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The surgical outcome of Lisfranc injuries accompanied by multiple metatarsal fractures: A multicenter retrospective study

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ABSTRACT

Background: This study assessed the surgical outcomes of Lisfranc injuries accompanied by multiple metatarsal fractures. Metatarsal fractures here refers to metatarsal head, neck, and shaft (including shaft fractures accompanied by fractures of the base) fractures, as well as mixed (i.e., segmental fracture) fractures, as seen on imaging studies.

Methods: Between 2002 and 2015, one hundred and seventy-six patients were followed-up for a mean of 92 months, including eight patients who underwent secondary arthrodesis due to severe arthritis after ORIF. All the patients underwent surgical fusion (primary partial arthrodesis, PPA; n = 78) or non-fusion (percutaneous or open reduction and internal fixation, ORIF; n = 98) procedures and the outcomes were evaluated by clinical examinations, radiography, visual analogue scale (VAS) pain score, the American Orthopaedic Foot and Ankle Society (AOFAS) midfoot score, the Foot and Ankle Outcome Score (FAOS), and the Short Form (SF)-36 physical and SF-36 mental questionnaires. The parameters between the fusion and non-fusion groups were analyzed by repeated-measures ANOVA. Statistically significant differences between the two groups were then further analyzed using a two-independent-samples *t*-test.

Results: Anatomical reduction was achieved in 161 patients. At the last follow-up, the mean AOFAS score was 74.67 (range: 39–91) in the non-fusion group and 82.79 (range: 67–97) in the fusion group (P = 0.003). The PPA and ORIF groups differed significantly with respect to the VAS pain score (1.93 vs. 1.21), the SF-36 physical (75.87 vs. 80.90) and mental (75.76 vs. 81.33) components, and the FAOS pain (72.74 vs. 84.06), symptoms (71.87 vs. 82.49), activities of daily life (ADLs: 73.12 vs. 81.54), sport/recreation (sport/rec: 57.99 vs. 73.23), and quality of life (QoL: 79.95 vs. 86.67) components. In the ORIF group, 23 patients had mild/moderate post-traumatic osteoarthritis.

Conclusions: With longer and more conservative postoperative management, fusion results in a better outcome than non-fusion in the treatment of Lisfranc injuries accompanied by multiple metatarsal fractures.

Introduction

The Lisfranc joint consists of the tarsometatarsal (TMT) joint complex, which includes the medial, middle, and lateral cuneiforms, the cuboid, and the articulations of the five metatarsal bases [1]. Lisfranc injuries are relatively rare, comprising <1% of all fractures (incidence of 1 per 55,000 fractures) [2]. This may explain why 20% of subtle Lisfranc injuries are missed on initial patient presentation [1,3–5]. Injuries involving the Lisfranc joint can be associated with long-term disability due to subsequent painful post-traumatic osteoarthritis, chronic instability, and residual deformity [2,6,7].

In addition, Lisfranc injuries are often accompanied by complex metatarsal fracture dislocations [8], defined here as fractures of the metatarsal head, neck, and shaft (including shaft fractures accompanied by fractures of the base), as well as mixed (segmental) fractures as seen on radiological imaging. Therefore, we performed a multi-center retrospective study to determine the surgical outcome of Lisfranc injuries accompanied by multiple metatarsal fractures.

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Patients and methods

This retrospective review was based on the data of 245 patients with Lisfranc injuries accompanied by multiple metatarsal fractures, treated between January 2002 and December 2015 at three hospitals in three cities: (Hangzhou, Zhongshan, Cixi) in the east and south of China separately. The study design was approved by the institutional review board of each hospital.

The inclusion criteria were acute Lisfranc injury of <2 weeks duration and needing surgical treatment. Indications for surgery were fractures and dislocations of the Lisfranc joint characterized by displacement >2 mm in any plane and accompanied by more than one metatarsal fracture in the same foot. The exclusion criteria were: ipsilateral limb fracture, metatarsal base fractures alone, other midfoot injuries besides metatarsal fractures, arthritis of the foot, prior foot injury or infection, prior foot surgery, prior foot pathology, chronic injury >3 months duration, associated medical comorbidities such as diabetes mellitus, peripheral vascular disease, peripheral neuropathy, or autoimmune disease, and patients younger than 18 years of age. The specific admission and exclusion criteria are described in Fig. 1.

