

Comparative analysis of the clinical efficacy of primary fusion and open reduction and internal fixation in the treatment of ligamentous three-column Lisfranc injury

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Abstract

Background

Three-column Lisfranc injury is a prevalent injury in midfoot that significantly affects athletes and active individuals, leading to impaired function and substantial economic burdens. This study aims to evaluate the clinical effects of primary fusion and open reduction and internal fixation in the treatment of ligamentous three-column Lisfranc injury by comparing clinical outcomes between patients in two groups.

Methods

A retrospective analysis of the medical records of 128 cases of ligamentous three-column Lisfranc injury with primary fusion and open reduction and internal fixation in 3 hospitals was conducted. Among them, primary fusion group contained 53 cases, and open reduction and internal fixation group contained 75 cases. There were 30 males and 23 females in the fusion group, with an average age of 37.8 years, 34 cases on the left and 19 cases on the right; the open reduction and internal fixation group had 51 males and 24 females, with an average age of 38.4 years and 48 cases on the left, 27 cases on the right. All patients with open reduction and internal fixation took out the internal fixation one year after the operation. Record the time from injury to surgery, operation time, time to return to work and occurrence of related complications for all patients. The American Orthopaedic Foot and Ankle Surgery Association (AOFAS) midfoot score, pain visual analogue scale (VAS) and SF-36 health survey summary scores were recorded at 3 months after operation and at the last follow-up.

Results

All patients were followed up for more than 2 years. The follow-up time of patients in the fusion group was 27.1 ± 2.2 months, while the follow-up time of the open reduction and internal fixation group was 26.9 ± 2.5 months. There was no statistical difference in gender and left and right sides between the two groups of patients ($P > 0.05$). There was no significant difference in age, time from injury to operation, follow-up time, and AOFAS score, VAS score, and SF-36 score in the three months after surgery ($P > 0.05$). The operation time, time to return to work and the AOFAS score, VAS score and SF-36 score at the last follow-up were significantly different ($P < 0.05$). In the fusion group, the AOFAS score, VAS score and SF-36 score of the two follow-ups were significantly different ($P < 0.05$). In the internal fixation group, the AOFAS scores between the two follow-ups were significantly different ($P < 0.05$), while the VAS score and SF-36 score were not significantly different ($P > 0.05$). The incisions healed in all patients after surgery. During the follow-up period, 19 patients (6 in fusion group and 13 in internal fixation group) found pain in the midfoot during walking. The 6 patients in the fusion group were all cuneiform navicular arthritis, which resolved after conservative treatment such as oral non-steroidal drugs. 13 patients in the internal fixation group were considered as Lisfranc joint traumatic arthritis or joint instability. Among them, 3

patients were relieved after conservative treatment such as oral non-steroidal drugs, and 4 patients experienced internal fixation fracture and secondary arch collapse and forefoot abduction deformity, and the other 6 patients had foot arch collapse and forefoot abduction deformity after the internal fixation was removed. The 10 patients were reoperated with fusion, and the postoperative follow-up recovered well. 30 patients (22 cases in the fusion group, 41.5%; 8 cases in the internal fixation group, 10.7%) complained of stiffness and discomfort in the midfoot. The reoperation rate in the fusion group was 0, while the reoperation rate in the internal fixation group was 13.3%.

Conclusion

The clinical efficacy of primary fusion in the treatment of ligamentous three-column Lisfranc injury is significantly better than open reduction and internal fixation, and it is worthy of widespread clinical promotion.

Introduction

Lisfranc injuries are relatively uncommon, accounting for only 0.2% of all fractures [1]. Most such injuries result from high-energy trauma. Inadequate management may lead to midfoot deformity, persistent pain and functional impairment, which substantially interfere with patients' occupational activities and daily life. Clinically, Lisfranc injuries carry a remarkably high rate of missed diagnosis, which has been reported to reach one-third in the literature [2–4]. Therefore, weight-bearing radiographs of the foot or computed tomography (CT) are essential examinations for patients with suspected injuries [5]. Weight-bearing CT or magnetic resonance imaging (MRI) should be implemented when necessary to avoid missed diagnoses [6–8].

