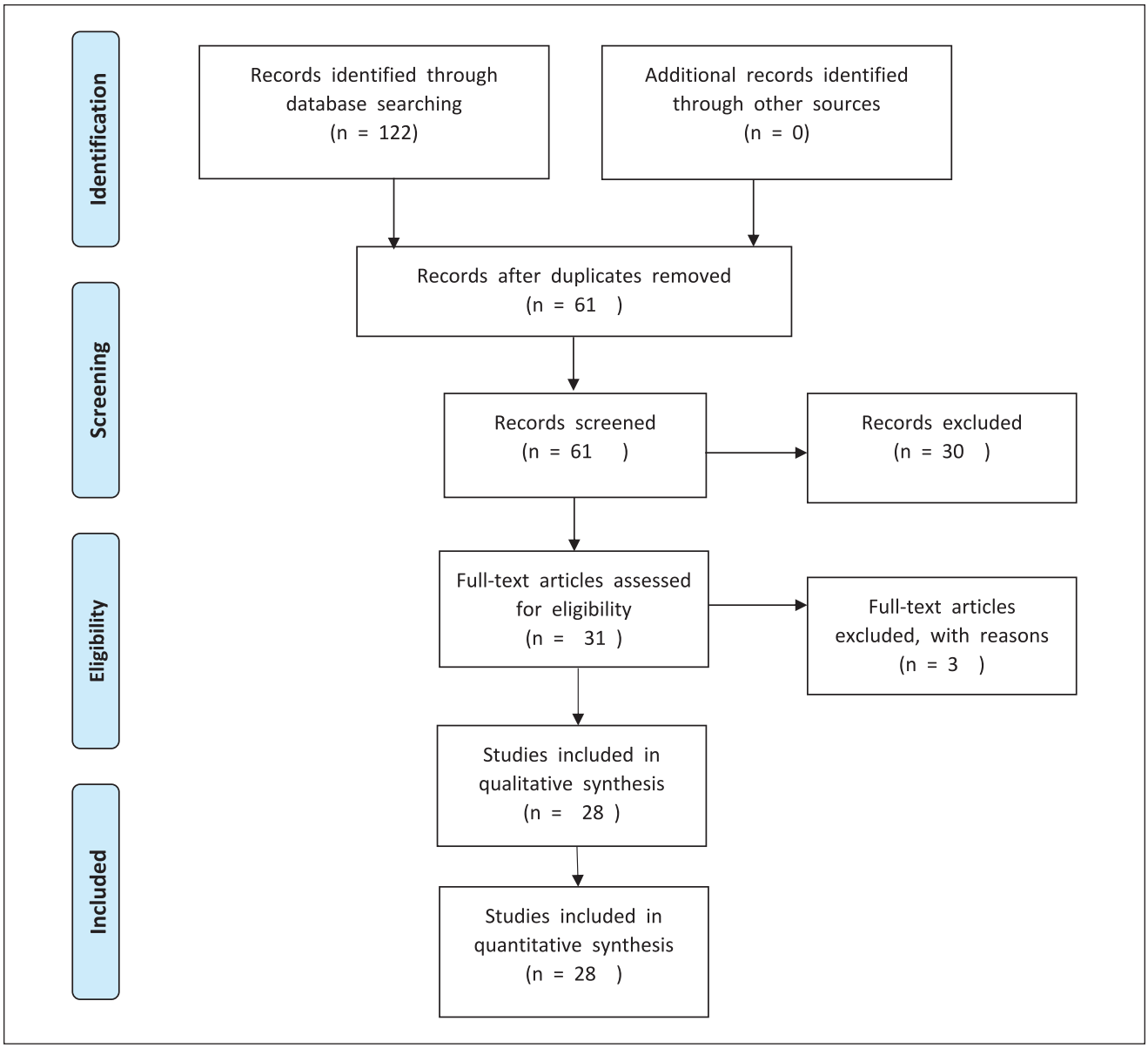

Figure 1. Flow diagram of study selection.

estimated according to the method reported by Hozo et al.[13] The weighted mean was calculated for outcome scores for groups A and B. The significance of the results was assessed using a *t* test.

It was not possible to measure heterogeneity between studies, as no preoperative functional scores were available, because of the nature of trauma. Considering the risk of bias, for statistical comparison of outcomes, significance was set at $P < .01$ to reduce the risk of type II error. Statistical analysis was performed using Meta-Essentials, version 1.5,[40] Microsoft Excel (2016; Microsoft Corporation, Redmond, WA).

Results

A total of 122 articles were identified, of which 28 were included for final review and quantitative analysis (Figure 1). From the 28 studies included, 1354 patients were analyzed with 1069 at final follow-up. Where reported, there were 519 males and 314 females in included studies. Average age was 33.6 (range, 21-54.5) years, and average follow-up was 39.2 (range, 12-130.8) months.

A summary of study characteristics from studies reporting metalwork retention and metalwork removal is shown in Table 1. Of the 28 studies, 10 (317 patients) reported

Table 1. Characteristics of the Studies Included in the Review.

	Group A: Retention Group	Group B: Removal Group
Number of studies	10	18
Number of patients initially	475	879
Number of patients at final follow-up	317	752
Loss to follow-up rate, %	33.3	14.5
Male/female, n	189:98	330:216
Age, y, mean (SD)	35.9 (13.0)	38.4 (14.4)*
Follow-up, mo, mean (SD)	43.3 (23.9)	42.7 (46.2)

*$P = .007$.

retention of hardware and 18 (752 patients) reported routine removal of metalwork. A statistically significant difference in age of patients between the 2 groups was found ($P = .007$).