The patients were divided into two groups according to the surgical technique: non-fusion (Fig. 2) and fusion (Fig. 3). Patients in the non-fusion group were further subdivided into those treated using percutaneous Kirschner wires (K-wires), i.e., closed reduction using percutaneous K-wire fixation combined with a mini-invasive incision, (2) open reduction and internal fixation (ORIF) using a combination of transarticular screws and K-wires, (3) ORIF with dorsal plates and K-wires, or (4) ORIF using a combination of transarticular screws fixation, dorsal plates and K-wires. Patients in the fusion group consisted of those treated by primary partial arthrodesis (PPA) and were further subdivided based on the following forms of treatment: PPA with screws and K-wires, PPA with plates and K-wires, or PPA using a combination of screws, dorsal plates and K-wires. Specifically, in the fusion group, dislocations of the fourth and/or fifth TMT joints were usually fixed with K-wires. Our group often uses plates to repair metatarsal neck fractures, K-wires or plates to repair head or shaft fracture of the metatarsals, and plates or plates in combination with K-wires to repair mixed fractures.

Of the 245 patients initially enrolled in the study, the data of 176 were included in the analysis. The remaining 69 patients were excluded from further analysis. All patients were followed-up for at least 24 months.

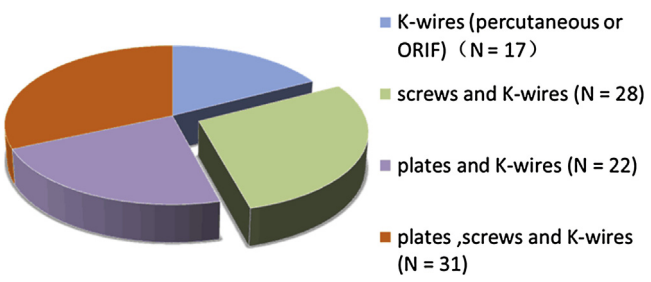

Fig. 2. Non-fusion group.

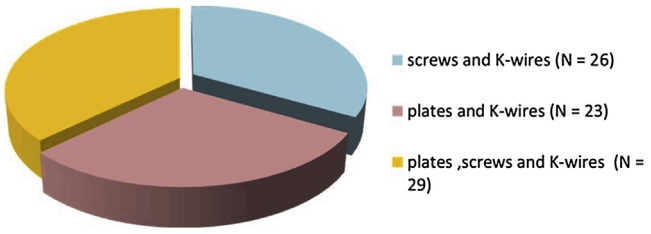

Fig. 3. Fusion group.

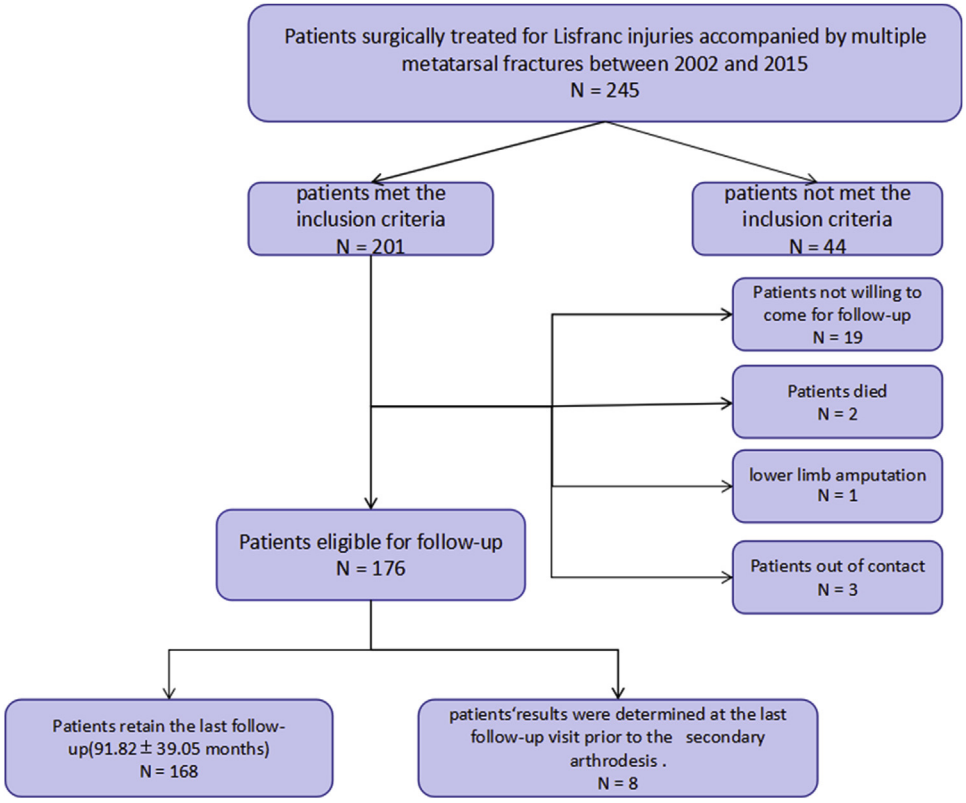

Fig. 1. Study followchart.