High-energy trauma often causes three-column injuries, which represent the most prevalent pattern in clinical practice. Controversies persist regarding the optimal treatment strategy for three-column Lisfranc injuries. An increasing number of researchers currently advocate that primary arthrodesis results superior outcomes compared with primary open reduction and internal fixation (ORIF) for ligamentous three-column Lisfranc injuries [9–11]. Particularly for young and middle-aged patients or those with high functional demands on weight-bearing of the foot, primary arthrodesis can achieve more stable fixation of the tarsometatarsal joints.

From December 2012 to December 2023, our hospital collaborated with other 2 Hospitals to conduct a retrospective analysis of clinical data from 128 patients diagnosed with ligamentous three-column Lisfranc injuries. The time to return to work and postoperative functional scores obtained during follow-up were recorded to compare clinical efficacy between the two surgical procedures. The results are reported as follows.

Methods

1. Study Subjects

This was a retrospective study. The protocol was approved by the Institutional Review Board of our hospital, and written informed consent was obtained from all enrolled patients.

Inclusion criteria: (1) Isolated ligamentous Lisfranc injury of a single foot predominantly presenting as dislocation with three-column involvement; (2) Good general health without concomitant systemic diseases; (3) Acute closed injury (time from injury < 1 week); (4) Transarticular fixation using bridging plates; (5) Minimum follow-up duration of 2 years.

Exclusion criteria: (1) Elderly patients or patients complicated with other underlying diseases; (2) Concomitant injuries in other regions of the affected limb; (3) no dislocation with three-column joints; (4) Open injury or complicated with neurovascular injury; (5) Previous trauma history of the affected foot; (6) Retained internal implants at 1 year after open reduction and internal fixation (ORIF).

According to the above inclusion and exclusion criteria, clinical data of 128 patients with ligamentous Lisfranc injuries treated with either primary arthrodesis or open reduction and internal fixation were collected from December 2012 to December 2023. The patients were recruited from 3 hospitals. Among these patients, 53 underwent primary arthrodesis, and 75 received ORIF.

In the arthrodesis group, there were 30 males and 23 females, with a mean age of 37.8 years; 34 injuries occurred on the left side and 19 on the right side. In the ORIF group, there were 51 males and 24 females, with a mean age of 38.4 years; 48 injuries were on the left side and 27 on the right side. Gender and injured side were compared between the two groups (Table 1). The interval from injury to surgery was also recorded for all patients (Table 2).

Table 1
Gender and injured side distribution in the arthrodesis group and ORIF group

Variables	Arthrodesis group	ORIF group	χ^2 value	P value
Gender (Male/Female)	30/23	51/24	1.736	0.188
Injured side (Left/Right)	34/19	48/27	0.000	0.986

Table 2
Preoperative baseline data of the arthrodesis group and ORIF group

Variables	Arthrodesis group	ORIF group	χ^2 value	P value
Age (years)	37.8 $\pm$ 8.7	38.4 $\pm$ 9.3	-0.389	0.698
Interval from injury to surgery (days)	4.6 $\pm$ 1.3	4.6 $\pm$ 1.1	0.080	0.937

2. Surgical Strategy and Techniques

All patients in the arthrodesis group received surgery under neuraxial anesthesia in the supine position, with an inflatable tourniquet applied around the proximal thigh. A longitudinal dual dorsal incision approach was adopted. Adequate skin bridge width between the two incisions should be preserved to avoid cutaneous and soft tissue complications. The medial incision was typically made dorsally over the second tarsometatarsal joint. After skin incision, layer-by-layer dissection was performed. The extensor hallucis longus tendon, together with the dorsal neurovascular bundle, was retracted laterally to expose the 1–3 tarsometatarsal joints.

Hematoma outside the joints and incarcerated periarticular soft tissues were debrided first. Subsequently, tarsometatarsal and intercuneiform joints were sequentially distracted using Kirschner wire retractors. Intra-articular incarcerated tissues and articular cartilage were thoroughly removed, followed by subchondral drilling with 2.0 mm Kirschner wires (microfracture technique). Guided by the windlass mechanism of the plantar fascia, the medial column (medial cuneiform and first metatarsal) was reduced under direct visualization. A pointed reduction clamp was applied for compressive stabilization, and temporary Kirschner wire fixation was implemented once anatomic reduction was achieved.

