

■ FOOT AND ANKLE

Dorsal bridge plating or transarticular screws for Lisfranc fracture dislocations

A RETROSPECTIVE STUDY COMPARING FUNCTIONAL AND RADIOLOGICAL OUTCOMES

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Aims

The aim of this retrospective study was to compare the functional and radiological outcomes of bridge plating, screw fixation, and a combination of both methods for the treatment of Lisfranc fracture dislocations.

Patients and Methods

A total of 108 patients were treated for a Lisfranc fracture dislocation over a period of nine years. Of these, 38 underwent transarticular screw fixation, 45 dorsal bridge plating, and 25 a combination technique. Injuries were assessed preoperatively according to the Myerson classification system. The outcome measures included the American Orthopaedic Foot and Ankle Society (AOFAS) score, the validated Manchester Oxford Foot Questionnaire (MOXFQ) functional tool, and the radiological Wilppula classification of anatomical reduction.

Results

Significantly better functional outcomes were seen in the bridge plate group. These patients had a mean AOFAS score of 82.5 points, compared with 71.0 for the screw group and 63.3 for the combination group ($p < 0.001$). Similarly, the mean Manchester Oxford Foot Questionnaire score was 25.6 points in the bridge plate group, 38.1 in the screw group, and 45.5 in the combination group ($p < 0.001$).

Functional outcome was dependent on the quality of reduction ($p < 0.001$). A trend was noted which indicated that plate fixation is associated with a better anatomical reduction ($p = 0.06$). Myerson types A and C2 significantly predicted a poorer functional outcome, suggesting that total incongruity in either a homolateral or divergent pattern leads to worse outcomes. The greater the number of columns fixed the worse the outcome ($p < 0.001$).

Conclusion

Patients treated with dorsal bridge plating have better functional and radiological outcomes than those treated with transarticular screws or a combination technique.

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Lisfranc fracture dislocations consist of injuries to the bases of the five metatarsals (MTs), their articulations with the four distal tarsal bones, and disruption of the Lisfranc ligamentous complex.¹ They have a reported incidence of one per 50 000 people each year, and account for approximately 0.2% of all fractures.^{2–5} One-third are the result of a low energy twisting injury: the remainder are typically the result of high-velocity trauma.⁶ Most are unstable or displaced and require operative intervention.⁷ The goals of treatment are to achieve a painless, plantigrade, stable foot, with return to its premorbid function.⁴ Evidence suggests that maintenance of anatomical alignment is a critical factor in

achieving a good functional outcome.^{7–10} However, despite the routine usage of surgical fixation post-traumatic arthritis remains a problem in up to 94% of cases.^{9,11,12}

Traditionally, the benchmark of treatment has been open reduction and internal fixation (ORIF) with transarticular screws.¹³ Recently, however, there has been a trend towards the use of dorsal bridge plating in an attempt to avoid additional damage to the joint from screw penetration.^{10,14–16} Cadaveric studies have shown that the use of transarticular screws leads to additional damage to the articular surface of between 2% and 6%.^{17,18} The use of plates was first described in 2003 as a temporary bridge over the medial column of

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Table I. Patient and trauma characteristics and functional outcome

Characteristic	Bridge plate (n = 45)	Transarticular screws (n = 38)	Combination (n = 25)
Male gender, n (%)	31 (69)	31 (82)	16 (64)
Median age at injury, yrs (range)	35 (19 to 77)	39 (21 to 81)	35 (23 to 67)
Smoker, n (%)	14 (31)	6 (16)	6 (24)
Diabetes, n (%)	3 (7)	5 (13)	2 (8)
Trauma mechanism, n			
Motor vehicle accident	21	18	15
Fall	7	11	4
Inversion injury	11	6	5
Crush injury	6	3	1
Open fracture, n (%)	8 (18)	4 (11)	3 (12)
Removal of metal, n (%)	33 (73)	36 (95)	20 (80)
Columns fixed, n	1.9	2.1	2.5
Median follow-up, months (range)	23 (6 to 96)	38 (12 to 131)	40 (7 to 110)
Myerson classification, n			
A	6	10	10
B1	19	8	2
B2	13	12	6
C1	5	5	4
C2	2	3	3
Mean AOFAS score (range)	82 (60 to 100)	71 (5 to 95)	63 (18 to 100)
MOXFQ score (range)	26 (16 to 49)	38 (17 to 77)	46 (16 to 77)
Overall satisfaction, n (%)	32 (71)	21 (55)	8 (32)

AOFAS, American Orthopaedic Foot and Ankle Society midfoot score; MOXFQ, Manchester Oxford Foot Questionnaire

the tarsometatarsal joint (TMTJ).⁸ Recent cadaveric studies have shown that plates provide stiffer fixation and result in less displacement than screws on static and cyclic loading,^{19,20} while avoiding additional damage to the TMTJ.¹⁷

Currently, there are only a few studies of small sample size which have compared the functional^{20,21} or radiological²² outcomes of transarticular screws and dorsal bridge plating for Lisfranc injuries. The primary purpose of this retrospective cohort study was to compare the functional and radiological outcomes of dorsal bridge plating for a Lisfranc fracture dislocation with transarticular screw fixation and a combination of both techniques.