The characteristics of the patients, including the Myerson classification of their fractures [9], are shown in Table 1. The metatarsal fractures of the 176 patients are described in Fig. 4 and Fig. 5. They consisted of 149 closed injuries and 27 open injuries; 21 required emergency surgery, including 9 cases in which debridement and temporary fixation at a local hospital were performed before the patient was transferred to one of three hospitals participating in this study. Six of the open injuries were missed during emergency surgery due to long distance transport. Ice therapy and splint fixation were commonly applied after injury. No patients suffered compartment syndrome of the foot. Fixation operations were performed after soft-tissue swelling had subsided. The mean waiting time for surgery was 12 days (range: 8–15 days) after injury.

Postoperative management

Follow-up consisted of examinations at 2 weeks, 4 weeks, 12 weeks, 6 months, and 12 months postoperatively. A short leg splint was applied for 2 weeks followed by a short leg cast for 4–6 weeks. After clinical confirmation of a stable midfoot, percutaneous K-wires, as well as the fourth and fifth TMT K-wires, were routinely removed at 12 weeks. In the non-fusion group, screws and dorsal plates were routinely removed after imaging confirmation that the fracture had healed (mean of 10 months (range: 8–13 months) postoperatively). In the fusion group, the internal fixation was not routinely removed. All patients were permitted full weight-bearing at 12 weeks.

Postoperative clinical outcomes, including satisfaction, function, and pain, were assessed by clinical follow-up. Function and pain were measured using the American Orthopaedic Foot and Ankle Society (AOFAS) midfoot score [10], the Foot and Ankle Outcome Score (FAOS) [11], the Short Form-36 (SF-36) [12] physical and SF-36 mental questionnaires, and a visual analogue scale (VAS) for pain [13].

Imaging was performed at each follow-up examination and consisted of anterior-posterior (AP), lateral (Lat), and oblique (Obl) radiographic views. Successful anatomical reduction was defined as a medial border of the second metatarsal in line with that of the middle cuneiform (as seen on AP radiographs), a medial border of the fourth metatarsal in line with that of the cuboid (as seen on Obl radiographs), and a lateral border of the third metatarsal in line with that of the lateral cuneiform (as seen on Obl radiographs) [14]. Nonanatomical reduction was defined as a displacement >2 mm in any of these three planes. Radiographs obtained during weight-bearing were evaluated for non-union, osteophytes, malalignment, subchondral cysts, subluxation, joint-space narrowing, and post-traumatic arthritis. The degree of post-traumatic osteoarthritis was classified as none, mild/moderate, or severe according to the Kellgren-Lawrence scale [15].

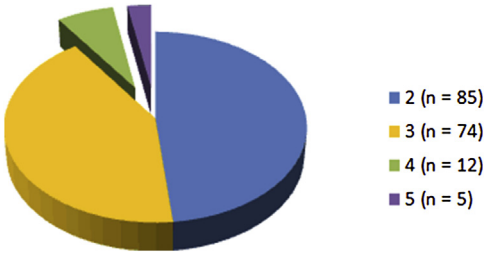

Fig. 4. Number of metatarsal fractures.

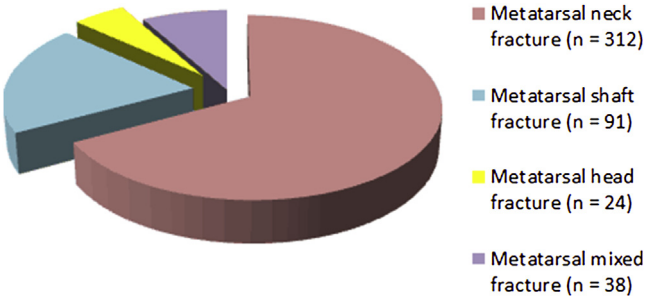

Fig. 5. Type of metatarsal fracture.

Statistical analyses

SPSS software (ver. 22.0; SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Differences in age, follow-up time, and other parameters between the fusion and non-fusion groups were analyzed by repeated-measures ANOVA. Statistically significant differences between the two groups were then further analyzed using a two-

Table 1
Demographic and Clinical Data.

	K-wires(percutaneous or ORIF)	ORIF			PPA			Total
		S+K	P+K	P+S+K	S+K	P+K	P+S+K	
Age (y)								
Mean	29.76	39.01	41.14	34.08	46.58	49.22	47.38	41.35
Range	22–43	23-50	29-53	19-49	39-57	36-61	41-53	19-61
Gender (n)								
Male	10	17	14	19	15	13	16	104
Female	7	11	8	12	11	10	13	72
Mechanism of injury (n)								
Motor vehicle accidents	9	12	10	12	9	15	13	80
Crush injuries	5	9	8	13	10	5	8	58
Falls from a height	3	7	4	6	7	3	8	38
Myerson classification (n)								
Type A	3	7	4	5	4	3	8	34
Type B1	1	0	1	2	2	3	0	9
Tybe B2	8	14	11	16	11	9	12	81
Type C1	2	5	4	5	5	4	6	31
Type C2	3	2	2	3	4	4	3	21

ORIF open reduction and internal fixation, PPA Primary partial arthrodesis. S = screw, K = K-wire, P = plate.

independent-samples *t*-test Differences between the fusion and non-fusion subgroups were analyzed by one-way ANOVA. A p value <0.05 was considered to indicate statistical significance.