Using the medial column as a template, the base of the second metatarsal was reduced to the corresponding medial and intermediate cuneiform bones. Temporary Kirschner wire fixation was similarly applied to the second tarsometatarsal and intercuneiform joints. The third tarsometatarsal and intercuneiform joints were reduced and stabilized in the same procedure. Intraoperative fluoroscopy with a C-arm image intensifier was used to confirm satisfactory reduction. Morselized autologous cancellous iliac bone graft was implanted into the spaces of the 1–3 tarsometatarsal joints. Transarticular dorsal bridging plates (2.0 mm or 2.7 mm, DePuy Synthes) were selected to fix the medial cuneiform to the first metatarsal, intermediate cuneiform to the second metatarsal, and lateral cuneiform to the third metatarsal.

The surgical procedure for the ORIF group was identical to that of the arthrodesis group, except that articular surfaces were preserved without debridement; fixation was performed directly after reduction.

For lateral column injuries, a longitudinal dorsal incision over the fourth tarsometatarsal joint was generally made. Care was taken to protect the extensor digitorum brevis tendon and superficial peroneal nerve during dissection. The fourth and fifth tarsometatarsal joints were debrided and reduced, followed by percutaneous Kirschner wire fixation when reduction was confirmed. In patients complicated by cuboid compression fracture, release and reduction were performed, and structural wedge-shaped iliac bone graft was implanted. After Kirschner wire fixation, a mini external fixator was applied to support the lateral column, to prevent forefoot abduction deformity secondary to lateral column shortening [12].

3. Postoperative Management and Follow-up

A negative-pressure drainage tube was routinely placed intraoperatively and removed at dressing change 2 days postoperatively. Prophylactic antibiotics, detumescent and analgesic agents were administered for symptomatic management. The ankle was immobilized in the neutral position using a posterior polymer splint. The splint was removed at 2 weeks postoperatively, followed by active and passive flexion-extension exercises of the ankle and toes. Kirschner wires and external fixators were removed at 6 weeks after surgery, and partial weight-bearing was initiated under the protection of a walking boot.

Planned follow-up visits with radiography were scheduled at 6 weeks, 3 months and 6 months postoperatively, followed by semiannual examinations thereafter. Implants were removed at 1 year after surgery in all patients receiving ORIF, with continued regular follow-up. Radiographic evaluation and physical examination were performed to assess osseous union. Full weight-bearing was permitted once clinical union was confirmed, and an arch support insole could be used for auxiliary support.

Data including the interval from injury to surgery, operative duration, time to return to work, and incidence of complications were recorded for all patients. The American Orthopaedic Foot & Ankle Society (AOFAS) midfoot score, Visual Analogue Scale (VAS) for pain, and Short Form-36 (SF-36) health survey scores were documented at 3 months postoperatively and at the final follow-up.

4. Statistical Analysis

Statistical analysis were performed using SPSS 23.0 software. The chi-square test was used for comparisons of gender and injured side. All measurement data were expressed as mean $\pm$ standard deviation. Intergroup comparisons were conducted using independent-samples t-test, and intragroup comparisons using paired t-test. P value < 0.05 was considered statistically significant.

Results

1. Intergroup and Intragroup Comparisons between the Two Groups

All patients completed a minimum follow-up of 2 years. The mean follow-up duration was 27.1 ± 2.2 months in the arthrodesis group and 26.9 ± 2.5 months in the ORIF group. No significant intergroup differences were observed with respect to gender and injured side ($P > 0.05$). Similarly, there were no statistically significant differences in age, interval from injury to surgery, follow-up duration, as well as the AOFAS midfoot score, VAS pain score and SF-36 score at 3 months postoperatively between the two groups ($P > 0.05$). Significant intergroup differences were identified in operative duration, time to return to work, and the AOFAS midfoot score, VAS pain score and SF-36 score at the final follow-up ($P < 0.05$) (Table 3).