Quality Assessment

No studies directly compared routine metalwork removal with metalwork retention. Of the 28 included studies, 15 were retrospective case series (level IV evidence). The remaining studies compared internal fixation with arthrodesis, of which 5 provided level IIb evidence and 8 were level IIIb (1 prospective comparative study, 3 prospective randomized controlled trials, and 9 retrospective comparative cohort studies).

Ten studies were found to have a high risk of bias (MINORS <50%), 14 a moderate risk of bias (MINORS 50%-75%), and 4 a low risk of bias (>75% MINORS).

Primary Outcome

Type of fixation was recorded as bridge plate for 587 patients, transarticular screws for 490 patients (with some patients receiving a combination of both methods), and tightrope fixation for 11 patients.

The AOFAS was the most frequently used functional outcome score, reported in 18 of the studies (752 patients). The weighted mean score for the retention group was 76.59 (±20.36; 65.4-94) and for the removal group was 79.97 (±16.09; 71-96) (Figure 2), giving a difference of 3.38 (95% CI –6.3 to –0.48, $P = .02$). The effect size was 0.192. The VAS was reported in 7 studies, 2 (38 patients) reporting retention and 5 (175 patients) removal. Return to preinjury activity level was reported in 3 studies for the retention group as 65%-88% and in 7 studies for the removal group as 79%-100%.

The physical component summary (PCS) of the Short Form–36 (SF-36) was reported in 5 studies including 224 patients, all of which reported on the routine removal of metalwork. The weighted average PCS was 54.84 (±14.67), with 50 representing a normal population score.

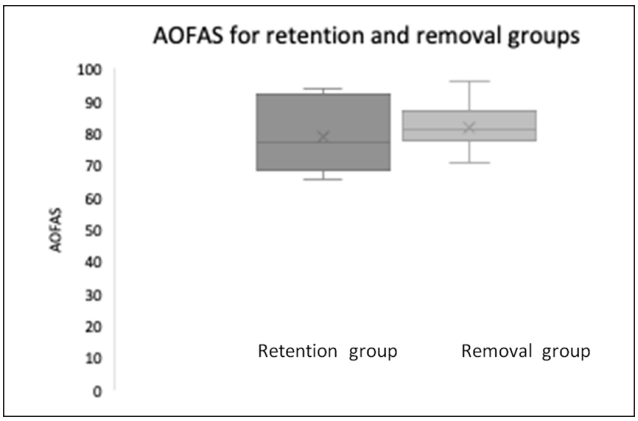

Figure 2. Boxplot (weighted mean score and SD) comparing AOFAS for metalwork retention and metalwork removal groups.

The Foot Function Index was reported in 4 studies, VAS in 7 studies, Foot and Ankle Ability Measure in 1 study, Maryland Foot Score in 2 studies, Short Musculoskeletal Functional Assessment in 2 studies and, Manchester-Oxford Foot Questionnaire in 1 study. The small number of studies reporting these outcomes prevented further analysis.

Secondary Outcomes

Intended metalwork retention was reported in studies describing 317 patients at final follow-up. Of these 317 patients, metalwork was removed in 198 cases, resulting in an unplanned removal rate of 62.5%. The reason provided for unplanned removal was for "broken metalwork" in 24 patients, "pain" in 39 patients, and no reason stated for the remaining cases.

Where routine removal of metalwork was planned and a time point specified, this was undertaken at a median of 3 months postoperatively (range 3-6 months). See Appendix 5 for summary table of studies reporting planned metalwork removal. There was no evidence provided in any study as justification for the described time frame of metalwork removal. Rates of secondary outcome measures are displayed in Table 2.

Overall Rates of Secondary Outcomes/ Complications

Infection rates were reported in 6 of the studies reporting routine retention of metalwork. None of these studies defined infection, nor differentiated between superficial and deep infection. Infection rates were reported as between 0% and 12%. For the routine removal group, 12 studies reported infection rates, with 1 study dividing infection into

Table 2. Rates of Secondary Complications Reported in Included Studies.

	Group A: Retention Group		Group B: Removal Group	
Secondary Outcome	Number of Papers	Reported Rate (%)	Number of Papers	Reported Rate (%)
Infection	6	0-12	12	0-12
Nerve injury	4	0-22	7	0-23
Loss of reduction	6	18-75	14	0-41
Secondary OA	3	6-25	10	0-72
Secondary arthrodesis	6	2-25	8	2-13
Pain	1	25	9	2-30
Broken metalwork	3	2-27	4	0-16

Abbreviation: OA, osteoarthritis.

superficial and deep. These 12 studies also reported an infection rate of 0% to 12%. The remaining secondary outcomes can be found in Table 2.

Discussion

The most important finding of this systematic review is the lack of relevant published data to allow comparison of routine removal to retention of metalwork. Literature searches revealed no randomized controlled trials, systematic reviews, nor meta-analyses examining this debated topic. Rates of unplanned removal of metalwork were high, further impeding meaningful comparison of treatment groups. From the available evidence, however, functional outcome scores (AOFAS) and complication rates were similar for each group.

The clinical significance of a difference of 3.38 in AOFAS score between the 2 groups is unknown, and not likely to be clinically important. Although the AOFAS score was the most frequently used scoring system, there are recognized limitations of this system including a ceiling effect, and the AOFAS score is no longer recommended to assess functional outcomes. Furthermore, there was inconsistent timing of postoperative scoring, which should be conducted at 6 months,[20] and ideally beyond 2 years to truly judge clinically important difference.