Results

There were 98 patients in the non-fusion group and 78 patients in the fusion group. The average follow-up time of the 176 patients was 91 months (range: 24–153 months). Anatomical reduction was obtained in 161 patients, and nonanatomical reduction in the remaining 15 patients. The mean fracture healing time was 9.8 weeks (range: 8–13 weeks). In the fusion group, six patients had delayed fusion in the TMT joint; the fusion time was 12.9 weeks (range: 12.7–13 weeks).

Complications

Cutaneous necrosis after inter-fixation surgery developed in 16 patients, including 5 with closed and 11 with open injuries. Among these 16 patients, cuticle necrosis occurred in 5, deep skin necrosis in 4, and wound breakdown in 7. In 12 patients, healing was achieved by anti-infection medications and dressing change. The remaining four patients required surgery, including split-thickness skin-graft coverage in three patients and flap coverage in one patient. Deep-vein thrombosis developed in one patient and was cured by thrombolytic therapy. There was no cases of postoperative infection and none of the patients suffered hardware breakage.

Post-traumatic osteoarthritis

Eight (8/98) patients underwent secondary arthrodesis surgery due to severe arthritis after ORIF. The mean follow-up period from ORIF to secondary arthrodesis was 53 months (range: 26–78 months). Six of these patients were in the ORIF group and had been treated with a combination of transarticular screws and K-wires; the other two patients were in the ORIF group treated with a combination of transarticular screw fixation, dorsal plates, and K-wires. Four of the eight patients achieved anatomical reduction and the remaining four nonanatomical reduction. In the anatomical reduction group, nine metatarsals were fractured in four patients: seven in the neck, one in the shaft and one mixed type. In the nonanatomic reduction, 11 metatarsals were fractured in four patients: 7 in the neck, 3 in the shaft, and 1 mixed type. The outcomes of the eight patients who underwent secondary arthrodesis were determined at the last follow-up visit prior to the arthrodesis.

In the non-fusion group, 23 (23/98) patients had mild/moderate post-traumatic osteoarthritis, but none of them elected to undergo secondary arthrodesis. The mean follow-up period for the postoperative onset of osteoarthritis was 46 months (range: 13–75 months). The average AOFAS and VAS scores for the 23 patients were 57.65 (range: 47–87) and 3.69 (range: 1–5) respectively. The mean score for the SF-36 physical and SF-36 mental was 64.25 (range: 55–85), and 69.39 (range: 60–84), respectively. The mean pain, symptoms, ADL, sports/recreation and QoL component score of the FAOS was 59.78 (range: 51–72), 56.61 (range: 49–67), 61.56 (range: 49–83), 34.91 (range: 29–50), and 45.57 (range: 37–54) respectively. In the fusion group, seven patients had asymptomatic post-traumatic osteoarthritis.

Clinical outcomes

Group comparison by repeated-measures ANOVA yielded the following F and P values for 'operation method (fusion and non-fusion), for the AOFAS, VAS, and SF-36 physical, and SF-36 mental evaluations: 8.084 and 0.005, 10.265 and 0.002, 22.745 and 0.000, 23.843 and 0.000, respectively. The F and P values for the FAOS (pain, symptoms, ADLs, sport/rec, QoL) were: 53.238 and 0.000, 36.395 and 0.000, 0.055 and 0.814, 218.770 and 0.000, 42.039 and 0.000, respectively. All of the differences between the groups were significant ($P < 0.05$), except in the case of the ADLs component of the FAOS ($P > 0.05$).

Clinical outcomes were assessed using the AOFAS (Table 2, Figs. 6 and 7), SF-36 physical and mental (Tables 2 and 3, Fig. 7), VAS (Tables 2 and 4, Fig. 7) and FAOS (Tables 2 and 5, Fig. 8).

At the last follow-up (92 months), there were no significant differences among the subgroups of the fusion group ($P > 0.05$). For each score (AOFAS, VAS, SF-36 physical, SF-36 mental and FAOS), the mean for the group of patients treated by PPA using screws, dorsal plates, and K-wires was higher than that for each of the other two subgroups. In the non-fusion group, the average subgroup scores were highest for the ORIF group treated with dorsal plates and K-wires, followed by the group treated with K-wires (percutaneous or ORIF), the group treated with plates, screws and K-wires, and the group treated with screws and K-wires ($P < 0.05$).