Within the arthrodesis group, significant differences were found in the AOFAS midfoot score, VAS pain score and SF-36 score between the two follow-up time points ($P < 0.05$). In the ORIF group, the AOFAS

midfoot score differed significantly between the two time points ($P < 0.05$), whereas no significant differences were detected in the VAS pain score and SF-36 score ($P > 0.05$) (Table 4).

Table 3
Postoperative follow-up outcomes of the arthrodesis group and ORIF group

Variables	Arthrodesis group	ORIF group	χ^2 value	P value
Follow-up duration (months)	27.1 $\pm$ 2.2	26.9 $\pm$ 2.5	0.480	0.632
Operative duration (minutes)	89.6 $\pm$ 7.8	70.1 $\pm$ 7.9	13.812	0.000
Time to return to work (months)	3.5 $\pm$ 0.6	4.1 $\pm$ 0.7	-4.965	0.000
Reoperation rate	0	13.3%		
Incidence of midfoot stiffness	41.5%	13.3%		
AOFAS midfoot score				
3 months postoperatively	77.9 $\pm$ 4.4	78.3 $\pm$ 4.6	-0.402	0.688
Final follow-up	85.8 $\pm$ 4.8	73.9 $\pm$ 4.2	14.951	0.000
VAS pain score				
3 months postoperatively	1.0 $\pm$ 0.8	1.0 $\pm$ 0.7	0.060	0.953
Final follow-up	0.5 $\pm$ 0.7	1.2 $\pm$ 0.9	-4.515	0.000
SF-36 score				
3 months postoperatively	73.7 $\pm$ 4.3	74.3 $\pm$ 4.7	-0.707	0.481
Final follow-up	83.7 $\pm$ 4.1	73.4 $\pm$ 4.5	13.223	0.000

Table 4
Intragroup comparisons within the arthrodesis group and ORIF group

Variables	3 months postoperatively	Final follow-up	t value	P value
Arthrodesis group				
AOFAS midfoot score	77.9 $\pm$ 4.4	85.8 $\pm$ 4.8	-16.561	0.000
VAS pain score	1.0 $\pm$ 0.8	0.5 $\pm$ 0.7	7.076	0.000
SF-36 score	73.7 $\pm$ 4.3	83.7 $\pm$ 4.1	-26.022	0.000
ORIF group				
AOFAS midfoot score	78.3 $\pm$ 4.6	73.9 $\pm$ 4.2	6.762	0.000
VAS pain score	1.0 $\pm$ 0.7	1.2 $\pm$ 0.9	-1.778	0.080
SF-36 score	74.3 $\pm$ 4.7	73.4 $\pm$ 4.5	1.649	0.103

2. Complications

All wounds achieved primary healing after surgery. During follow-up, 19 patients (6 in the arthrodesis group and 13 in the ORIF group) presented with midfoot pain during weight-bearing ambulation. The six symptomatic patients in the arthrodesis group were diagnosed with naviculocuneiform osteoarthritis, and symptoms were alleviated after conservative management including oral nonsteroidal anti-inflammatory drugs (NSAIDs).

The 13 patients in the ORIF group were considered to have post-traumatic arthritis or persistent instability of the Lisfranc joint complex. Among them, three obtained pain relief via conservative treatment with oral NSAIDs. Four patients suffered implant breakage complicated by secondary arch collapse and forefoot abduction deformity, and another six developed arch collapse and forefoot abduction deformity after implant removal. All these ten patients underwent secondary arthrodesis and achieved satisfactory recovery during subsequent follow-up.

Thirty patients reported discomfort related to midfoot stiffness, including 22 patients in the arthrodesis group (41.5%) and eight in the ORIF group (10.7%). The reoperation rate was 0% in the arthrodesis group and 13.3% in the ORIF group.

Representative cases are shown in Fig. 1 and Fig. 2.