Patients and Methods

Using our hospital's electronic database, orthopaedic unit audit and the search terms 'open reduction of fracture of the TMTJ with internal fixation' and the Medicare benefits schedule (MBS) codes 47624, 47648, and 47621, we identified all patients who had sustained a Lisfranc fracture dislocation between 1 January 2005 and 30 June 2016. The Alfred hospital's human research ethics committee provided ethical approval for the study.

In the 11-year study period, a total of 158 patients presented with a Lisfranc injury. Patients were excluded from the study if they had been managed conservatively (n = 22), lost to follow-up, refused involvement, or had undergone primary arthrodesis (n = 25). A further two patients had died before the time of contact: one patient with a Charcot foot²³ was also excluded leaving 108 patients in the study (Table I). There were 78 men and 30 women with a mean age of 39.40 years (19 to 81). The

injury was in the right foot in 57 patients and the left in 51. Bridge plating was used in 45 patients (42%), transarticular screws in 38 patients (35%), and a combination of the two in 25 patients (23%). There were a high proportion (65%) of high-energy injuries, smokers (24%) and diabetics (9%). This is likely due to the level 1 trauma and tertiary referral nature of our hospital. The demographics of the three groups were comparable, although the bridge plate group had a greater percentage of smokers (31%) and open fractures (18%), and a shorter mean follow-up. The mechanism of injury, Myerson classification²⁴ and the mean number of columns fixed are given in Table I. The mean follow-up period was 34 months.

Patient data, including gender, age, smoking habits, diabetic status, trauma mechanism, open or closed injury, operation type, postoperative complications, implant removal, and follow-up data were retrieved. Postoperative complications were assessed from follow-up outpatient clinic notes and divided into: soft-tissue complications, including superficial and deep wound infections and neurovascular injury; malfixation and loss of fixation, including broken screws; severe pain; and nonunion or malunion. The institution's human research ethics committee provided ethical approval for the study.

The preoperative radiographs and CT scans were reviewed to identify associated injuries: the type of injury was categorized using the Myerson classification.²⁴ The postoperative imaging studies and operating notes were used to divide patients into three groups according to the type of surgery performed: 1) fixation of the TMTJ with transarticular screws; 2) dorsal plate fixation of the TMTJ; or 3) fixation of the TMTJ with a combination of dorsal plates and transarticular screws. In group 3, the use of



Fig. 1

Radiograph of a foot from the transarticular screw group, a foot from the bridge plate group, and a foot from the combination group.

plates and screws did not necessarily occur across the same TMTJ (Fig. 1). In terms of choice of implants, there was a move away from screws to plate fixation in 2007. Initially, plates were used in combination with screws for more severe injuries, in an attempt to provide adequate fixation. As evidence emerged that plate fixation was performing well, it started to be used on its own. Plates also became more popular as newer designs such as locking plates with reduced profiles became available. Ultimately, the choice of fixation selected was surgeon dependent. Other than the first two, all patients were fixed with locking plates. Of the 68 locking plates, 58 were manufactured by Synthes (DePuy Synthes; 2.7-mm foot plating system, Paoli, Pennsylvania) and ten were manufactured by Medartis; 2.8-mm APTUS trilock plating system (Basel, Switzerland). In total, 70 patients underwent plate fixation.

As the Lisfranc interval was only fixed with a transarticular screw in all cases, it was excluded when determining to which of the three groups the fixation belonged. Similarly, screws which transfixated any intercuneiform dislocation were also ignored when classifying the type of fixation. Group 3 therefore only included plate and/or screw fixation across multiple TMTJs. Surgery was performed by three surgeons (HB, HC, and DG), who were all members of a single surgical unit. The two junior surgeons (HC and DG) were previous fellows of HB and used similar techniques. All procedures were open to ensure good reduction. The intention of the surgeon was to achieve joint reduction and fixation rather than fusion.