AOFAS and SF-36 scores

At the last follow-up, the mean AOFAS score was 80.49 (range: 61–97) in the anatomical reduction group and 54.47 (range: 39–72) in the nonanatomical reduction group. A comparison of the mean SF-36 physical and mental scores of the anatomical and nonanatomical reduction groups yielded the following results: 80.34 (range: 65–95) vs. 54.00 (range: 40–70) ($P < 0.05$) and 80.67 (range: 60–92) vs. 52.00 (range: 36–72) ($P < 0.05$), respectively.

Table 2
Outcomes in pain, function and satisfation in lisfranc injuries accompanied by multiple metatarsal fractures.

		Follow-up	Non-fusion group	Fusion group	P value*
AOFAS		6 Months	58.69	58.09	0.900
		12 Months	69.81	70.50	0.059
		24 Months	82.31	82.23	0.111
		Last follow-up	74.67	82.79	0.003†
VAS		6 Months	2.77	2.55	0.505
		12 Months	2.08	1.81	0.286
		24 Months	1.69	1.42	0.329
		Last follow-up	1.93	1.21	0.009†
SF-36 physical		6 Months	61.53	61.99	0.056
		12 Months	67.14	73.59	0.335
		24 Months	78.37	79.68	0.089
		Last follow-up	75.87	80.90	0.013†
SF-36 mental		6 Months	59.92	63.09	0.096
		12 Months	65.92	71.85	0.916
		24 Months	78.14	79.38	0.441
		Last follow-up	75.76	81.33	0.003†
FAOS	Pain	6 Months	53.36	57.42	0.398
		12 Months	67.50	70.09	0.529
		24 Months	72.50	76.82	0.256
		Last follow-up	72.74	84.06	0.000†
	Symptoms	6 Months	59.20	57.13	0.169
		12 Months	66.48	72.65	0.609
		24 Months	73.41	77.85	0.331
		Last follow-up	71.87	82.49	0.000†
	ADLs	6 Months	56.07	54.29	
		12 Months	66.90	61.72	
		24 Months	74.14	71.77	
		Last follow-up	73.12	81.54	
	Sport/Rec	6 Months	26.78	32.87	0.975
		12 Months	36.35	40.82	0.142
		24 Months	49.54	60.53	0.069
		Last follow-up	57.99	73.23	0.000†
	QoL	6 Months	58.58	61.95	0.293
		12 Months	67.56	74.28	0.554
		24 Months	77.60	80.50	0.201
		Last follow-up	79.95	86.67	0.000†

VAS Visual Analogue Scale, AOFAS Midfoot American Orthopedic Foot and Ankle Society Midfoot Score, SF-36 Short Form 36, FAOS Foot and Ankle Outcome Score, *Two-Independent-Samples *t*-test.
† Statistically significant.

