Functional Outcomes of Dorsal Bridge Plating for Lisfranc Injuries With Routine Implant Retention: A Major Trauma Center Experience

Elliot Onochie, MBBS, BSc, Nelson Bua, MBBS, Kingsley Mmerem, MBBS, Nima Heidari, MBBS, MSc, FRCS, Alexandros Vris, MD, Francesc Malagelada, LMS, FEBOT, PhD, Lee Parker, BM, FRCS, and Luckshmana Jeyaseelan, MBBS, BSc, FRCS

Objectives: To assess medium-term functional outcomes and the complication profile for unstable Lisfranc injuries treated with dorsal bridge plate (DBP) fixation when implants are not routinely removed.

Design: Large single-center retrospective case series.

Setting: Level-1 Trauma Center, London, United Kingdom.

Patients: Consecutive cases of skeletally mature individuals with unstable Lisfranc injuries treated operatively between 2014 and 2019.

Intervention: Open reduction and DBP fixation with implants not routinely removed.

Main Outcome Measurements: Patient-reported outcome measures at final follow-up. The Manchester-Oxford Foot Questionnaire summary index was the primary outcome measure. The American Orthopaedic Foot and Ankle Society (AOFAS) midfoot scale, complications, and all-cause reoperation rates were secondary outcome measures. Logistic regression models were used to identify risk factors that influenced outcomes.

Results: Eighty-five patients were included. Mean follow-up was 40.8 months (24–72). The mean Manchester-Oxford Foot Questionnaire Summary Index was 27.0 (SD 7.1) and mean AOFAS score 72.6 (SD 11.6). The presence of an intra-articular fracture was associated with poorer outcomes, with worse MOXFQ and AOFAS scores (both $P < 0.001$). Eighteen patients (21%) required implants removal, with this more likely in female patients (OR 3.89, 95% confidence interval, 1.27 to 12.0, $P = 0.02$). Eight patients (9%) required secondary arthrodesis.

Conclusions: This is the largest series of Lisfranc injuries treated with DBP fixation reported to-date and the only to routinely retain implants. Medium-term outcomes are comparable to existing literature in which implants are routinely removed. The presence of an intra-articular fracture is a poor prognostic indicator. Implant removal is more likely to be needed in female patients.

Key Words: Lisfranc, midfoot, open reduction internal fixation, bridge pate, outcomes, implant retention, hardware retention, metalwork retention

Level of Evidence: Therapeutic Level IV. See Instructions for authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2023;37:e22–e27)

INTRODUCTION

Lisfranc injuries are uncommon, accounting for an estimated 0.2% of all fractures.[1,2] Injuries range from mild sprains to extensive midfoot dislocations. The appropriate management of these injuries is important to prevent adverse sequelae including chronic pain, post-traumatic arthritis, and deformity.[3,4]

Ongoing debate exists as to which strategies are optimal in the surgical fixation of unstable Lisfranc complex injuries. Dorsal bridge plate (DBP) fixation is a recognized technique that offers rigid fixation while preventing iatrogenic damage to the tarsometatarsal joint (TMTJ) articular cartilage. The articular damage caused by transarticular (TA) screw fixation has been demonstrated, and the fact that DBPs withstand loading equally to screws.[5] A recent systematic review and meta-analysis[6] comparing bridge plates with TA screws found better functional outcome scores with bridge plates and a trend towards fewer cases of post-traumatic arthritis.[7–10] Meanwhile, several randomized prospective studies have evaluated primary arthrodesis (PA) when compared with open reduction and internal fixation. These studies have generally demonstrated no difference in medium-term functional outcomes,[11,12] although it has also been suggested that when injuries are purely ligamentous, PA may be superior.[13]

There is little evidence examining whether or not bridge plates should be electively removed. Routine removal is most often described,[7,11,14] or otherwise the decision has simply been left to surgeon discretion.[8–10,15] It has been recognized that some patients do not want implants removed[8] and that

Accepted for publication August 1, 2022.
From Barts Bone and Joint Health, Barts Health NHS Trust, London, United Kingdom.
The authors report no conflict of interest.
Presented as a virtual poster at the Annual Meeting of the American Orthopaedic Foot & Ankle Society (AOFAS), September 24, 2021, North Carolina.
Reprints: Elliot Onochie, MBBS, BSc, Barts Bone and Joint Health, Barts Health NHS Trust, Whitechapel Road, London E1 1FR, United Kingdom (e-mail: e.onochie@nhs.net).

