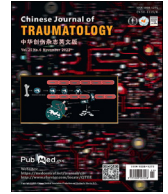




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Original Article

A modified three-incision approach to treating three-column Lisfranc injuries

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ABSTRACT

Purpose: The most popular surgical approach to manage Lisfranc fracture-dislocations is the double-incision approach, which frequently causes a variety of complications, such as skin necrosis, rotational malreduction of the first tarsometatarsal joint (TMTJ) and lateral column dorsoplantar malreduction of the TMTJ. We introduce a three-incision approach to treat Lisfranc fracture-dislocations with only minor postoperative complications and good foot function.

Methods: We prospectively selected 30 previously healthy patients, ranging from 18 to 60 years of age, but only 23 patients completed the follow-up and thus were finally included, with an average age of 38.1 ± 12.9 years. All patients have sustained Lisfranc fracture-dislocations involving all three-column; 13.0% (3/23) were Myerson classification type A (medial), 47.8% (11/23) were type A (lateral), and 39.1% (9/23) were type C2. All patients were treated via a three-incision approach: a long incision made along the lateral border of the second ray was used as a working incision to visualize and reduce the first three TMTJs, as well as to apply internal fixation instrumentation; a 2 cm medial incision was made at the medial side of the first TMTJ as an inspecting incision, ensuring good reduction of the first TMTJ in medial and plantar view; another 1 cm inspecting incision was made at the dorsal side of the fourth/fifth TMTJ to prevent sagittal subluxation of the lateral column. Mean \pm SD was used for quantitative data such as operation time, follow-up time and foot function scores. Postoperative complications were documented, and foot function was evaluated using the American orthopaedic foot & ankle society score, foot function index and Maryland foot score at follow-up. The foot function of the injured foot and contralateral foot of the same patient was at the end of follow-up, and independent sample *t*-test was used for statistical analysis.

Results: The median operation time was 117.9 ± 14.6 min (range 93 - 142 min). All complications occurred within three months after the operation, and included delayed wound healing (17.4%), superficial infection (8.7%), complex regional pain syndrome (4.3%) and neuroma (4.3%). There was no case of postoperative skin necrosis or malreduction. At the end of follow-up of 14.1 ± 1.2 months (range 12–16 months), the median American orthopaedic foot & ankle society score of the operated foot was 89.7 ± 5.7 , the median foot function index was 21.7 ± 9.9 , and the median Maryland foot score was 88.7 ± 4.8 . There were no significant differences between the operated and contralateral sides, in terms of foot function, at the end of followup ($p > 0.05$).

Conclusion: The three-incision approach can provide adequate visualization of all TMTJs to ensure anatomical reduction and offer sufficient working space to apply internal fixation instrumentation, which is effective in treating three-column Lisfranc fracture-dislocations with minor soft tissue complications and satisfactory functional recovery.

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Introduction

Lisfranc fracture-dislocation is a common injury, accounting for 0.2% of all orthopaedic injuries, but the actual incidence is higher as one third of Lisfranc injuries are missed.^{1, 2} Three-column injuries results in a very unstable midfoot, and even after surgical

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treatment, it had unsatisfactory outcomes.³ The classic dorsal surgical approach (two-incision approach) for managing Lisfranc injuries consists of making incisions between the first and second rays and along the fourth ray. This approach provides good visualization of the dorsal aspect of all tarsometatarsal joints (TMTJs), which is advantageous for applying internal fixation instrumentation. However, this approach is frequently blamed for various soft tissue complications, such as skin necrosis between incisions, delayed wound healing and infection.⁴ In addition, the two-incision approach fails to provide a three-dimensional view of the first TMTJ. Thus, malrotation of the first TMTJ or sagittal malreduction of the medial column frequently occurs, which cause a poor long-term prognosis.

The purpose of this study was to introduce a new three-incision approach, including a long working incision and two small inspecting incisions, which provides good visualization of all three columns to ensure good reduction without narrow skin flap formation in incisions to minimize soft tissue complications, not previously described. The complications of this approach were summarized, and the foot functional recovery was analysed in the study. We expected this to be an excellent surgical approach to achieve good anatomical and functional recovery with minimal complications.

Methods

The research was approved by Ethics Committee of Shen Zhen Ping Le Orthopaedic Hospital. We prospectively selected 30 patients with three-column Lisfranc fracture-dislocations since October 2018. The mechanisms of injury were motor vehicle accidents, fall from height, foot sprain, crushing by a vehicle or heavy object, etc. All patients were treated by the three-incision approach (After preoperative tests and radiological studies were performed).