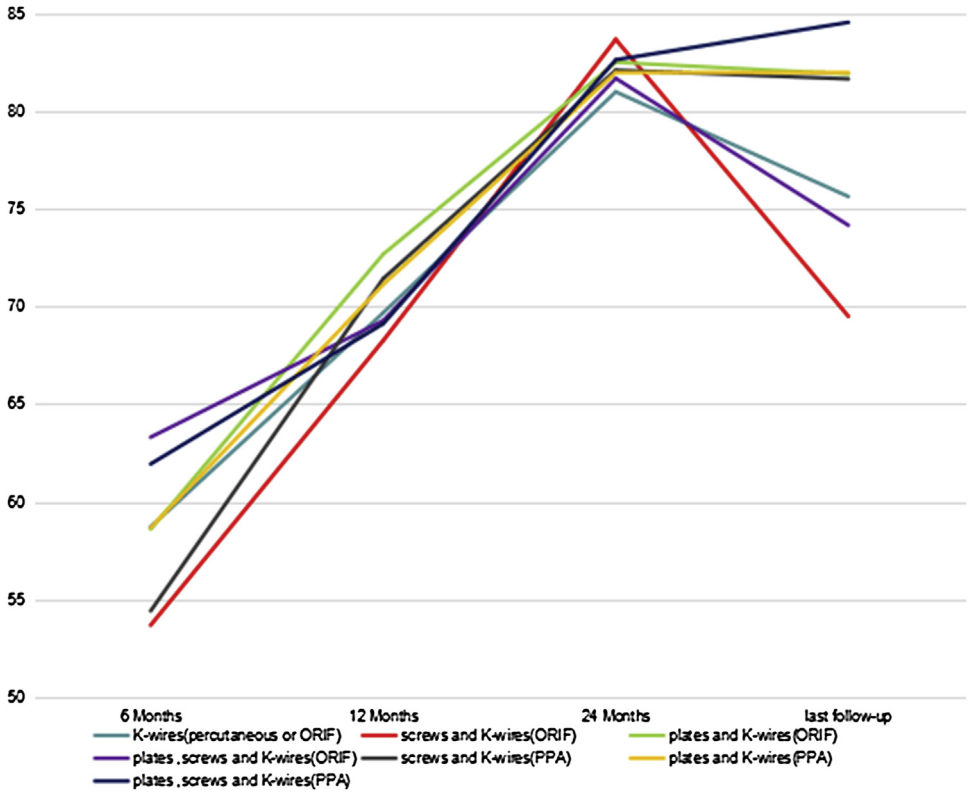

Fig. 6. Postoperative scores of AOFAS.

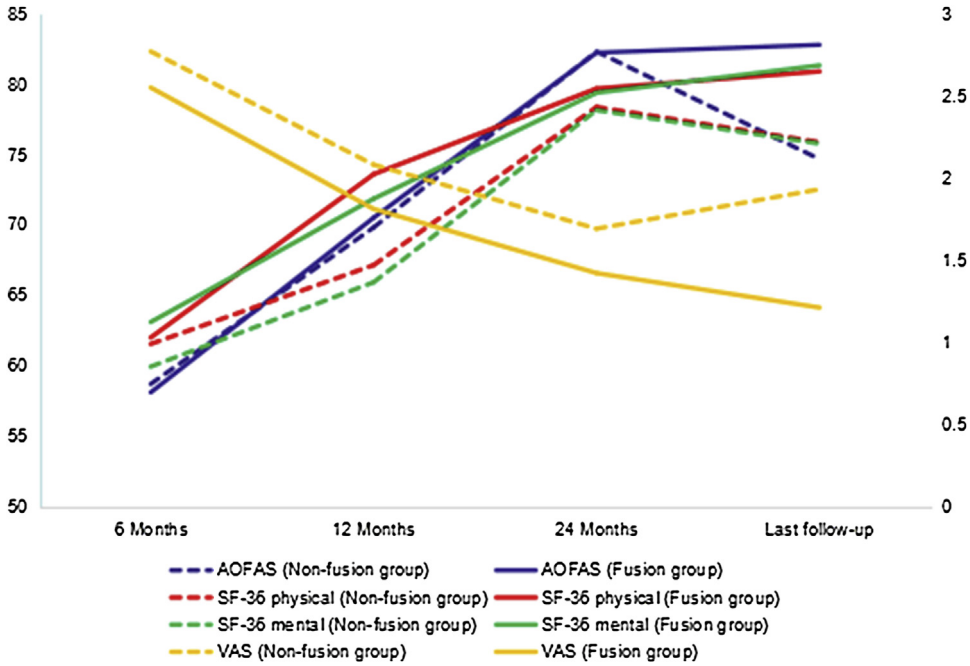

Fig. 7. Comparison of AOFAS, VAS, SF-36 physical and mental scores between Non-fusion group and Fusion group.

VAS and FAOS scores

At the last follow-up, the mean VAS score in the anatomical and nonanatomical reduction groups was 1.39 (range: 0–4), and 4.02 (range: 0–7), respectively; the difference was significant ($P < 0.05$). In a comparison of the average pain, symptoms, ADLs, sports/rec, and QoL scores of the FAOS, the results for the anatomical and nonanatomical reduction groups were as follows: 80.32 (range: 51–96) vs. 50.42 (range: 31–73), 78.51 (range: 59–99) vs. 55.57 (range: 41–72), 78.93 (range: 57–97) vs. 55.25 (range: 33–74), 66.96 (range: 40–89) vs. 41.16 (range: 23–66), and 83.61 (range: 56–97) vs. 56.28 (range: 43–75), respectively.

Table 3
Postoperative scores of SF-36 Physical and SF-36 Mental.

	K-wires(percutaneous or ORIF)	screws and K-wires(ORIF)	plates and K-wires (ORIF)	plates, screws and K-wires(ORIF)	screws and K-wires(PPA)	plates and K-wires(PPA)	plates, screws and K-wires(PPA)
Physical							
6 months	59.71	61.30	59.77	62.90	61.15	63.48	61.55
12 months	64.41	68.04	63.41	70.48	73.27	74.35	73.28
24 months	77.64	77.86	79.09	78.71	79.42	79.35	79.81
last follow-up	80.59	72.32	80.68	73.06	79.42	80.32	82.76
Mental							
6 months	56.23	60.71	60.73	60.65	61.38	64.87	62.07
12 months	62.12	67.29	62.18	69.42	70.77	72.70	72.14
24 months	79.53	78.64	77.45	77.42	76.62	80.70	80.83
last follow-up	80.47	70.86	81.45	73.55	80.46	79.65	83.45

ORIF open reduction and internal fixation, PPA primary partial arthrodesis, SF-36 Short Form 36.