DOI: 10.1097/BOT.0000000000002469

routine removal may be associated with an increased risk of damage to neurovascular structures.[16]

Although literature to date suggests a positive role for the use of DBP fixation in the treatment of displaced Lisfranc injuries, recent comprehensive reviews on current concepts clearly highlight the need to expand the evidence base.[17–20]

We present the largest case series to date of the surgical fixation of displaced Lisfranc injuries with DBPs and the first in which the treatment intention involves routine retention of internal fixation. The primary aim of this study was to assess medium-term patient-reported functional outcomes in this patient group treated at our Level-1 major trauma center. Secondarily, we reviewed the demographic, surgical, and injury-related risk factors that may influence outcomes. We hypothesized that DBP fixation leads to good medium-term functional outcomes with acceptably low complication rates and that routine retention of implants does not adversely affect outcomes.

MATERIALS AND METHODS

This retrospective case series review was conducted at our Level 1 Major Trauma Center. Consecutive patients who underwent open reduction and DBP fixation of displaced Lisfranc injuries between January 2014 and January 2019 were identified via an electronic trauma database. Inclusion criteria were acute displaced Lisfranc injury with a surgery date within 2 weeks of injury, age over 18 years and skeletal maturity, the use of a standardized departmental surgical technique and a minimum of 24 months follow-up. Patients with open fractures, previous ipsilateral foot surgery, severe ipsilateral or contralateral lower limb injury affecting weight-bearing, complex polytraumatized patients, and those with incomplete medical documentation were excluded.

Demographic data including age, gender, co-morbidities, and smoking status, were noted, as well as the mechanism of injury and time between injury and surgical intervention. Preoperative plain radiographs and CT scans were assessed to categorize injuries according to the Myerson[3] and Quenu & Kuss[21] classifications. Injuries were as assessed for presence of intra-articular or extra-articular fractures. Purely ligamentous injuries are defined as those with no associated fracture. In this series, even a small avulsion ruled out a purely ligamentous injury. A review of operation notes allowed recording of operative approach and fixation construct. Complications and all-cause re-operations were recorded. A diagnosis of "CRPS" was made only after referral to a pain specialist consultant, with the subsequent application of the Budapest criteria, which currently offer among the best standards in making this complex diagnosis.

The primary outcome measure was the Manchester-Oxford Foot Questionnaire Summary Index, a Patient-Reported Outcome Measure (PROM) validated in foot and ankle surgery. Lower scores indicate superior outcomes. The American Orthopaedic Foot and Ankle Society (AOFAS) midfoot scale was a secondary measure used to provide a reference for comparison with existing literature. The AOFAS scoring system is not validated and not solely a PROM, because objective data from the surgeon are also reported. Higher scores indicate superior outcomes. Outcome scores were collected at a final follow-up in-person review, and documented on electronic patient records. If a full score was not available, patients were contacted by telephone to complete their scoring at an appointment of their convenience.