The inclusion criteria were as follows¹: (1) previously healthy status,² (2) aged 18–60 years,³ (3) closed injuries,⁴ (4) no soft tissue compromise,⁵ (5) surgical treatment within 3 weeks after injury,⁶ (6) unilateral foot injury,⁷ (7) three-column Lisfranc fracture-dislocation,⁸ (8) simple intra-articular fracture, and (9) treatment of all TMTJ columns by open reduction and internal fixation (ORIF). The exclusion criteria were as follows¹: (1) previous midfoot injury,² (2) previous foot deformity,³ (3) autoimmune disease,⁴ (4) peripheral vascular disease,⁵ (5) infectious foot disease,⁶ (6) TMTJ fusion for the treatment of comminuted intra-articular TMTJ fracture-dislocation, and⁷ (7) loss to follow-up within 1 year.

Theoretically, the approach can be applied to appropriate minor open Lisfranc injuries, primary closed fractures and delayed injuries with sound soft tissue recovery. To avoid bias, all cases in this study are early closed fractures absent of unacceptable swelling or subacute cases when foot wrinkles appear. Ultimately, 7 patients lost the follow-up postoperatively, and all other 23 patients completed the follow-up with an age of 38.1 ± 12.9 years. The patient information is summarized in Table 1. The cases were classified by the Myerson classification: 13.0% (3/23) were type A (medial) injuries, 47.8% (11/23) were type A (lateral) injuries, and 39.1% (9/23) were type C2 fracture-dislocations. All patients were treated by ORIF via the three-incision approach.

Procedure

After epidural or general anaesthesia, patients were placed in the supine position. Pneumatic tourniquets were applied. After skin preparation and draping, a middle long incision was made along the second ray as a working incision, which was created from 1 cm proximal to the TMTJ distally to the second metatarsal head level. The dorsal aspect of the first TMTJ was visualized by lateral

Table 1
Patient information (n = 23).

Variables	Values
Age (year), mean ± SD	38.09 ± 12.88
Sex, n (%)	
Male	15 (65)
Female	8 (35)
Mechanism of injury, n (%)	
MVA	6 (26)
Fall	5 (22)
Sprain	9 (39)
Crush	1 (4)
Other	2 (9)
Myerson classification (three columns only), n (%)	
Type A (medial)	3 (13)
Type A (lateral)	11 (48)
Type C2	9 (39)
Time to surgery (day), mean ± SD	3.0 ± 3.1
Duration of surgery (min), mean ± SD	117.9 ± 14.7
Length of follow-up (month), mean ± SD	14.1 ± 1.2

* MVA: motor vehicle accident.

retraction of the extenso hallux longus and dorsal pedis vessel/nerve bundle, and the second and third TMTJs can be visualized by medial retraction of the dorsal pedis vessel/nerve bundle. The ruptured dorsal and interosseous Lisfranc ligament and the separation between the first and second rays can also be visualized. Then, a 2 cm inspecting incision was made as the medial incision at the medioplantar aspect of the first metatarsal to facilitate reduction to avoid dorsoplantar or rotational subluxation of the first TMTJ. After reduction of the first TMTJ, medial and dorsal bone clips were applied to maintain reduction, and 2 Kirschner wires were placed to temporarily maintain reduction. Then, the second ray was reduced to approach the first ray to achieve the anatomical niche structure, and the reduction was held by a bone clip. Intraoperative fluoroscopy was used to confirm anatomical reduction. After satisfactory reduction was achieved, the first to third rays were then fixed using trans-articular screws or bridging plates through middle incision. Finally, a 1 cm inspecting lateral incision was made at the dorsal foot between the fourth and fifth TMTJs to exposure the lateral column. Bone clips were used to perform reduction temporarily, and then Kirschner wires were placed. The procedure diagram is shown in Fig. 1, and the incisions are demonstrated in Fig. 2.

Statistical analysis

Mean ± SD was used for quantitative data such as operation time, follow-up time and foot function scores. The median operation time was 117.9 ± 14.6 min (range 93–142 min). Postoperative complications were documented, and foot function was evaluated using the American orthopaedic foot & ankle society (AOFAS) score, foot function index (FFI) and Maryland foot score, after a follow-up of 14.1 ± 1.2 months (range 12–16 months). Functional data on both sides were evaluated, function on the injured side and contralateral side was compared, and independent sample *t*-test was used. Analysis was performed using statistical software (Stata version 12, StataCorp, College Station, Texas, USA), and *p* < 0.05 was considered a statistically significant difference.