The columns fixed were grouped into three, as previously described:²⁵ the rigid medial column (1st metatarsal and 1st cuneiform), a middle column (2nd and 3rd metatarsals and their respective cuneiforms), and the relatively mobile lateral column (consisting of 4th and 5th metatarsals articulating with the cuboid).^{1,26} After fixation of the medial two columns, the lateral column was assessed fluoroscopically and, if unstable or incompletely reduced, Kirschner wire (K-wire) fixation

was undertaken. The K-wires were removed after six to eight weeks. Postoperative rehabilitation was the same in all groups and consisted of six weeks non-weight-bearing, followed by protected weight-bearing in a controlled ankle motion (CAM) boot until three months had elapsed. Arch supports were used between three and six months. Implant removal, when carried out, occurred at a minimum of six months postoperatively.

Functional outcomes were measured by the American Orthopaedic Foot and Ankle Society (AOFAS) midfoot score²⁷ and the validated Manchester Oxford Foot Questionnaire (MOXFQ).²⁸ The latter is scored inversely, a lower score indicating a better outcome. Finally, patient responses were recorded for overall satisfaction as either satisfied or not satisfied.

The anatomical reduction (alignment, length, and Lisfranc interval diastasis) was assessed on postoperative images using the Wilppula classification of good, fair, or poor. Using this system a good anatomical reduction is described as a good overall shape of the foot, with a diastasis between the 1st and 2nd metatarsal bases < 5 mm and the presence of slight or no arthrosis. A fair anatomical reduction is described as a 1st and 2nd metatarsal base diastasis of 6 mm to 9 mm and slight or moderate arthrosis. Finally, a poor anatomical reduction is defined as marked deformity (e.g. cavus, abduction or adduction, shortening, or 1st metatarsal dislocation), with a diastasis between the 1st and 2nd metatarsal bases of > 10 mm and moderate to severe arthrosis.²⁹

Differences in proportions between groups were compared using the chi-squared test for equal proportions or Fisher's exact test where numbers were small. Comparisons of functional outcomes between groups were made using one-way analysis of variance or the Kruskal-Wallis test where appropriate.

Results

Primary functional outcomes are presented in Table I. Statistically, dorsal bridge plate fixation was significantly better than both screw fixation and a combination technique. The mean AOFAS score was 82.5 (59 to 100) in the bridge plate group, 71.1 (5 to 95) in the screw group, and 63.3 (18 to 100) in the combination group ($p < 0.001$). Overall, 24 patients had an excellent outcome (score ≥ 90); 36 a good outcome ($90 > \text{score} \geq 75$); 36 a fair outcome ($75 > \text{score} \geq 50$); and 12 a poor outcome (score < 49). This was reflected by the mean MOXFQ scores which were 25.6 (16 to 49) in the bridge plate group, 38.1 (17 to 77) in the screw group, and 45.5 (16 to 77) in the combination group ($p < 0.001$).

Anatomical reduction was determined using Wilppula's classification system.²⁹ Good or anatomical reduction was achieved in 37 of 45 (82.2%) cases of bridge plate fixation, 26 of 38 (68.4%) of transarticular screw fixation, and 14 of 25 (56.0%) cases in which a combination of the two fixation techniques was used. The type of surgery and grade

Table II. Immediate and latest Wilppula anatomical reduction stratified by type of surgery

Surgical technique	Wilppula anatomic reduction			p-value*
	Good	Fair	Poor	
Screws, immediate vs latest POR, n (%)	35 (92) vs 26 (68)	3 (8) vs 9 (24)	0 (0) vs 3 (8)	0.003
Plates, immediate vs latest POR, n (%)	42 (93) vs 37 (82)	3 (7) vs 7 (16)	0 (0) vs 1 (2)	0.03
Combo, immediate vs latest POR, n (%)	20 (80) vs 14 (56)	5 (20) vs 7 (28)	0 (0) vs 4 (16)	0.014

*chi-squared

POR, Postoperative radiograph

Table III. Myerson classification, Wilppula anatomical reduction, and columns fixed, stratified by functional outcome measures

Variables	AOFAS foot score	MOXFQ foot score
Myerson classification		
A	65	43
B1	81	28
B2	77	33
C1	81	30
C2	53	48
Wilppula anatomical reduction		
Good	80	29
Fair	67	41
Poor	30	66
No. of columns fixed		
1	84	24
2	77	33
3	64	42

AOFAS, American Orthopaedic Foot and Ankle Society midfoot score; MOXFQ, Manchester Oxford Foot Questionnaire

Table IV. Wilppula²⁸ anatomical reduction stratified by type of surgery across two time periods