Table 4
Postoperative scores of VAS.

	K-wires(percutaneous or ORIF)	screws and K-wires(ORIF)	plates and K-wires (ORIF)	plates, screws and K-wires(ORIF)	screws and K-wires(PPA)	plates and K-wires(PPA)	plates, screws and K-wires(PPA)
6 months	2.83	2.87	2.84	2.49	2.81	2.47	2.53
12 months	2.31	2.47	1.89	1.82	2.05	1.75	1.76
24 months	1.69	1.72	1.64	1.76	1.67	1.27	1.35
last follow-up	1.36	2.51	1.24	2.19	1.48	1.25	0.94

ORIF open reduction and internal fixation, PPA Primary partial arthrodesis, VAS Visual Analogue Scale.

Discussion

Lisfranc injuries are commonly accompanied by complex midfoot fracture dislocations [8], especially multiple metatarsal fractures. Anatomical reduction and stable internal fixation of the Lisfranc joint are a prerequisite and the foundations for an optimal outcome [2,8,9,16–18]. Patients with nonanatomical reduction have a significantly higher prevalence of persistent pain, post-traumatic osteoarthritis, and midfoot collapse compared with those in whom anatomical reduction is achieved [16,18]. In our study, 161 patients with an anatomical reduction and 15 with a nonanatomical reduction were followed-up for 92 months. The mean AOFAS score and the average scores for the FAOS components of pain, symptoms, ADLs, sports/rec, and QoL were compared in the two groups. As demonstrated in previous studies [9,16], we found that anatomical reduction led to a satisfactory outcome.

Whether ORIF or PPA is the best surgical treatment for Lisfranc injuries is unclear [1,8]. In our study, patients were classified into non-fusion (percutaneous K-wires or ORIF) and fusion (PPA) groups and the outcomes after > 24 months of follow-up differed significantly (Table 2). The average AOFAS, VAS, FAOS, and SF-36 physical and mental scores were slightly higher in the fusion group than in the non-fusion group. There are several reasons for the good outcomes in the fusion group. First, all of the patients in the non-fusion group underwent a second round of surgery to remove the internal fixtures, while in the fusion group only those in whom K-wires were used to repair the fractures and dislocations underwent a second round of surgery (performed on an outpatient basis), to remove the K-wires [19]. Second, post-traumatic osteoarthritis is prone to occur in patients treated with non-fusion techniques, and is an important cause of postoperative dysfunction. Similar results were reported in recent studies [7,19–22], but not all of the patients in those studies had multiple metatarsal fractures, which may lead to different outcomes.

At the last follow-up, among patients in the non-fusion group, those who underwent ORIF with dorsal plates and K-wires had a better postoperative outcome than did those treated using other approaches ($P < 0.05$). In the fusion group, patients who underwent PPA with screws, dorsal plates, and K-wires had a better outcome, but the differences compared with the other forms of PPA were not significant ($P > 0.05$). Hu et al. [23] also reported better outcomes in a plate-fixation group than in a screw-fixation group. Our result may be attributable to the more stable support that is provided by plates than by screws. The use of plates may also limit the loss of position during screw insertion [24]. In addition, compared with transarticular screws, transarticular plates do not damage the articular cartilage surface, as demonstrated in non-fusion groups in previous reports [16,22,25].

Due to the unstable fixation and loss of position resulting from fixation with K-wires, these patients may have a relatively poor outcome [16,18]. However, in our study, the rate of K-wire loosening was relatively low and the postoperative outcomes were much the same as those of patients treated with other surgical options, as also reported previously [7,19,20,22,26]. In our series, this outcome can be explained as follows: the fractures

Table 5
Postoperative scores of FAOS.