Although a statistically significant difference was found in the age of the individuals between group A and group B (36 years vs 38 years), this is not clinically significant, with only 2 years found between the averages. Therefore, results between the 2 groups can be compared despite the statistical difference.

One recent retrospective review of 61 patients with tarsometatarsal joint dislocation/fracture fixation concluded that routine removal of metalwork was not necessary.[44] No difference in infection rates between the 2 groups was found in this review, but whether routine removal of metalwork surgery is not only unnecessary, but poses increased risk, remains unknown. Another recent study of a single-surgeon case series reported on the rates of nerve injury complications, specifically of the primary fixation and of the subsequent planned surgery to remove metalwork 3-4 months later. This showed an overall nerve injury rate of 23% when routine metalwork removal was planned,[21] consistent with the results of this review.

In keeping with recent studies,[12,21] this review found that when planned, metalwork removal was scheduled most commonly at 3-4 months post fixation. The absence of justification found for the timing of metalwork removal, and variation in current practice,[31] further supports the notion of true equipoise regarding Lisfranc metalwork management.

Evidence of international growing interest in this area is provided by an ongoing randomized controlled trial registered by the University of Calgary, Canada.[9] It is the first to directly compare patient outcomes following removal or retention of metalwork following Lisfranc fixation. Recruitment is still under way so results are yet unknown.

The studies included in this review demonstrated a wide variety in study design (including variation in choice of functional outcome score), and high risk of bias based on the MINORS criteria. Further subgroup analysis, including separating patients who had undergone transarticular screw fixation in particular, would have been preferable but was prevented by study heterogeneity. All these factors limit the strength of conclusions drawn and demonstrates the need for further research in this area, namely, randomization to allow direct comparison of outcomes.

This review shows that there is no available evidence to support different strategies for metalwork management following Lisfranc injury fixation, yet this is an area of great interest and relevance to surgeons at an international level. In the United Kingdom this year, the role and timing of routine removal of metalwork was identified as one of the top 18 research priorities for complex fractures.[15] Robust comparison of patient outcomes, complication rates, return to work, return to sport, rates of secondary osteoarthritis, and cost effectiveness of routine metalwork removal vs retention is greatly needed to improve our understanding and standards of care of these injuries. The modern trend toward use of bridging plates[27,31] was not examined in this study but method of fixation is a key variable that needs to be controlled for in future analyses.

Conclusion

The current study demonstrates similar functional outcomes comparing routine removal of metalwork vs planned retention following fixation for a Lisfranc injury. The rates of unplanned metalwork removal were high, and there appears to be wider variation in functional outcomes compared with routine metalwork removal. However, because of the high risk of bias and limitations of many of the included studies, the strength of evidence to recommend routine removal of metalwork is low. Comparative prospective studies are required in order to determine the optimal management strategy following Lisfranc fixation.

Ethics Approval

Ethical approval was not sought for this study because it involved information freely available in the public domain (published studies) and analysis of properly anonymized data sets only.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Amanda M. L. Rhodes, BSc, FRCS(Tr&Orth), https://orcid.org/0000-0003-3009-0409