Results

The complications of the surgery are summarized in Table 2. No patient experienced wound healing failure or developed skin necrosis, but 17.4% of patients had wound healing for more than 3 weeks. Fig. 3 showed the postoperative wound condition. All patients underwent postoperative radiography to evaluate the

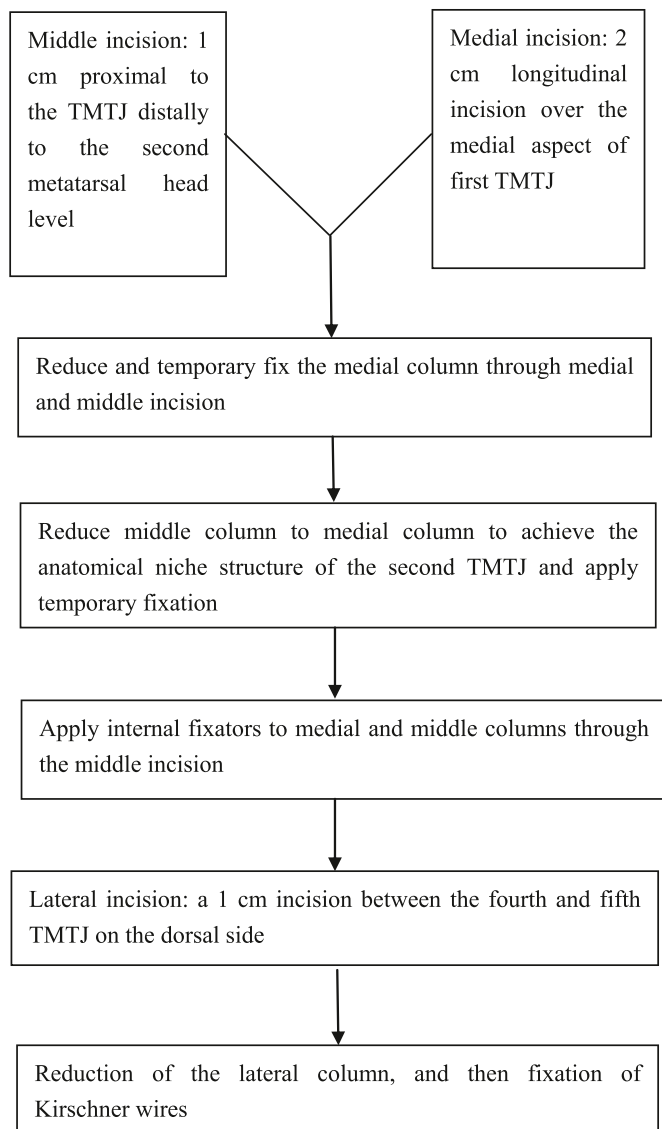


Fig. 1. The diagram of using three-incision approach to treat three-column Lisfranc fracture-dislocations. TMTJ: tarsometatarsal joint.

efficacy of reduction and placement of internal fixation devices. Anatomical reduction was achieved in all cases. Preoperative and postoperative radiographs are shown in Fig. 4. Unfortunately, one patient suffered complex regional pain syndrome postoperatively, and was successfully treated with pain relievers and physical therapy. Another patient presented a deep peroneal nerve neuroma

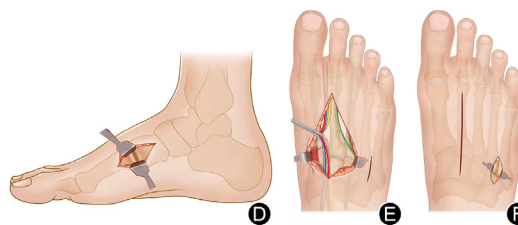
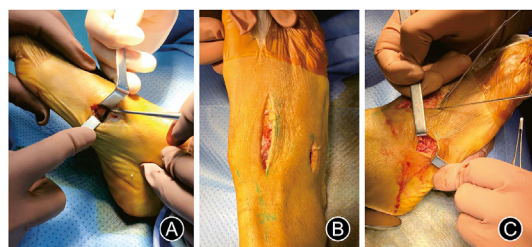


Fig. 2. The intraoperative demonstration and diagrams of the three incisions of the approach. (A) The medial view of the first TMTJ via medial incision; (B) The middle and lateral incisions; (C) The fourth and fifth TMTJs via lateral incision; (D) The diagram of the medial incision; (E) The diagram of middle incision which explores first to third TMTJs dorsally, the neurovascular bundle and extensor tendons; and (F) The diagram of lateral incision to explore the dorsal aspect of fourth and fifth TMTJs.