Discussion

The optimal surgical strategy for Lisfranc injuries, namely primary arthrodesis versus open reduction and internal fixation (ORIF), remains a controversial clinical topic [13–15]. Magill et al. [16] demonstrated that primary arthrodesis yields superior pain relief, better functional scores, and a lower revision rate compared with ORIF. In contrast, Alcelik et al. [17] found no significant differences in postoperative functional outcomes between the two techniques; however, patients treated with ORIF exhibited significantly higher rates of implant removal and secondary arthrodesis. These findings are consistent with the results of the present study, which revealed a markedly higher reoperation rate in the ORIF group. Patel et al. [18] suggested that ORIF is suitable for Lisfranc injuries with positive stress test results and subluxation of the second tarsometatarsal joint without dorsal displacement, whereas primary arthrodesis is recommended for injuries characterized by dorsal displacement or comminuted articular fractures to ensure reliable midfoot stability. Coetzee et al. [19] reported that primary arthrodesis achieves superior short- and medium-term clinical outcomes compared with ORIF for isolated ligamentous Lisfranc injuries.

In the current study, the superiorities of primary arthrodesis for ligamentous Lisfranc three-column injuries are summarized as follows. Firstly, for young and middle-aged patients or athletes with high postoperative functional demands, primary arthrodesis provides a more stable biomechanical structure than ORIF, meeting the requirements of daily activities and occupational work [20,21]. Secondly, for patients with pure ligamentous injuries, scar healing of damaged ligaments leads to irreversible

alterations in tissue morphology, texture, and mechanical strength, which fail to maintain the physiological stability of the tarsometatarsal joints, thereby resulting in a high secondary surgery rate in ORIF patients. Thirdly, primary arthrodesis significantly reduces the reoperation rate, effectively lowering medical costs and shortening the postoperative rehabilitation period. Nevertheless, primary arthrodesis has inherent limitations. Prolonged operative duration may increase the risk of perioperative complications. Additionally, midfoot stiffness and impaired fine foot mobility are unavoidable sequelae of arthrodesis. Moreover, iliac bone graft harvesting may cause donor-site morbidity.

The Lisfranc complex possesses unique anatomical characteristics. The second metatarsal is the longest, with its base wedged between the medial and intermediate cuneiform bones, forming a mortise-and-tenon structure that enhances the transverse stability of the first to third tarsometatarsal joints. An anatomical study by Yu-Kai et al. [22] verified that a deeper and wider mortise-and-tenon structure correlates with greater midfoot stability. The Lisfranc ligament is critical for stabilizing the interval between the first and second tarsometatarsal joints [23]. The medial and middle columns have limited physiological mobility, making them suitable for rigid fixation and arthrodesis [24]. Arthrodesis maintains permanent tarsometatarsal stability via osseous fusion. In comparison, the joint stability of ORIF patients is entirely dependent on internal implants in the early postoperative period. After implant removal, stability is solely maintained by scarred ligaments with compromised mechanical properties.

In this study, no significant intergroup differences were observed in AOFAS midfoot scores, VAS pain scores, or SF-36 scores at 3 months postoperatively. However, the arthrodesis group achieved substantially better scores in all three evaluation systems at the final follow-up. This phenomenon can be explained by the fact that internal fixators remained in situ at the 3-month follow-up, providing auxiliary joint stability for the ORIF group. After implant removal before the final follow-up, midfoot stability relied merely on scarred ligaments, leading to a gradual decline in functional outcomes in the ORIF group. Among the ORIF patients, 10 developed complications including implant breakage, foot arch collapse, and forefoot abduction deformity, of whom 6 suffered secondary deformities after implant removal. These results confirm that ligamentous scar healing alone cannot provide sufficient and durable midfoot stability.

Prolonged retention of internal implants is not clinically feasible. Even with gradual postoperative functional recovery, internal fixation cannot permanently withstand the mechanical load of midfoot movement, as evidenced by 4 cases of implant breakage in the ORIF group. Furthermore, most patients with Lisfranc injuries sustain work-related trauma, and implant removal is a mandatory prerequisite for occupational injury assessment, which necessitates secondary surgery in most ORIF cases.