References

1. Abbasian MR, Paradies F, Weber M, Krause F. Temporary internal fixation for ligamentous and osseous Lisfranc injuries: outcome and technical tip. *Foot Ankle Int*. 2015;36(8):976-983.
2. Brown R, Wheelwright E, Chalmers J. Removal of metal implants after fracture surgery—indications and complications. *J R Coll Surg Edinb*. 1993;38(2):96-100.
3. Buda M, Kink S, Stavenuiter R, et al. Reoperation rate difference between open reduction internal fixation and primary arthrodesis of Lisfranc Injuries *Foot Ankle Int*. 2018; 39(9):1089-1096.
4. Cochran G, Renninger C, Tompane T, et al. Primary arthrodesis versus open reduction and internal fixation for low-energy Lisfranc injuries in a young athletic population. *Foot Ankle Int*. 2017;38(9):957-963.
5. Crates JM, Barber A, Sanders EJ. Subtle Lisfranc subluxation: results of operative and nonoperative treatment. *J Foot Ankle Surg*. 2015;54:350-355.
6. Del Vecchio JJ, Ghioldi M, Raimondi N, De Elias M. Minimally invasive medial plating of low energy Lisfranc injuries: preliminary experience with five cases. *Adv Orthop*. 2016;2016:4861260.
7. Deol RS, Roche A, Calder JDF. Return to training and playing after acute Lisfranc injuries in elite professional soccer and rugby players. *Am J Sports Med*. 2016;44(1):166-170.
8. Dubois-Ferriere V, Chowdry A, Stern R, et al. Clinical outcomes and development of symptomatic osteoarthritis 2 to 24 years after surgical treatment of tarsometatarsal joint complex injuries. *J Bone Joint Surg Am*. 2016;98:713-720.
9. Fixation In-situ vs Removal for Midfoot Lisfranc Injuries (FIRM). Accessed January 2021. https://clinicaltrials.gov/ct2/show/NCT03694288.
10. Ghate SD, Sistla VM, Nemade V, et al. Screw and wire fixation for Lisfranc fracture dislocations. *J Orthop Surg*. 2012;20(2):170-175.
11. Hawkinson MP, Tennent DJ, Belisle J, Osborn P. Outcomes of Lisfranc injuries in an active duty military population. *Foot Ankle Int*. 2017;38(10):1115-1119.
12. Henning J, Jones C, Sietsema D, et al. Open reduction internal fixation versus primary arthrodesis for Lisfranc injuries: a prospective randomised study. *Foot Ankle Int*. 2009;30(10):913-922.
13. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. *BMC Med Res Methodol*. 2005;5:13. https://doi.org/10.1186/1471-2288-5-13
14. Hu SJ, Chang SM, Li XH, Yu GR. Outcome comparison of Lisfranc injuries treated through dorsal plate fixation versus screw fixation. *Acta Orthop Bras*. 2014;22(6):315-320.
15. James Lind Alliance Complex Fractures: Questions 1-18 and evidence summary. Accessed January 2022. https://www.jla.nihr.ac.uk/priority-setting-partnerships/complex-fractures/downloads/JLA-Complex-Fractures-Indicative-Questions-1-18-and-evidence-summary.pdf
16. Kirzner N, Zotov P, Goldbloom D, et al. Dorsal bridge plating or transarticular screws for Lisfranc fracture dislocations: a retrospective study comparing functional and radiological outcomes. *Bone Joint J*. 2018;100-B:468-474.
17. Kuo RS, Tejwani NC, DiGiovanni CW, et al. Outcome after open reduction and internal fixation of Lisfranc joint injuries. *J Bone Joint Surg Am*. 2000;82(11):1609-1618.
18. Lau S, Guest C, Hall M, et al. Functional outcomes post Lisfranc injury—transarticular screws, dorsal bridge plating or combination treatment *J Orthop Trauma*. 2017;31:447-452.
19. Ly T, Coetzee JC. Treatment of primary ligamentous Lisfranc joint injuries: primary arthrodesis compare with open reduction and internal fixation *J Bone Joint Surg Am*. 2006;88 (3):514-520.
20. Malviya A, Makwana N, Laing P. AOFAS scores. Trend and correlation with QALY score. *Orthop Proc*. 2018;87-B:Suppl III.
21. Meyerkort D, Gurel R, Maor D, et al. Deep peroneal nerve injury following hardware removal for Lisfranc joint injury *Foot Ankle Int*. 2020;41(3):320-323.
22. Mulier T, Reynders P, Dereymaeker G, Broos P. Severe Lisfranc injuries: primary arthrodesis or ORIF? *Foot Ankle Int*. 2002;23(10):902-905.
23. Nunley JA, Vertullo CJ. Classification, investigation, and management of midfoot sprains: Lisfranc injuries in the athlete *Am J Sports Med*. 2002;30(6):871-878.

24. Onche I, Osagie O, Inuhu S. Removal of orthopaedic implants: indications, outcome and economic implications. *J West Afr Coll Surg*. 2011;1(1):101-112.
25. Perugia D, Baslle A, Battaglia A, et al. Fracture dislocations of Lisfranc's joint treated with closed reduction and percutaneous fixation. *Int Orthop*. 2003;23:30-35.
26. Phillips B, Ball C, Sackett D, et al. Oxford Centre for Evidence-based Medicine – levels of evidence (March 2009). Accessed January 2022. https://www.cebm.net/2009/06/oxford-centre-evidence-basedmedicine-levelsevidence-march-2009/2009.
27. Philpott A, Epstein D, Lau S, et al. Lisfranc fixation techniques and postoperative functional outcomes: a systematic review. *J Foot Ankle Surg*. 2021;60(1):102-108.
28. Qiao YE, Li JK, Shen H, et al. Comparison of arthrodesis and non-fusion to treat Lisfranc injuries. *Orthop Surg*. 2017;9:62-68.
29. Rammelt S, Schneiders W, Schikore H, et al. Primary open reduction and fixation compared with delayed corrective arthrodesis in the treatment of tarsometatarsal (Lisfranc) fracture dislocation. *J Bone Joint Surg Br*. 2008;90(11):1499-1506.
30. Reith G, Schmitz-Greven, Hensel K, et al. Metal implant removal: benefits and drawbacks—a patient survey. *BMC Surg*. 2015;15:96.
31. Rhodes A, Elliot R, Marsland D. Elective removal of metalwork following Lisfranc injury fixation: results of a national consensus survey of practice. *Foot (Edinb)*. 2021;47:101811.
32. Rhodes A, Marsland D. A systematic review of outcomes following Lisfranc injury fixation: removal versus retention of hardware. June 2021. Accessed June 2021. https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020187258
33. Richards R, Palmer J, Clarke NM. Observations on removal of metal implants. *Injury*. 1992;23(1):25-28.
34. Sanderson P, Ryan W, Turner P. Complications of metalwork removal. *Injury*. 1992;23(1):29-30.
35. Scofield HO, Lam KC, Stautberg EF, et al. Outcomes of Lisfranc injuries treated with joint-preserving fixation. *Ind J Orthop*. 2020;54:594-598.
36. Sheibani-Rad S, Coetzee JC, Giveans MR, et al. Arthrodesis versus ORIF for Lisfranc fractures. *Orthopedics*. 2012;35(6):e868-673.
37. Slim K, Nini E, Forestier D, et al. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. *ANZ J Surg*. 2003;73(9):712-716.
38. Stavlas P, Roberts CS, Xypnitos FN, Giannoudis PV. The role of reduction and internal fixation of Lisfranc fracture-dislocations: a systematic review of the literature. *Int Orthop*. 2010;34:1083-1091.
39. Stodle AH, Hvaal KH, Brogger HM, et al. Temporary bridge plating vs primary arthrodesis of the first tarsometatarsal joint in Lisfranc injuries: randomised controlled trial. *Foot Ankle Int*. 2020;41(8):901-910.
40. Suurmond R, Rhee H, Hak T. Introduction, comparison, and validation of metaessentials: a free and simple tool for meta-analysis. *Res Synth Methods*. 2017;8:537. doi:http://dx.doi.org/10.1002/jrsm.1260.
41. Teng AL, Pinzur MS, Lomasney L, et al. Functional outcome following anatomic restoration of tarsal-metatarsal fracture dislocation *Foot Ankle Int*. 2002;23(10):922-926.
42. van den Boom NA, Stollenwerck G, Lodewijks L, et al. Lisfranc injuries: fix or fuse? A systematic review and meta-analysis of current literature presenting outcome after surgical treatment for Lisfranc injuries. *Bone Jt Open*. 2021;2(10):842-849.
43. Van Koperen PJ, de Jong VM, Luitse JSK, Schepers T. Functional outcomes after temporary bridging with locking plates in Lisfranc Injuries. *J Foot Ankle Surg*. 2016;55:922-926.
44. Van Pelt M, Athey A, Yao J, et al. Is routine hardware removal following open reduction internal fixation of tarsometatarsal joint fracture/dislocation necessary? *J Foot Ankle Surg*. 2019;58(2):226-230.
45. Vosbikian M, O'Neil JT, Piper C, et al. Outcome after percutaneous reduction and fixation of low energy Lisfranc injuries *Foot Ankle Int*. 2017;38(7):710-715.
46. Wagner E, Ortiz C, Villalon IE, et al. Early weight-bearing after percutaneous reduction and screw fixation for low-energy Lisfranc injury. *Foot Ankle Int*. 2012;34(7):978-983.
47. Yan A, Chen SR, Ma X, et al. Updates on Lisfranc complex injuries. *Foot Ankle Orthop*. 2021;6(1):2473011420982275.