Table 2
Surgical complications.

Complications	Cases (n)	Percentage (%)
Delayed wound healing	4	17.4
Superficial infection	2	8.7
Skin necrosis	0	0
CRPS	1	4.3
Neuroma	1	4.3
Malreduction of any TMTJ	0	0
Screw breakage	3	13.0
Additional surgery	1	4.3

CRPS: complex regional pain syndrome, TMTJ: tarsometatarsal joint.

due to intraoperative tractive injury and postoperative scar tissue compression. After failure of cortisone steroid injection, symptoms are relieved by surgical release. As a common occurrence in Lisfranc ORIF surgeries, there were 3 cases of Lisfranc screw breakage before implant removal, all without adverse consequences.

The postoperative radiographs were taken, all of which showed satisfactory reduction of the fracture-dislocation (Fig. 4). At the end of follow-up, the AOFAS midfoot score of the operated foot ranged from 77 to 100, the FFI ranged from 5 to 43, and the Maryland foot score ranged from 80 to 95. All patients showed good or excellent foot function as assessed by all functional assessment scores. At the end of follow-up, there were no significant differences between the operated and contralateral sides, in terms of foot function ($p > 0.05$). The statistical results of foot function are summarized in Table 3.

Discussion

The Lisfranc joint refers to the TMTJ, which consists of 5 metatarsals, 3 cuneiforms, cuboid and their articulations. The first to third TMTJs compose the medial and middle columns, which are relatively rigid articulations, and the fourth and fifth TMTJs have greater flexibility. These features require rigid fixation of the medial and middle columns using bridging plates or transarticular screws, while the lateral columns are usually fixed by Kirschner.⁵

The classic approach to treat three-column Lisfranc fracture-dislocations is the double-dorsal-incision approach. The medial incision is made along the space between the first and second metatarsals and centred over the TMTJ, which provides good exposure of the dorsal aspect of the first and second TMTJs. The internal fixation of these TMTJs can be performed through this incision. The lateral incision is made along the fourth metatarsal and centred over the fourth TMTJ. Through this incision, the fourth TMTJ can be seen, and reduction is achieved. If the incision is long enough, the third and fifth TMTJs can be accessed. The third TMTJ fracture-dislocations can be managed, and internal fixation can be performed. This approach allows dorsal access to all TMTJs, and provides space to perform internal fixation. However, there are



Fig. 3. No skin necrosis at 1 week postoperatively.



Fig. 4. Case demonstration. (A) Preoperative radiographs and CT; (B) Radiographs at 2 weeks postoperatively; and (C) Radiographs at 1 year postoperatively after implant removal.

Table 3
Statistic results of foot function.

Scoring systems	Operated side (mean ± SD)	Contralateral side (mean ± SD)	p value
AOFAS midfoot	89.7 ± 5.7	98.3 ± 3.1	>0.05
FFI	21.7 ± 9.9	4.0 ± 3.3	>0.05
Maryland foot score	88.7 ± 4.8	97.9 ± 3.8	>0.05

AOFAS: American orthopaedic foot & ankle society, FFI: foot function index.

disadvantages in using this approach. First, it is impossible to access the medial and plantar sides of the first and fifth rays. Malreduction of the first TMTJ has been reported, and often appears as malrotation or plantar angulation. Furthermore, it is impossible to reduce the incidence of plantar fragments through a dorsal incision. Therefore, an additional incision is usually required at the medial side of the first TMTJ to facilitate reduction, as with our approach. Second, the narrow skin flap created between incisions often leads to skin necrosis.⁶ Postoperative tension due to swelling after creating multiple incisions often results in failed or delayed wound healing or infection.

An extensile dorsal salvage incision (EDSI) is useful for managing extensive injuries of the midfoot and provides satisfactory visualization of the first to fifth TMTJs. It runs from the dorsal aspect

of the second metatarsal head and extends proximally to the lateral malleolus, if there is a combined ankle injury. The EDSI approach also has some limitations in exploring the medial and plantar views of the first TMTJ. Therefore, a small medial incision is necessary to assist in reduction of the first ray. Another disadvantage of the EDSI approach is that it requires a long incision and extensive soft tissue dissection, if the fourth and fifth TMTJs need to be explored. The same drawback is present in the modified dorsal approach, which has been described as a single long incision along the second metatarsal starting from the second metatarsophalangeal joint extending proximally to the tarsometatarsal joint.⁴ Alternatively, the incision can be made between the second and third rays.⁷ This approach provides good exposure of the dorsal aspect of the first to third TMTJs without risk of skin necrosis, because it consists of a

Table 4
Comparison of classic approach, modified approach and three-incision approach.