Clinically, transient reduction of ligamentous three-column Lisfranc injuries is easily overlooked and misdiagnosed. Initial plain radiographs may show negative findings, while weight-bearing radiographs are conducive to definitive diagnosis. Most patients with missed injuries eventually progress to chronic Lisfranc injuries, for whom arthrodesis is the predominant treatment option [25,26]. Six patients in the arthrodesis group developed naviculocuneiform osteoarthritis, a common complication after

tarsometatarsal arthrodesis. Tarsometatarsal fusion alters the mechanical transmission of the midfoot, resulting in increased stress on adjacent joints. Therefore, precise restoration of foot alignment during arthrodesis is essential to reduce compensatory stress on neighboring articular structures. Although midfoot stiffness was significantly more prevalent in the arthrodesis group, which is an inevitable consequence of eliminating the physiological micromovement of the Lisfranc complex that contributes to fine foot function, the rigid and stable midfoot construct allows early intensive functional training and earlier return to work.

The longer operative duration in the arthrodesis group was attributed to additional procedural steps, including articular cartilage debridement and iliac cancellous bone graft harvesting. Notably, the arthrodesis group exhibited significant improvements in AOFAS, VAS, and SF-36 scores from 3 months postoperatively to the final follow-up, indicating that stable osseous fusion enables progressive recovery of foot function over time. Boffeli et al. [27] reported that selective medial column arthrodesis combined with middle column ORIF can achieve satisfactory clinical outcomes in specific patient populations. Zhang et al. [28] demonstrated that the first tarsometatarsal joint plays a pivotal role in foot stability. For Lisfranc injuries complicated by first tarsometatarsal joint dislocation, primary arthrodesis is recommended to relieve pain and prevent long-term complications such as recurrent dislocation, implant failure, and the need for secondary revision. The medial column serves as the cornerstone of midfoot integrity, maintaining the medial foot arch and providing structural support for the middle and lateral columns. Unstable medial column injuries are highly susceptible to foot arch collapse and forefoot abduction deformity, indicating that medial column stabilization is more critical than middle column reconstruction. Currently, an increasing number of scholars advocate the hybrid strategy of medial column arthrodesis combined with middle column ORIF, which requires further clinical verification.

The present study has several limitations. Firstly, as a multicenter retrospective study, it possesses a relatively low level of clinical evidence, and further prospective multicenter trials are required to validate the conclusions. Secondly, the sample size is limited, and subsequent studies with larger patient cohorts from multiple medical centers are needed for supplementation. Thirdly, the follow-up duration is relatively short, with only short- and medium-term outcomes reported; long-term clinical efficacy remains to be further evaluated through continuous follow-up.

Conclusion

Primary arthrodesis provides a more stable biomechanical structure than ORIF, meeting the requirements of daily activities and occupational work. Primary arthrodesis significantly reduces the reoperation rate and shortening the postoperative rehabilitation period. The current results demonstrate that primary arthrodesis provides superior clinical efficacy for ligamentous three-column Lisfranc injuries compared with conventional ORIF, which warrants widespread clinical application.

Declarations

Competing Interests

The authors declare no competing interests.

Consent to Publish Declaration

We hereby confirm that we have read and fully understand the publishing terms and copyright regulations of the journal.

Author Contribution

Literature search, material preparation, data collection, and analysis were performed by Tianhao Wang, Guodong Shen and Tonglong Xu. The first draft of the manuscript was written by Wenqi Gu and Jian Tian, and Zhongmin Shi contributed to the conceptualization, and critical revisions of the manuscript. All tables and figures are original work by the authors and research team. All authors read and approved the final manuscript.

Data availability

The data could be obtained by contacting the corresponding author.