Appendices

Appendix 1

Search Terms and Strategy.

#	Database	Search term	Results
1	EMBASE	("Lisfranc injur*").ti,ab	324
2	EMBASE	"TARSOMETATARSAL JOINT"/	947
3	EMBASE	("Lisfranc fracture*").ti,ab	165
4	EMBASE	(lisfranc).ti,ab	745
5	EMBASE	(midfoot).ti,ab	2658
7	EMBASE	FRACTURE/	82241
8	EMBASE	(fracture*).ti,ab	294489

(continued)

(continued)

#	Database	Search term	Results
9	EMBASE	INJURY/	317933
10	EMBASE	(injur*).ti,ab	1010556
11	EMBASE	(ligamentous).ti,ab	7711
12	EMBASE	(7 OR 8 OR 9 OR 10 OR 11)	1394439
13	EMBASE	'tarsometatarsal joint' OR "TARSOMETATARSAL JOINT"/	1174
14	EMBASE	(4 OR 5 OR 13)	3855
15	EMBASE	(12 AND 14)	1508
16	EMBASE	(1 OR 3)	436
17	EMBASE	(15 OR 16)	1508
18	EMBASE	(hardware).ti,ab	26208
19	EMBASE	(metalwork OR screw).ti,ab	37732
20	EMBASE	"FRACTURE FIXATION"/	21884
21	EMBASE	"ORTHOPEDIC FIXATION DEVICE"/ OR "BONE SCREW"/	25687
22	EMBASE	(18 OR 19 OR 20 OR 21)	91160
23	EMBASE	(17 AND 22)	293
24	EMBASE	"DEVICE REMOVAL"/	19600
25	EMBASE	(removal).ti,ab	425734
26	EMBASE	(24 OR 25)	436806
27	EMBASE	(23 AND 26)	42
28	EMBASE	('posttraumatic arthritis').ti,ab	611
29	EMBASE	('post traumatic arthritis').ti,ab	541
30	EMBASE	OSTEOARTHRITIS/	83832
31	EMBASE	(osteoarthritis).ti,ab	90311
32	EMBASE	("enhanced recovery").ti,ab	6423
33	EMBASE	("early motion").ti,ab	581
34	EMBASE	("early weight bearing").ti,ab	718
35	EMBASE	(28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34)	134064
36	EMBASE	(14 AND 35)	326
37	EMBASE	(26 AND 36)	17
38	EMBASE	(27 OR 37)	53
39	EMBASE	38 [DT 1999-2020] [English language]	52
40	Medline	("Lisfranc injur*").ti,ab	263
41	Medline	("Lisfranc fracture*").ti,ab	130
42	Medline	(lisfranc).ti,ab	710
43	Medline	(midfoot).ti,ab	2151
44	Medline	(fracture*).ti,ab	250436
45	Medline	(injur*).ti,ab	781415
46	Medline	(ligamentous).ti,ab	6258
47	Medline	("tarsometatarsal joint").ti,ab	324
49	Medline	"FRACTURES, BONE"/	63647
51	Medline	(42 OR 43 OR 47)	2887
52	Medline	(44 OR 45 OR 46 OR 49)	994960
53	Medline	(51 AND 52)	1182
54	Medline	(40 OR 41 OR 53)	1182
55	Medline	(hardware).ti,ab	21762
56	Medline	(metalwork OR screw).ti,ab	32495
57	Medline	"ORTHOPEDIC FIXATION DEVICES"/ OR "FRACTURE FIXATION"/	22832
58	Medline	"BONE SCREWS"/	22807
59	Medline	(55 OR 56 OR 57 OR 58)	83271
60	Medline	(54 AND 59)	211
61	Medline	"DEVICE REMOVAL"/	13013
62	Medline	(removal).ti,ab	339639