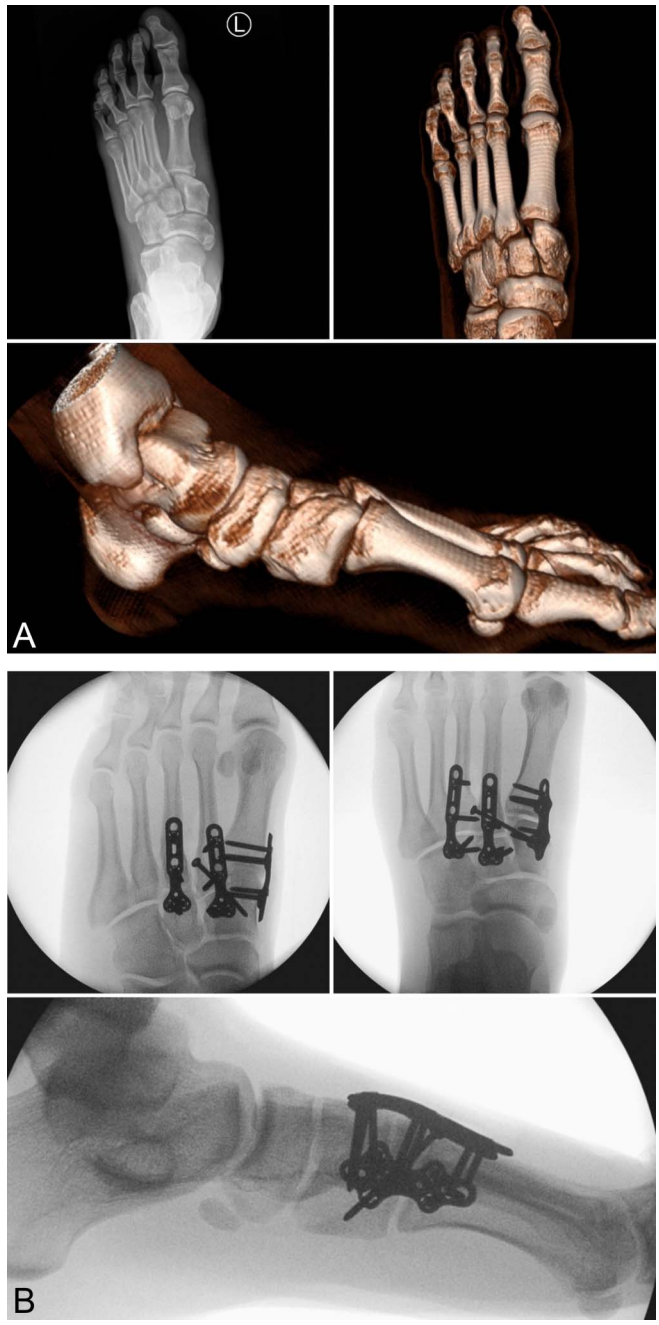

FIGURE 1. A, Preoperative plain radiographs and computerized tomography with 3D reconstruction of an unstable Lisfranc complex injury from our series. B, Fixation with DBPs of and a retrograde Lisfranc screw.

Surgical Technique

All surgery was performed by one of 5 orthopaedic surgeons with a subspeciality interest and fellowship training in foot and ankle surgery. Standardized preoperative consent forms were used to counsel patients, with the risk of needing removal of implants explicitly discussed and documented. All patients underwent general anesthesia with standard antibiotic prophylaxis and regional nerve block performed by the anesthetic team under ultrasound guidance. A tourniquet was used for all cases.

Each articulation of the Lisfranc complex was assessed and fixed individually according to congruity and stability, guided by radiologic and/or intraoperative findings. A single dorsolateral or a dual (dorsolateral and medial) incision was used depending on the number of TMTJs that needed fixation. A limited dorsal periosteal window in the joint capsule was required to precisely confirm anatomical reduction of the TMTJ. Reconstruction commenced with reduction and provisional stabilization of the first TMTJ then progressed laterally. Anatomic, low-profile locking compression plates from the DePuy Synthes 2.7 mm VA foot system were used to stabilize the relevant TMTJs. After bridge-plate fixation, any residual mechanical instability across the Lisfranc ligament or the intercuneiform joint was stabilized with 2.7-mm fully-threaded cannulated screws. A retrograde Lisfranc position screw from the base of the second metatarsal to the medial cuneiform and/or an intercuneiform screw from medial to lateral were used. The Lisfranc screw is an established technique used to augment DBP or TA screw fixation and does not violate any TMTJ. Fourth and fifth TMTJ instability was treated with single buried TA 1.6-mm kirschner wires. A typical Lisfranc injury and bridging construct is shown in Figure 1 below.