Surgical type	Wilppula anatomic reduction, 2005 to 2012			Wilppula anatomic reduction, 2013 to 2016			p-value*
	Good	Fair	Poor	Good	Fair	Poor	
Screw, n (%)	20 (69)	7 (24)	2 (7)	6 (67)	2 (22)	1 (11)	1.00
Plate, n (%)	8 (80)	2 (20)	0 (0)	29 (83)	5 (14)	1 (3)	1.00
Combination, n (%)	9 (64)	3 (22)	2 (14)	5 (45)	4 (37)	2 (18)	0.44
Total	37 (70)	12 (23)	4 (7)	40 (73)	11 (20)	4 (7)	0.74

*chi-squared

of anatomical reduction are shown in Table II. There was a loss of quality of reduction in all three groups over time. However, the rate of loss of a good quality reduction was twice as high in the screw and combination groups as in the plate group (24% versus 11%). Furthermore, there was a trend towards a better anatomical reduction at final follow-up than in the screw and combination groups. However, this did not quite reach statistical significance (chi-squared = 5.64, $p = 0.06$).

Subgroup analyses directly compared functional outcome scores with the Myerson classification, the number of columns fixed, and quality of anatomical reduction (Table III). Myerson types A and C2 had worse functional outcomes than types B1, B2, and C1 ($p < 0.001$) on both the AOFAS (65 and 53, respectively) and MOXFQ (43 and 48, respectively) scores. An association was also

found between the radiological and functional outcome measures. A poor functional outcome was seen in patients with a poor Wilppula classification (AOFAS 30, MOXFQ 66; $p < 0.001$). A worse functional outcome was also associated with an increased number of columns fixed. Three-column fixation had a mean AOFAS score of 64 (5 to 100) and MOXFQ of 42 (16 to 77), compared with an AOFAS of 77 (36 to 100) and MOXFQ of 33 (16 to 65) with two-column fixation, and an AOFAS of 84 (52 to 100) and MOXFQ of 24 (16 to 38) with one-column fixation ($p < 0.001$).

To ensure that the improved outcomes seen in the bridge plating group were not the result of a learning curve phenomenon, the data set was chronologically ordered and divided into roughly equal halves. There were 53 patients in the earlier time period, between January 2005 and May

Table V. Complications by type of surgery

Operative type	Soft-tissue injury or infection	Pain	Nonunion or malunion	Malfixation	Total
Screws, n (%)	5 (13)	4 (11)	1 (3)	0 (0)	10 (26)
Plates, n (%)	6 (13)	1 (2)	0 (0)	4 (9)	11 (24)
Combination, n (%)	2 (8)	9 (36)	1 (4)	3 (12)	15 (60)

2012, and 55 in the later period between June 2012 and June 2016. There was no observed improvement in the quality of reduction between the two time periods using any method of fixation, suggesting that a learning curve was not a confounding factor (Table IV).

The complications for each type of operation are listed in Table V. In the screw fixation group, there was one patient with osteomyelitis who required washout and debridement of the wound, a prolonged course of intravenous antibiotics and removal of the implants. Two other patients had superficial wound infections which were treated solely with antibiotics. In the dorsal plate fixation group, three patients had ongoing deep peroneal nerve (DPN) paraesthesia and four had broken screws. In the combination group, three patients had broken screws. Severe postoperative pain was reported in nine of 25 patients in this group: two patients required an arthrodesis.

Discussion

Currently, there is no consensus about best practice and few studies^{20,21} which compare the radiological and functional outcomes after dorsal bridge plating and transarticular screw fixation. While debate continues about the best method of fixation, there is, however, a consensus that the anatomical, stable reduction of a Lisfranc injury is a prerequisite for a good outcome.^{13,22,25,30-32} A recent retrospective study by Lau et al²² reported that the risk of osteoarthritis is dependent on the quality of the reduction. A good reduction has an 18.2 times decreased risk of severe osteoarthritis compared with a fair or poor reduction. Similarly, Adib et al³³ found that in patients with an anatomical reduction, 35% developed osteoarthritis, compared with 80% of those who had a non-anatomical reduction. We also found that functional outcome improved significantly with the quality of the reduction.