(continued)

(continued)

#	Database	Search term	Results
63	Medline	(61 OR 62)	347 094
64	Medline	(60 AND 63)	30
65	Medline	('posttraumatic arthritis').ti,ab	1022
66	Medline	('post traumatic arthritis').ti,ab	817
67	Medline	(osteoarthritis).ti,ab	61 882
68	Medline	("enhanced recovery").ti,ab	3727
69	Medline	("early motion").ti,ab	532
70	Medline	("early weight bearing").ti,ab	572
71	Medline	OSTEOARTHRITIS/	36 613
72	Medline	(65 OR 66 OR 67 OR 68 OR 69 OR 70 OR 71)	83 447
73	Medline	(51 AND 72)	184
74	Medline	(63 AND 73)	11
75	Medline	(64 OR 74)	36
76	Medline	75 [DT 1999-2020] [Languages English]	34
77	CINAHL	("Lisfranc injur*").ti,ab	205
78	CINAHL	("Lisfranc fracture*").ti,ab	82
79	CINAHL	(lisfranc).ti,ab	396
80	CINAHL	(midfoot).ti,ab	1318
81	CINAHL	(fracture*).ti,ab	73 123
82	CINAHL	(injur*).ti,ab	223 338
83	CINAHL	(ligamentous).ti,ab	1988
84	CINAHL	("tarsometatarsal joint").ti,ab	140
85	CINAHL	"METATARSAL FRACTURES"/ OR "FOOT FRACTURES"/	677
86	CINAHL	FRACTURES/	19 814
87	CINAHL	"LISFRANC JOINT INJURY"/	157
88	CINAHL	(77 OR 78 OR 87)	308
89	CINAHL	(79 OR 80 OR 84)	1678
90	CINAHL	(81 OR 82 OR 83 OR 85 OR 86)	284 347
91	CINAHL	(89 AND 90)	703
92	CINAHL	(88 OR 91)	734
93	CINAHL	(hardware).ti,ab	4015
94	CINAHL	(metalwork OR screw).ti,ab	12 499
95	CINAHL	"ORTHOPEDIC FIXATION DEVICES"/ OR "FRACTURE FIXATION"/	24 396
96	CINAHL	"BONE SCREWS"/	3048
97	CINAHL	(93 OR 94 OR 95 OR 96)	34 043
98	CINAHL	(92 AND 97)	222
99	CINAHL	"DEVICE REMOVAL"/	4554
100	CINAHL	(removal).ti,ab	33 726
101	CINAHL	(99 OR 100)	36 487
102	CINAHL	(98 AND 101)	33
103	CINAHL	('posttraumatic arthritis').ti,ab	396
104	CINAHL	('post traumatic arthritis').ti,ab	248
105	CINAHL	(osteoarthritis).ti,ab	28 070
106	CINAHL	("enhanced recovery").ti,ab	1439
107	CINAHL	("early motion").ti,ab	145
108	CINAHL	("early weight bearing").ti,ab	185
109	CINAHL	OSTEOARTHRITIS/	14 537
110	CINAHL	(103 OR 104 OR 105 OR 106 OR 107 OR 108 OR 109)	35 801
111	CINAHL	(89 AND 110)	96
112	CINAHL	(101 AND 111)	7
113	CINAHL	(102 OR 112)	37
114	CINAHL	113 [DT 1999-2020] [Languages eng]	36

Appendix 2

Specific Study Characteristics Used as Criteria for Eligibility

Study characteristics recorded:

- Study type
- Type of surgery
- Sample size
- Protocol postfixation (routine removal or metalwork retained)
- Duration of follow-up
- Type of outcome scoring system and final score
- Types and respective rates of complications

Appendix 3

Methodological Index for Non-Randomized Studies (MINORS) Assessment of Studies

The revised and validated version of Methodological Index for Non-Randomized Studies (MINORS).

Methodological items for non-randomized studies	Score[†]
1. A clearly stated aim: the question addressed should be precise and relevant in the light of available literature.	
2. Inclusion of consecutive patients: all patients potentially fit for inclusion (satisfying the criteria for inclusion) have been included in the study during the study period (no exclusion or details about the reasons for exclusion).	
3. Prospective collection of data: data were collected according to a protocol established before the beginning of the study.	
4. Endpoints appropriate to the aim of the study: unambiguous explanation of the criteria used to evaluate the main outcome which should be in accordance with the question addressed by the study. Also, the endpoints should be assessed on an intention-to-treat basis.	
5. Unbiased assessment of the study endpoint: blind evaluation of objective endpoints and double-blind evaluation of subjective endpoints. Otherwise the reasons for not blinding should be stated.	
6. Follow-up period appropriate to the aim of the study: the follow-up should be sufficiently long to allow the assessment of the main endpoint and possible adverse events.	
7. Loss to follow up less than 5%: all patients should be included in the follow up. Otherwise, the proportion lost to follow up should not exceed the proportion experiencing the major endpoint.	
8. Prospective calculation of the study size: information of the size of detectable difference of interest with a calculation of 95% confidence interval, according to the expected incidence of the outcome event, and information about the level for statistical significance and estimates of power when comparing the outcomes.	
Additional criteria in the case of comparative study	
9. An adequate control group: having a gold standard diagnostic test or therapeutic intervention recognized as the optimal intervention according to the available published data.	
10. Contemporary groups: control and studied group should be managed during the same time period (no historical comparison).	
11. Baseline equivalence of groups: the groups should be similar regarding the criteria other than the studied endpoints. Absence of confounding factors that could bias the interpretation of the results.	
12. Adequate statistical analyses: whether the statistics were in accordance with the type of study with calculation of confidence intervals or relative risk.	