Postoperative Management

All patients had review of their intraoperative fluoroscopic images at a trauma multidisciplinary team (MDT) meeting to assess the adequacy of operative reduction and fixation. The MDT included multiple (minimum 3) consultant orthopaedic surgeons from within the trauma center, who reviewed images on a large high-definition screen. The reviewers were blinded to the operating surgeon and were asked to agree on a grading. Specifically, reduction was graded as; "anatomical—no concerns" "suboptimal—need for close follow up" or "inadequate—need to counsel patient and consider revision procedure."

Patients were kept non–weight-bearing for 6 weeks and then progressed to protected weight-bearing in a walking boot for 4 weeks. During the non–weight-bearing period, active range of motion exercises were permitted. Postoperative follow-up schedule was 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and then annually. Plain weight-bearing AP, lateral and oblique foot radiographs were performed at each follow-up appointment to examine for late displacement and implant failure. Routine postoperative CT scans were not performed.

All DBP implants were left in situ unless a patient was symptomatic and nonoperative therapies had been exhausted. The main predefined indications set out for removal of implants were; deep infection, prominence, soft tissue irritation or unexplained pain without radiological arthritic changes. Any kirschner wires used were scheduled for operative removal between 8 and 10 weeks before commencement of weight-bearing.

Specific criteria were exercised to proceed with any early secondary arthrodesis procedures. Namely, patients were functionally symptomatic with pain, and also exhibited arthritic changes on follow-up imaging.

Statistical Methods

Statistical analysis of the data was conducted using SPSS (SPSS Inc, Chicago, IL). All baseline characteristics, injury characteristics, and surgical details as detailed in Tables 1–3 were reviewed against all of our outcome measures looking for trends and associations. Two of the outcomes, MOXFQ and AOFAS, were continuous in nature. Examination of the data suggested that both of these were approximately normally distributed. As a result, linear regression was used to examine factors associated with these outcomes. Other secondary outcomes were binary in nature and analyzed using logistic regression. The exception was variables that there were no occurrences of the outcome in some categories. In such instances, Fisher exact test was performed. A P-value <0.05 was considered to be a statistically significant.

All regression analyses were performed in 2 stages. First, the separate association between each factor and the outcome was examined in univariate analyses. The second stage considered the joint association between the factors and outcome in a multivariate analysis. A backward selection procedure was used to retain only the significant (or near significant) factors in the final model.

RESULTS

Eighty-five patients were included in this study. After application of exclusion criteria, 22 other cases operated during the timeframe, were not included. The baseline characteristics of the study group are summarized in Table 1. The mean age in the group was 38.8 (18–88) years and the mean follow-up was 40.2 months (24–72). Table 2 summarizes the injury characteristics of the series. 58 patients (68%) sustained their injury through a high-energy

TABLE 1. Baseline Characteristics

Gender	Male	57 (67%)
	Female	28 (33%)
Mean age (y)		38.8 ± 15.1 {18, 88}
Comorbidities	Diabetes	7 (8%)
	Inflammatory arthritis	1 (1%)
	Cardiac	8 (9%)
	Respiratory	9 (11%)
	Other autoimmune	6 (7%)
Smoking history		51 (60%)
Mean follow-up (mo)		40.8 ± 14.3 {24, 72}

TABLE 2. Injury Characteristics

Variable	Category	Number (Percentage)
Mechanism	Crush injury	3 (4%)
	High energy	58 (68%)
	Low energy	24 (28%)
Quenu & Kuss classification	Isolated	71 (85%)
	Homolateral	10 (11%)
	Divergent	4 (5%)
Myerson classification	A	10 (12%)
	B1	35 (41%)
	B2	36 (42%)
	C1	4 (5%)
	C2	0 (0%)
Intra-articular fracture	No	37 (44%)
	Yes	48 (56%)
Extra-articular fracture	No	44 (52%)
	Yes	41 (48%)
Purely ligamentous	No	82 (96%)
	Yes	3 (4%)

mechanism. Forty-eight patients (56%) had injuries that included an intra-articular fracture and 41 (48%) had an extra articular fracture, with these not always being mutually exclusive.