		6 months	12 months	24 months	Last follow-up
K-wires(percutaneous or ORIF)	Pain	60.96	71.03	76.14	81.20
	Symptoms	54.69	63.26	70.74	74.94
	ADLs	42.83	65.43	73.50	78.10
	Sport/Rec	32.40	45.05	54.92	64.24
	QoL	46.43	70.46	80.83	82.57
screws and K-wires(ORIF)	Pain	54.13	67.69	69.76	62.12
	Symptoms	64.61	71.50	71.19	69.10
	ADLs	56.99	61.70	71.93	69.48
	Sport/Rec	22.59	37.52	40.89	48.27
	QoL	61.65	67.17	77.44	72.30
plates and K-wires(ORIF)	Pain	57.90	71.83	79.40	82.55
	Symptoms	61.81	61.89	74.99	74.71
	ADLs	61.38	71.60	74.68	77.89
	Sport/Rec	22.60	33.96	49.14	68.78
	QoL	66.37	75.91	74.96	83.97
plates, screws and K-wires(ORIF)	Pain	45.28	62.30	68.07	73.30
	Symptoms	54.6	66.94	75.79	70.42
	ADLs	58.88	68.98	76.16	70.17
	Sport/Rec	30.45	32.33	54.74	57.52
	QoL	56.90	60.43	77.90	75.13
screws and K-wires(PPA)	Pain	57.09	65.15	75.27	80.63
	Symptoms	54.01	71.85	75.78	79.57
	ADLs	48.12	57.90	64.93	79.76
	Sport/Rec	35.21	42.34	59.63	74.68
	QoL	58.73	68.49	73.20	83.71
plates and K-wires(PPA)	Pain	55.10	69.73	76.59	84.51
	Symptoms	58.10	66.89	77.72	81.27
	ADLs	56.40	65.13	68.76	83.69
	Sport/Rec	30.54	39.16	69.70	72.49
	QoL	60.18	73.78	80.24	88.07
plates, screws and K-wires(PPA)	Pain	59.50	74.90	78.43	86.83
	Symptoms	61.91	78.12	79.74	86.01
	ADLs	58.23	62.39	80.45	81.31
	Sport/Rec	32.58	40.69	54.17	72.53
	QoL	66.26	79.92	87.21	88.31

ORIF open reduction and internal fixation, PPA Primary partial arthrodesis,FAOS Foot and Ankle Outcome Score.

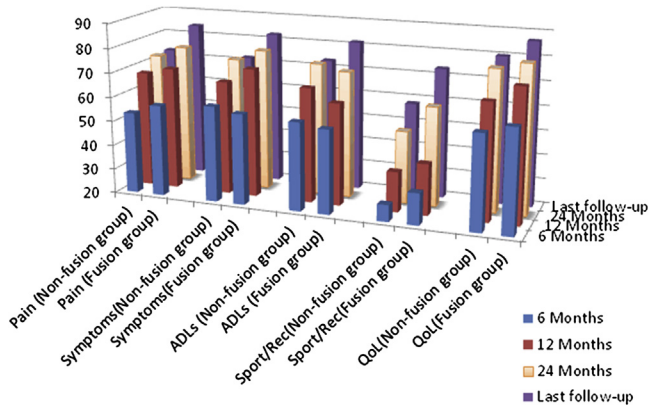

Fig. 8. Comparison of FAOS scores between Non-fusion group and Fusion group.

repaired with percutaneous K-wires were less severe, K-wires caused less damage to the joint surface than did screws [27], and patients probably benefited from both the long external fixation time achieved using a plaster splint and the delay in weight-bearing. Qu et al. [27] and Herscovici and Scaduto [26] reported accurate joint restoration and K-wire fixation in patients with soft-tissue damage resulting from high-energy injuries.

Patients with severe post-traumatic osteoarthritis after ORIF require secondary arthrodesis. Among the eight patients in our study who underwent secondary arthrodesis, the mean duration from ORIF to this procedure was 53 months (range: 26–78 months). In the ORIF group, 23 patients had mild/moderate post-traumatic osteoarthritis and secondary arthrodesis was not performed, an approach also chosen by Dubois et al. [28]. The rate of fusion after primary fixation was low, but might have been higher after longer follow-up. Secondary fusion was rejected for 23/98 patients. The main cause of post-traumatic osteoarthritis is disruption of the articular cartilage by transarticular screws and K-wires [16,22,25], such that primary PPA has been recommended for these patients [19,22]. The asymptomatic post-traumatic osteoarthritis detected in seven patients in the fusion group can be explained by our decision to fuse only the middle column medially or partially, with asymptomatic osteoarthritis developing in the non-fusion joints.

The mean time to fracture healing was 9.8 weeks, which was earlier than in other reports [1,8,19,20,22]. Local congestion caused by multiple injuries to the foot may have accelerated fracture healing but this hypothesis remains to be investigated in future studies.

Our study had a limitation. It was retrospective and a multi-center study, surgeons chose treatments according to their experience rather than by following a uniform hospital protocol. Thus, a prospective randomized controlled trial is needed.

Conclusion

In patients with Lisfranc injuries accompanied by multiple metatarsal fractures, longer and more conservative postoperative management resulted in a better outcome at the last follow-up in the fusion group than in the non-fusion group. Among patients in the fusion group, the best outcome was achieved in patients treated by PPA with screws, dorsal plates, and K-wires. Within the

non-fusion group, patients who underwent ORIF with dorsal plates and K-wires had an optimal postoperative outcome.

Conflict of interest

None.

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Ethical approval

Our study involving human participants was approved by the institutional review board of each participating hospital. No animals were used in the study.

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