Evaluation items	Classic approach	Modified approach	Transverse approach	Transverse “T” approach	Three-incision approach
Medial incision	±	±	–	+	+
Visualization of the medial and plantar of medial column	±	±	–	+	+
Visualization of the lateral column	+	–	+	+	+
Skin flap	+	–	–	+	–
Extensive (three columns) soft tissue stripping	+	–	+	+	–
Risk of wound failure due to postoperative swelling	+	–	–	+	–

± means required, + means present, - means absent.

single incision without skin flap. However, the single incision alone impossibly accesses the medial aspect of the first TMTJ and visualizes the fourth and fifth TMTJs in three-column fracture-dislocations. In addition, excessive traction of the dorsalis pedis artery during the operation may jeopardize the perforating branches to the first and second toes. Extensive dissection of fat tissue from the deep peroneal nerve makes it possible to devascularize the nerve, and leads to numbness in the first web space of the foot.

Apart from longitudinal incisions, the transverse approach also has merits. The incision is made transversely along the TMTJs, with the length depending on the number of columns involved. The TMTJs are accessed through the intervals of tendons and neurovascular bundles to achieve excellent exposure of the dorsal aspect of the TMTJs. Nevertheless, it is also difficult to achieve good exposure of the medial and plantar aspects of the first TMTJ through the transverse incision. To overcome these deficiencies, a longitudinal incision can be added to create a “T”-shaped incision by extending the transverse incision into the medial and plantar aspect of the first TMTJ. However, the right-angle flaps are at risk for skin necrosis, which often occurs.⁸ If the exposure of the medial column is required, the transverse approach can be converted to create an “L”- or “J”-shaped incision rather than a “T”-shaped incision, which effectively reduces the incidence of sharp-angle skin flap necrosis.

To summarize the key points of management of three-column Lisfranc injuries, there is a balance between exposure and soft tissue preservation. A long double incision compromises the skin of the flap between the incisions, while a single long incision in the treatment of three-column Lisfranc fracture-dislocations can lead to a postoperative deglove injury to the entire midfoot. The three-incision approach introduced in this study shows the advantages in treating three-column Lisfranc fracture-dislocations. A long middle incision provides good dorsal exposure of the TMTJs from the first ray to the third ray. A small medial incision provides sufficient access to the medial and plantar sides of the TMTJs, and another small dorsal incision is used to facilitate reduction of the fourth and fifth TMTJs. By performing this approach, there is no inter-incision flap or intensive soft tissue dissection. There were no cases of skin necrosis in our case series. The assessment of all TMTJs was achieved, and reduction as well as internal fixation instrumentation was performed. Long-term follow-up showed excellent foot function on the operated side compared to the contralateral side. The comparison between classic approach, modified approach and three-incision approach is summarized in Table 4.

There are several limitations in this study. First, the sample size of this study is small. Second, the duration of follow-up for all cases was no longer than 2 years. Previous new approach has shown promising results, and further studies with more cases and longer follow-up may provide more evidence of its effectiveness or identify its unknown shortcomings. Last, this study showed a significant improvement in foot function of patients with Lisfranc injuries by comparing with the contralateral foot. There is no cohort-controlled study to demonstrate its superiority over the

traditional approach. Therefore, the cohort-controlled study needs to be performed in the near future.

We introduce the three-incision approach to manage three-column Lisfranc fracture-dislocations, which showed a low rate of soft tissue complications, provided satisfactory exposure and resulted in good functional recovery at the end of follow-up. This approach can be used as a safe and effective method to treat three-column Lisfranc fracture-dislocations.

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Ethical statement

The study was approved by the Ethics committee of Ping Le Orthopedic Hospital.

Declaration of competing interest

The authors declared that there are no potential conflicts of interest with respect to the research, authorship, or publication of this article.

Author contributions

Ting-Hu Zhao and Wei Ren designed the study; Ting-Hu Zhao performed all the surgeries; Han-xin Chen performed patients' follow-up and data acquisition; Bin Jia and Yun-bo Bai contributed data analyses; Wei Ren wrote the manuscript; Jike Lu edit the manuscript and construct the discussion.

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