Data regarding surgical fixation details is summarized in Table 3. Overall, the most common construct was DBPs fixation of 3 TMTJs (41 patients), whereas a further 9 patients required 3 DBPs and additional Kirschner wire stabilization of the lateral rays. The trauma MDT graded all cases in this series as "anatomical" in the adequacy of reduction and fixation. There were no cases that had secondary displacement after fixation.

The mean MOXFQ score was 27.0 (16–43) with an SD of 7.1. An intra-articular fracture was associated with worse MOXFQ values. Univariate analysis found that patients with an intra-articular fracture had scores that were, on average, 10.3 units higher than those without an intra articular fracture [$P < 0.001$, 95% confidence interval (CI), −8.1 to −12.4]. The association held true when multivariate analysis was performed ($P < 0.001$). There was a trend for diabetic patients to have worse MOXFQ, but this did not reach statistical significance ($P = 0.07$).

The mean AOFAS score was 72.6 (47–89) with an SD of 11.6. An intra-articular fracture was associated with worse AOFAS values. Univariate analysis found that patients with an intra-articular fracture had scores that were, on average, 9.3 units lower than those without an intra articular fracture ($P < 0.001$, 95% CI, −14.0, −4.7). This association held true when multivariate analysis was performed ($P < 0.001$). There were trends for worse outcomes in diabetic patients ($P = 0.06$) and when a Lisfranc screw was used as part of surgical fixation ($P = 0.06$).

There were 5 complications (6%) with these being in the form of 2 superficial infections that resolved with antibiotics, 2 patients with CRPS and one broken screw.

Implant removal was required in 18 patients (21.2%). Seventeen of these were for symptoms of soft tissue irritation or pain without radiological evidence of arthritis and one was for a broken and symptomatic screw. Eight of 57 male patients required removal of implants, compared with 10 of 28 female patients. The odds of implant removal were over 3 times higher in women than in men ($P = 0.03$, OR 3.40 95% CI, 1.16–9.97). When multivariate analysis was performed, female patients were more likely to need implant removal ($P = 0.02$, OR 3.89 95% CI, 1.27–12.0).

Eight patients (9.4%) in total went on to have secondary arthrodesis within the follow-up period. There was no evidence that any factors studied were associated with an increased propensity for secondary arthrodesis.

All other variables (Tables 1–3) were reviewed against the outcome measures, with no other associations found that reached statistical significance.

DISCUSSION

To our knowledge, this is the largest series to date that documents functional outcomes in patients undergoing open reduction and DPB fixation of unstable Lisfranc complex

TABLE 3. Surgical Details

Variable	Category	Number (Percentage)
Approach	Single (dorsolateral) approach	28 (33%)
	Dual (dorsolateral and medial) approach	57 (67%)
Dorsal bridge plate	1st TMTJ	64 (75%)
	2nd TMTJ	85 (100%)
	3rd TMTJ	65 (76%)
TMTJ fixation category	1 DBP	8 (9%)
	2 DBPs	27 (32%)
	3 DBPs	41 (48%)
	3 DBPs + K wires to 4th and 5th	9 (11%)
Lisfranc screw	No	13 (15%)
	Yes	72 (85%)
Intercuneiform screw	No	77 (91%)
	Yes	8 (9%)

injuries. The largest preceding studies have included between 19 and 33 cases[7–9,11,14,15] with one other study appraising 45 pure DBP cases and a further 25 cases that implemented a hybrid DBP and screw fixation technique.[10] This is also the first study to report on outcomes using a surgical methodology involving routine retention of implants.

Open reduction and DBP fixation in this series resulted in a mean MOXFQ score of 27, which is comparable with scores documented in the existing literature. Kirzner et al[10] reported a mean MOXFQ score of 45.5 in a group of 25 patients in which DBPs and screws were used in a similar way to our surgical methodology. They also reported on a separate group of 45 patients in which only DBPs were used for fixation, with a mean MOXFQ score of 25.6. In their study, implants were removed at a minimum of 6 months "when carried out;" however, this was not their main study focus and thus it was not documented how many participants had removal of implants nor the rationale for removal.

