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, MRCS¹, Richard Connell, MRCS¹, Robin Elliot, MA(Oxon) (Tr&Orth), FRCS¹, 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.¹⁴,⁴⁷ 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.¹⁶,⁴²,⁴⁷ The potential but unproven purported benefits of metalwork removal include

¹Hampshire 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

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

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.

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 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 EuroQol-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 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.

**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...
estimated according to the method reported by Hozo et al.\textsuperscript{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,\textsuperscript{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

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**Figure 1.** Flow diagram of study selection.
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 ($\pm$20.36; 65.4-94) and for the removal group was 79.97 ($\pm$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%.

**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 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)           |

* $P = .007$.

![Figure 2. Boxplot (weighted mean score and SD) comparing AOFAS for metalwork retention and metalwork removal groups.](image)
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, 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 tarso-metatarsal joint dislocation/fracture fixation concluded that routine removal of metalwork was not necessary. 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, consistent with the results of this review.

In keeping with recent studies, 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, 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. 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. 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 was not examined in this study but method of fixation is a key variable that needs to be controlled for in future analyses.

| Secondary Outcome | Group A: Retention Group | | Group B: Removal Group | |
|-------------------|--------------------------|--------------------------|--------------------------|
|                   | 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 arthrod | 6 | 2-25 | 8 | 2-13 |
| Pain              | 1 | 25 | 9 | 2-30 |
| Broken metalwork  | 3 | 2-27 | 4 | 0-16 |

Abbreviation: OA, osteoarthritis.
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

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ORCID iD

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

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Appendices

Appendix I

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 |
| 6 | EMBASE | FRACTURE/ | 82241 |
| 7 | EMBASE | (fracture*).ti,ab | 294489 |

(continued)
# Database Search term Results

|   | 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   | "ORTHEPATIC 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   | OSTEARTHRITIS/ | 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 OR 35) | 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    |
| 48| Medline  | "FRATURES, BONE"/ | 63647  |
| 49| Medline  | (42 OR 43 OR 47) | 2887   |
| 50| Medline  | (44 OR 45 OR 46 OR 49) | 994960 |
| 51| Medline  | (51 AND 52) | 1182   |
| 52| Medline  | (40 OR 41 OR 53) | 1182   |
| 53| Medline  | (hardware).ti,ab | 21762  |
| 54| Medline  | (metalwork OR screw).ti,ab | 32495  |
| 55| Medline  | "ORTHEPATIC FIXATION DEVICES"/ OR "FRATURE FIXATION"/ | 22832  |
| 56| Medline  | "BONE SCREWS"/ | 22807  |
| 57| Medline  | (55 OR 56 OR 57 OR 58) | 83271  |
| 58| Medline  | (54 AND 59) | 211    |
| 59| Medline  | "DEVICE REMOVAL"/ | 13013  |
| 60| Medline  | (removal).ti,ab | 339639 |