[†]The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The global ideal score is 16 for noncomparative studies and 24 for comparative studies.

Nonrandomized Studies.

Study	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Score	Rating
Abbasian et al[1]	2	0	0	1	1	2	0	0	2	2	2	2	14	Moderate
Buda et al[3]	2	2	0	2	1	2	0	0	2	2	0	2	15	Moderate
Cochran et al[4]	2	1	0	2	2	2	0	0	1	2	0	1	13	Moderate
Crates et al[5]	2	2	0	1	1	2	2	0	0	2	0	1	13	Moderate
Del Vecchio et al[6]	1	2	1	1	0	1	2	0	n/a	n/a	n/a	n/a	8	Moderate
Deol et al[7]	2	2	1	1	1	2	2	0	n/a	n/a	n/a	n/a	11	Moderate
Dubois- Ferriere et al[8]	2	2	0	2	1	2	0	0	2	2	2	2	17	Moderate
Ghate et al[11]	2	2	0	1	1	2	2	0	n/a	n/a	n/a	n/a	10	Moderate
Hawkinson et al[10]	2	0	0	2	2	2	0	0	2	2	2	2	16	Moderate
Henning et al[12]	2	2	2	2	1	2	0	2	2	2	2	2	21	Low
Hu et al[14]	2	2	2	2	1	2	2	0	2	2	2	1	20	Low
Kirzner et al[16]	2	1	0	2	1	2	0	0	1	2	1	1	13	Moderate
Kuo et al[17]	2	1	0	1	1	2	0	0	n/a	n/a	n/a	n/a	7	High
Lau et al[18]	2	0	0	1	1	2	0	0	n/a	n/a	n/a	n/a	6	High
Ly et al[19]	2	2	2	1	1	2	2	2	2	2	2	2	22	Low
Mulier et al[22]	1	0	0	2	1	2	0	0	2	2	0	0	10	High
Meyerkort et al[21]	2	1	0	1	1	1	0	0	n/a	n/a	n/a	n/a	6	High
Nunley et al[23]	1	1	0	1	1	0	1	0	1	1	1	1	9	High
Perugia et al[25]	1	1	0	1	1	1	2	0	n/a	n/a	n/a	n/a	7	High
Qiao et al[28]	2	2	0	2	1	1	0	0	2	2	0	1	13	Moderate
Rammelt et al[29]	2	2	0	1	1	1	0	0	0	1	1	1	10	High
Scofield et al[35]	1	1	0	1	1	1	2	0	n/a	n/a	n/a	n/a	7	High
Stodle et al[39]	2	1	2	2	1	2	0	2	2	2	2	2	20	Low
Teng et al[41]	2	1	0	1	1	1	1	0	n/a	n/a	n/a	n/a	7	High
Van Koperen et al[43]	2	2	0	2	1	1	0	0	1	0	1	1	11	High
Van Pelt et al[44]	2	2	0	1	1	1	2	0	n/a	n/a	n/a	n/a	9	Moderate
Vosbikian et al[45]	2	2	0	1	1	2	0	0	n/a	n/a	n/a	n/a	8	Moderate
Wagner et al[46]	1	2	0	1	1	1	2	0	n/a	n/a	n/a	n/a	8	Moderate

Appendix 4

Summary of Studies Reporting Metalwork Retention Following Lisfranc Injury Fixation

Characteristics of Studies Examining Planned Retention of Metalwork.

Author	Type of Study	No. of Participants	Fixation Method	Mean Follow-up (mo)	Primary Outcome	Secondary Outcome
Cochran et al[4]	Retrospective, comparative cohort	18	ORIF with plate and screws	32	VAS, FAAM, and return to activity	Infection, nerve injury, loss of reduction, secondary OA, unplanned secondary surgery
Crates et al[5]	Retrospective, comparative cohort	20	Dual screw (9) or dual mini-tightrope (11)	33	AOFAS	
Hawkinson et al[10]	Case series	91	ORIF with plate and screws		Return to activity	Unplanned secondary surgery
Kuo et al[18]	Case series	48	Transarticular screws ± dorsal plate ± K-wire fixation of lateral rays	52	AOFAS, SMFA	Loss of reduction, secondary OA, unplanned secondary surgery, metalwork complications
Lau et al[18]	Case series	50	3 groups: fixation by transarticular screws vs fixation with dorsal bridging plate alone vs fixation with combination (Lisfranc interval screw not counted as transarticular)	57.7	AOFAS, FFI	Infection, loss of reduction, unplanned secondary surgery, metalwork complications, pain
Ly et al[19]	Prospective RCT	20	ORIF with plate and screws	42	AOFAS, VAS, return to activity	Loss of reduction, unplanned secondary surgery
Scofield et al[35]	Case series	14	Fixation with screws that do not breach the articular surface and a Lisfranc screw	57	AOFAS	Loss of reduction, unplanned secondary surgery
Van Koperen et al[43]	Retrospective, comparative cohort	34	Bridging plates, locking plates and transarticular screws or K-wires	49	AOFAS, FFI	Infection, loss of reduction, unplanned secondary surgery
Vanpelt et al[44]	Case series	61	ORIF with plates and 3.5-mm fully threaded cortical screws	12	Satisfaction	Infection, loss of reduction, secondary OA, unplanned secondary surgery, metalwork complications
Wagner et al[46]	Case series	22	3.0-mm cannulated screw, percutaneous transarticular	33.2	AOFAS	Nil