The AOFAS score has more frequently been used as an outcome measure in the existing literature on this subject.[20] The mean AOFAS score in our patient group was 72.6. Previous reported AOFAS scores after DBP fixation have a range between 63.3 and 85.[7–11,14,15] In comparison, the most recent published systematic review of fixation techniques for displaced Lisfranc injuries found a weighted mean AOFAS score of 74.2 ± 9.4 for TA screw fixation.[20]

It is of interest to contrast our results with other studies that have removed implants as part of their surgical methodology. There have been 2 studies that removed all implants electively. Hu et all[7] reported a mean AOFAS score of 83.1 in a series of 32 DBP cases, whereas Stodle et al[11] found a mean score of 85 in their series of 24. Choosing to leave it to surgeon discretion, Van Kopren et al[8] removed 81% of their implants and reported a mean AOFAS score of 76, whereas Lau et al[9] removed 88.2% of the implants in a combined DBP and screw fixation group of 17 patients, with an AOFAS score of 65.4. Our results compare well, suggesting that there is no necessity to remove implants. Potential to avoid a second surgery has implications in reducing further surgical risks and also costs to healthcare services. Analysis of functional outcome scores of patients before and after removal of any implants would have offered a very useful additional point of discussion; however, these scores were not routinely collected.

When considering risk factors for poorer prognoses, our study found that an intra-articular fracture was associated with worse MOXFQ and AOFAS scores. This is a factor that has previously been highlighted.[22] Being able to counsel and offer patients preoperative prognostic information based on injury patterns is of great use to patients and surgeons. Kirzner et al[10] reviewed prognostic indicators and suggested poorer outcomes with suboptimal anatomical reduction, increasing number of columns of the foot fixed, and in Myerson Type A and C2 injuries. It is otherwise well documented that good anatomical reduction plays a key role in optimizing functional outcomes.[3,23,24]

The overall complication rate was 6%. Two patients had superficial wound infections, 2 patients were diagnosed with CRPS, and there was one broken screw. There were no broken plates and no fracture nonunions. The reported superficial infection rate of 2% also compares well with existing literature, which includes rates between 0% and 13.9% and has included some deep infections.[7–11,14,15] Female patients were more likely to need removal of implants. There is little documented literature on this specific topic, but we hypothesize that this may be because of footwear choices, or anatomical differences between the male and female foot.[25] Interestingly, within their surgical methodology of removing implants at the surgeon's discretion "in dialogue with the patient," Van Kopren et al[8] noted that a group of patients "did not want the material removed."

Eight patients in this study went on to require early secondary arthrodesis (9%). Previous studies have reported rates ranging from 0% to 8%,[7–10,14,15] whereas the most recent systematic review of TA screws found a rate of 7.8%.[26] Secondary arthrodesis is an accepted salvage procedure in patients with debilitating post-traumatic arthritis.[27,28] Secondary arthrodesis was not more common in patients with intra-articular fractures ($P = 0.28$), and thus we found no evidence to support that this cohort of patients would be more suitable for PA as their index procedure.

Limitations of the study include the retrospective nature, and the lack of a control group or preoperative baseline PROMs. A PA comparator group would also have offered very useful information. It is also recognized that the sample size remains quite small. We note that there is some inherent heterogeneity of fixation constructs across this series, including the use of a Lisfranc screw to augment fixation or not. Statistical methodology did examine whether any of the variety of fixation constructs influenced outcomes. We acknowledge that this study does not provide any radiological outcome measures. Finally, when considering the generalizability of results; it is important to note that there were only 3 injuries that were purely ligamentous and thus applicability in this group of patients should be considered with that in mind. Further study in the form of high-quality prospective, randomized controlled studies, would address these issues.

CONCLUSIONS

This is the largest study of Lisfranc injuries treated with DBP fixation reported to date. Bridge plating is safe and, can offer good medium-term outcomes. The presence of an intraarticular fracture is a poor prognostic indicator.

This is the first study to report routine retention of DBPs. If implants are retained, one in 5 patients may require implant removal and this is more likely in female patients. Patient-reported outcomes and secondary arthrodesis rates were comparable with the existing literature in which bridge plates are routinely removed. This research therefore questions the justification for routine implant removal.

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