(continued)
| #   | Database | Search term                                                                 | Results  |
|-----|----------|-----------------------------------------------------------------------------|----------|
| 63  | Medline  | (61 OR 62)                                                                   | 347094   |
| 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                                                      | 61882    |
| 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/                                                              | 36613    |
| 72  | Medline  | (65 OR 66 OR 67 OR 68 OR 69 OR 70 OR 71)                                    | 83447    |
| 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                                                            | 73123    |
| 82  | CINAHL   | (injur*).ti,ab                                                               | 223338   |
| 83  | CINAHL   | (ligamentous).ti,ab                                                          | 1988     |
| 84  | CINAHL   | (“tarsometatarsal joint*”).ti,ab                                             | 140      |
| 85  | CINAHL   | “METATARSAL FRACTURES”/ OR “FOOT FRACTURES”/                               | 677      |
| 86  | CINAHL   | FRACTURES/                                                                   | 19814    |
| 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)                                                 | 284347   |
| 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                                                   | 12499    |
| 95  | CINAHL   | “ORTHOPEDIC FIXATION DEVICES”/ OR “FRACTURE FIXATION”/                      | 24396    |
| 96  | CINAHL   | “BONE SCREWS”/                                                               | 3048     |
| 97  | CINAHL   | (93 OR 94 OR 95 OR 96)                                                       | 34043    |
| 98  | CINAHL   | (92 AND 97)                                                                  | 222      |
| 99  | CINAHL   | “DEVICE REMOVAL”/                                                            | 4554     |
| 100 | CINAHL   | (removal).ti,ab                                                              | 33726    |
| 101 | CINAHL   | (99 OR 100)                                                                  | 36487    |
| 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                                                       | 28070    |
| 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/                                                              | 14537    |
| 110 | CINAHL   | (103 OR 104 OR 105 OR 106 OR 107 OR 108 OR 109)                             | 35801    |
| 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 post-fixation (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           | 2           | 0           | 13     | Moderate |
| Del Vecchio et al\(^6\)  | 2           | 2           | 2           | 0           | 1           | 1           | 0           | 1           | 2           | 0           | n/a         | n/a         | 8      | Moderate |
| Deol et al\(^7\)         | 2           | 2           | 1           | 1           | 2           | 2           | 0           | n/a         | 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 |
| Ghaete 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           | 0           | 0           | 2           | 2           | 2           | 2           | 2           | 16     | Moderate |
| Henning et al\(^2\)      | 2           | 2           | 2           | 2           | 2           | 2           | 0           | 2           | 2           | 2           | 2           | 2           | 21     | Low     |
| Hu et al\(^14\)          | 2           | 2           | 2           | 2           | 2           | 2           | 0           | 2           | 2           | 2           | 2           | 2           | 22     | Low     |
| Kirchner et al\(^16\)    | 2           | 2           | 2           | 2           | 2           | 2           | 0           | 2           | 2           | 2           | 2           | 2           | 22     | Low     |
| Kuo et al\(^17\)         | 2           | 1           | 0           | 1           | 1           | 2           | 0           | 0           | 1           | 2           | 1           | 1           | 13     | Moderate |
| Lau et al\(^18\)         | 2           | 0           | 0           | 1           | 1           | 2           | 0           | n/a         | n/a         | n/a         | n/a         | n/a         | 7      | High    |
| Ly et al\(^19\)          | 2           | 2           | 1           | 1           | 2           | 2           | 2           | 2           | 2           | 2           | 2           | 2           | 22     | Low     |
| Mulier et al\(^22\)      | 1           | 0           | 0           | 2           | 1           | 2           | 0           | 2           | 2           | 0           | 0           | 0           | 10     | High    |
| Meyerkort et al\(^21\)   | 2           | 1           | 0           | 1           | 1           | 1           | 0           | n/a         | n/a         | n/a         | n/a         | n/a         | 6      | High    |
| Nunley et al\(^23\)      | 1           | 1           | 0           | 1           | 1           | 1           | 0           | 1           | 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           | 1           | 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    |
| Stolte et al\(^39\)      | 2           | 2           | 2           | 2           | 2           | 2           | 0           | 2           | 2           | 2           | 2           | 2           | 20     | Low     |
| Teng et al\(^41\)        | 2           | 1           | 0           | 2           | 1           | 1           | 2           | 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 Piet et al\(^44\)    | 2           | 2           | 0           | 1           | 1           | 2           | 0           | 0           | n/a         | n/a         | n/a         | n/a         | 9      | Moderate |
| Vosbiikan et al\(^45\)   | 2           | 2           | 0           | 1           | 1           | 2           | 0           | n/a         | n/a         | n/a         | n/a         | n/a         | 8      | Moderate |
| Wagner et al\(^46\)      | 1           | 2           | 0           | 1           | 1           | 2           | 0           | n/a         | 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   | 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    | Retrospective, comparative cohort       | 20                  | Dual screw (9) or dual mini-tightrope (11)                                     | 33                 | AOFAS                                                                          |                                                                                   |
| Hawkinson et al | Case series                            | 91                  | ORIF with plate and screws                                                      |                    | Return to activity                                                              | Unplanned secondary surgery                                                                 |
| Kuo et al       | 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       | 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 |
| Ly et al        | Prospective RCT                        | 20                  | ORIF with plate and screws                                                      | 42                 | AOFAS, VAS, return to activity                                                 | Loss of reduction, unplanned secondary surgery                                      |
| Scofield et al  | 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 | 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   | 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    | 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 al¹   | 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 al²       | 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 al³ | 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 al⁷       | Case series                | 17                  | Lisfranc screw and bridging plate                                             | 24                  | Return to activity                                                           | Nerve injury, pain                                                              |
| Dubois Ferriere et al⁸ | 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 al¹¹     | 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 al¹²   | 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 al¹⁴        | 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)
| Author          | Type of Study           | No. of Participants | Fixation Method                                                                 | Mean Follow-up (mo) | Primary Outcome               | Secondary Outcome                                      |
|-----------------|-------------------------|---------------------|----------------------------------------------------------------------------------|---------------------|--------------------------------|---------------------------------------------------------|
| Kirzner et al 16| Retrospective,          | 108                 | Bridge plating 45, transarticular screws 38, combination 25                      | 33                  | AOFAS, MOxFQ                    | Infection, loss of reduction, pain,                     |
|                 | comparative cohort      |                     |                                                                                  |                     |                                |                                                         |
| Mulier et al 22 | Retrospective,          | 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    |
|                 | comparative cohort      |                     |                                                                                  |                     |                                |                                                         |
| 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 22 | Retrospective,          | 8                   | ORIF with partially threaded 4.5-mm screws                                      | 27                  | Return to activity             | Loss of reduction, pain                                 |
|                 | comparative cohort      |                     |                                                                                  |                     |                                |                                                         |
| Perugia et al 23| 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,          | 20                  | 22 ORIF (11 had K-wires only, rest with screws)                                 | 37                  | AOFAS, Maryland Foot Score,    | Infection, loss of reduction, unplanned secondary       |
|                 | comparative cohort      |                     |                                                                                  |                     | satisfaction                   | 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.