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; FAAM, Foot and Ankle Ability Measure; FFI, Foot Function Index; K-wire, Kirschner wire; OA, osteoarthritis; ORIF, open reduction internal fixation; RCT, randomized controlled trial; SMFA, Short Musculoskeletal Functional Assessment; VAS, visual analog scale.

Appendix 5

Summary of Studies Reporting Metalwork Removal Following Lisfranc Injury Fixation

Characteristics of Studies Examining Planned Removal of Metalwork.

Author	Type of Study	No. of Participants	Fixation Method	Mean Follow-up (mo)	Primary Outcome	Secondary Outcome
Abbasian et al[1]	Retrospective, comparative cohort	58	Transarticular screws ± dorsal plate ± K-wire fixation of lateral rays	104.4	AOFAS, FFI, SF-36, VAS, return to activity	Pain, loss of reduction, secondary OA, unplanned secondary surgery, metalwork complications
Buda et al[3]	Retrospective, comparative cohort	163	ORIF with plates and screws	62.5	Satisfaction	Infection, loss of reduction, secondary OA, unplanned secondary surgery, metalwork complications
Del Vecchio et al[6]	Case series	5	Minimal osteosynthesis performed through a minimally invasive approach using a 2.7-mm bridge plate implanted between the first cuneiform (C1) and the first metatarsal (M1), and a 3.0-mm cannulated screw placed between C1 and the second metatarsal (M2)	19.4	AOFAS, VAS	Loss of reduction
Deol et al[7]	Case series	17	Lisfranc screw and bridging plate	24	Return to activity	Nerve injury, pain
Dubois Ferriere et al[8]	Case series	50	ORIF transarticular screws (1-3) and K-wires (4-5)	130.8	AOFAS, FFI, SF-36, VAS, return to activity	Infection, loss of reduction, secondary OA
Ghate et al[11]	Case series	19	Screw and K-wire (5 screws alone, 4 K-wires alone, 10 both)	30	AOFAS, Maryland Foot Score	Infection, nerve injury, loss of reduction, unplanned secondary surgery, pain, metalwork complications
Henning et al[12]	Prospective RCT	32	Screws (±fourth/fifth ray buried K-wires)	24	SF-36, SMFA, VAS, return to activity	Infection, nerve injury, loss of reduction, unplanned secondary surgery, metalwork complications, pain
Hu et al[14]	Prospective comparative study	60	Open reduction and dorsal plate fixation or screw fixation	31	AOFAS, return to activity	Infection, loss of reduction, secondary OA, unplanned secondary surgery, pain, metalwork complications

(continued)

(continued)

Author	Type of Study	No. of Participants	Fixation Method	Mean Follow-up (mo)	Primary Outcome	Secondary Outcome
Kirzner et al[16]	Retrospective, comparative cohort	108	Bridge plating 45, transarticular screws 38, combination 25	33	AOFAS, MOxFQ	Infection, loss of reduction, pain,
Mulier et al[22]	Retrospective, comparative cohort	16	16 ORIF 4.5-mm screws, transarticular ± K-wire stabilization laterally	30.1	Baltimore painful foot score	Loss of reduction, unplanned secondary surgery, pain
Myerkort et al[21]	Case series	50	Locking plates or extra-articular screws depending on injury pattern	15	Patient satisfaction	Infection, nerve injury, secondary OA, unplanned secondary surgery
Nunley et al[23]	Retrospective, comparative cohort	8	ORIF with partially threaded 4.5-mm screws	27	Return to activity	Loss of reduction, pain
Perugia et al[25]	Case series	42	Closed reduction and percutaneous fixation with 4-mm transarticular screws	58.4	AOFAS	
Qiao et al[28]	Case series	17	ORIF using 3-mm cannulated compression screws ± K-wires laterally where required	10	AOFAS, SF-36, VAS	Infection, loss of reduction, pain
Rammelt et al[29]	Retrospective, comparative cohort	20	22 ORIF (11 had K-wires only, rest with screws)	37	AOFAS, Maryland Foot Score, satisfaction	Infection, loss of reduction, unplanned secondary surgery
Stodle et al[39]	Prospective RCT	45	Bridge plate	24	AOFAS, SF-36, VAS	Infection, secondary OA, unplanned secondary surgery, pain
Teng et al[41]	Case series	11	Screws in a variety of orientations	41.2	AOFAS	Loss of reduction, secondary OA
Vosbikan et al[45]	Case series	31	Percutaneous with Lisfranc screw ± intra-articular screws as required 4.0-mm	66	Return to activity, FAAM	Infection

Abbreviations: AOFAS, American Orthopaedic Ankle & Foot Society; FAAM, Foot and Ankle Ability Measure; FFI, Foot Function Index; MoxFQ, Manchester-Oxford Foot Questionnaire; OA, osteoarthritis; SF-36, Short Form–36; SMFA, Short Musculoskeletal Functional Assessment; VAS, visual analog scale.