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Figures

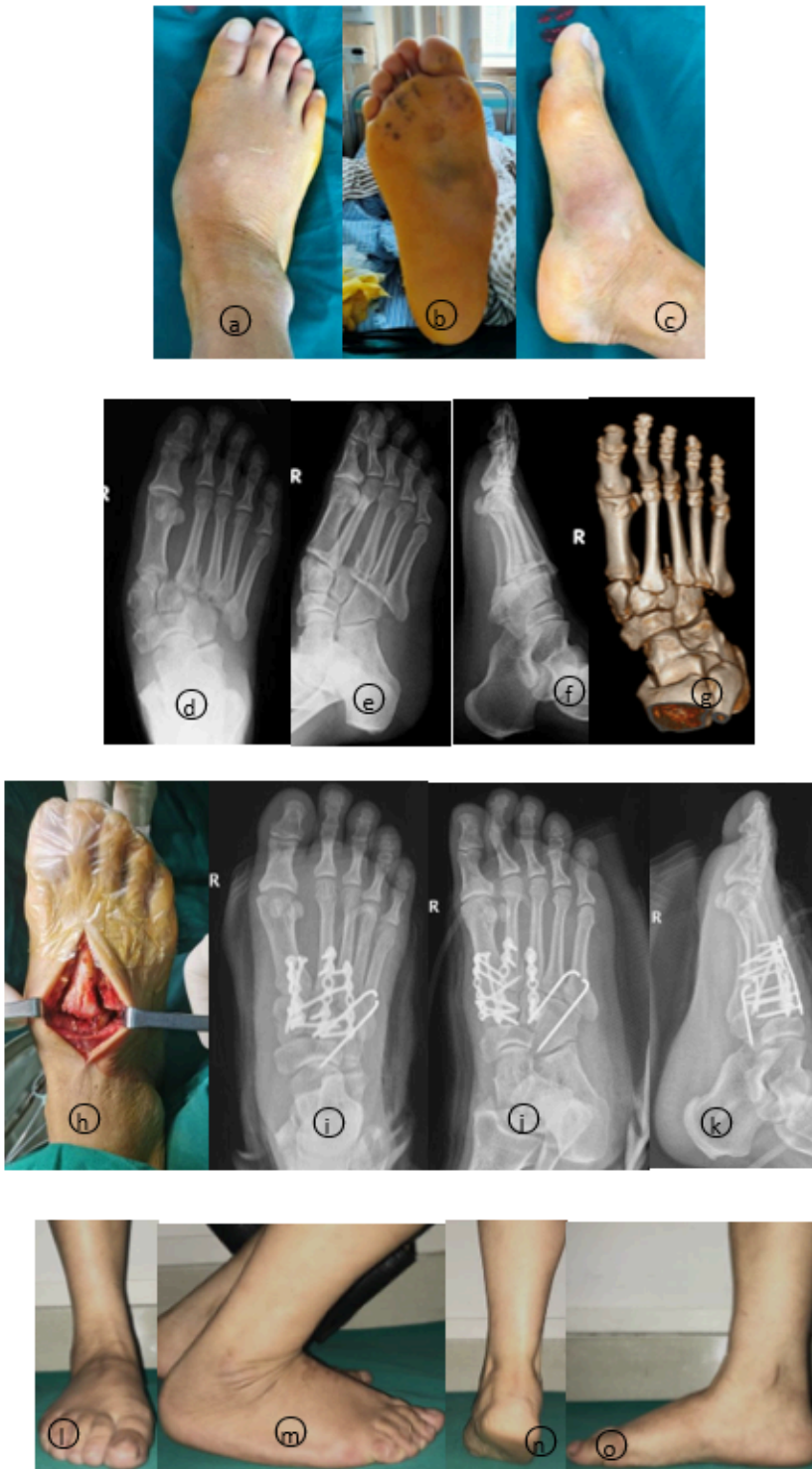


Figure 1

Case 1 (Arthrodesis group), a 51-year-old male patient with injury caused by a fall from height.

Figure 1. a–c: Preoperative clinical photographs; d–f: Anteroposterior, oblique and lateral radiographs; g: Preoperative three-dimensional computed tomography reconstruction; h: Intraoperative view

demonstrating dislocated joints; i–k: Postoperative radiographs showing satisfactory reduction; l–o: Satisfactory functional recovery at 28 months after surgery.



Figure 2

Case 2 (ORIF group), a 46-year-old female patient with right foot crush injury.

Figure 2. a, b: Anteroposterior and oblique radiographs obtained after trauma; c, d: Anteroposterior and oblique radiographs after closed manipulation reduction; e–h: Preoperative CT scans and three-dimensional reconstructions; i: Intraoperative fluoroscopic anteroposterior and oblique views confirming adequate reduction and fixation; j, k: Radiographs at 3 months postoperatively demonstrating favorable bone healing; l: Radiograph after implant removal; m–o: Satisfactory functional recovery at 26 months after surgery.