In our study, dorsal bridge plate fixation gave a better functional outcome than screw fixation. Reported AOFAS midfoot scores for functional outcome have ranged from 67.5 to 84 for screw fixation:^{13,32,34-37} these are consistent with our findings. In 2014, Hu et al²⁰ described a prospective study of 60 patients which compared the functional outcome in patients with a Lisfranc injury treated by dorsal plating or transarticular screws. At short- and medium-term follow-up, the AOFAS score was only marginally better in the plate group (83.1 *versus* 78.5). A recent retrospective study of 34 patients by van Koperen et al²¹ also showed better AOFAS scores (77 *versus* 66) and levels of patient satisfaction (90% *versus* 80%) for bridge

plate fixation than screw fixation, but no statistical significance was reported. Their results were potentially confounded by the inclusion of patients treated with a combination of techniques within the bridge plate group. In addition, no analysis of anatomical reduction was undertaken. In our study, a trend was noted which suggested that plate fixation is associated with improved anatomical reduction, although this did not achieve statistical significance ($p = 0.06$). This was probably due to the small sample size. We suspect the improved functional outcomes in the plate fixation group may be related to the improved maintenance of anatomical reduction. Another potential consideration is that by avoiding further damage to the articular surface, bridge plating results in less arthrosis thereby improving the functional outcome.

Considerably worse functional outcomes were seen when a combination of plating and screws were used. There are several potential explanations for this, all of which are probably due to the severity of the initial injury. Firstly, a greater proportion of Myerson type A and C2 injuries were treated with the combination technique (52%), than by plating (16%) or screw fixation (34%). Secondly, the combination group had a greater mean number of columns fixed (2.5) compared with the plate group (1.9) and screw group (2.1). This study showed that the outcome is significantly worse when three columns have to be fixed. When more than one column has to be fixed, a more extensive soft-tissue dissection is needed which may result in greater scarring. Lastly, compounding the above issues is the use of transarticular screws, often through several joints, which results in increased articular damage and potentially more severe arthrosis.

Several classification systems for Lisfranc joint injuries are currently in use.^{24,38} To date, minimal evidence exists to show that these systems are predictors of outcome. In this study, we used the Myerson classification. In 2014, a retrospective study by Yu et al³⁹ of 80 patients with Lisfranc injuries and a mean follow-up of 24 months showed a statistically significant difference in functional outcome between Myerson type B (homolateral incomplete medially or laterally) compared with Myerson types A (homolateral complete) and C (divergent partially or completely). The results of our study agree with these findings in showing a significantly worse functional outcome in the types A and C2 than in types B1, B2, and C1. This was consistent across all three treatment groups, suggesting that complete Lisfranc injuries, either homolateral or divergent, have considerably worse outcomes whichever method of treatment is used.

A proposed drawback of plate fixation is the potential need for greater dissection, which may lead to higher rates of infection and stiffness. Bridge plating caused more paraesthesiae of the DPN, although patient satisfaction was not compromised. In this study, surgical site infection occurred more commonly in the transarticular screw group (8%) than in the plate group (4%); this concurs with previous studies.^{20,21} Notably, a lower infection rate occurred in a group with a higher proportion of smokers. Complications, particularly problems with severe pain which occurred in 36% of patients, occurred most frequently in the combination group.

This study has a number of limitations. It is primarily limited by its retrospective nature and the possibility that bias occurred in the allocation of patients to differing treatment groups. Despite this potential drawback, the three groups had similar patient demographics and proportion of open injuries. There was, however, a slightly greater proportion of complete (Myerson A and C) injuries in the combination fixation group and a greater number of columns needing to be fixed. This may have affected the results of this particular group but does not appear to have affected any direct comparison between screw and plating groups. There was a shorter duration of follow-up in the plate fixation group which reflects the fact that this is a relatively new technique. There is a possibility that if results deteriorate over time that the improved functional outcome seen in this group will become diluted. This needs to be addressed by a prospective study. Similarly, radiological follow-up was not of sufficient duration to determine whether the prevention of secondary damage to the articular surface leads to less post-traumatic arthritis: this also merits further investigation. Finally, the relatively small sample size, although still larger than other comparable studies, limited the statistical power of some of our results.

In conclusion, bridge plate fixation for Lisfranc injuries gives a better functional outcome and quality of reduction than transarticular fixation or a combination of the two techniques. Anatomical reduction gives a better functional outcome independent of the fixation technique. A combination technique is associated with a significantly poorer outcome, although this may, in part, be secondary to selection bias, with a trend noted towards more severe injuries in this group. Primary arthrodesis may be a preferred option for more severe injuries such as those of Myerson types A and C2.



Take home message:

- Bridge plate fixation for Lisfranc injuries showed improved functional outcomes and quality of reduction compared to transarticular screw fixation or a combination technique
- Better functional outcomes were also seen with anatomic reduction, independent of the fixation technique
- Complete Lisfranc injuries, either homolateral or divergent, result in considerably worse outcomes independent of the treatment modality

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