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Categorization and surgical management of posttraumatic midfoot malunion

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Abstract

Objective: To assess a classification system for midfoot injury that was based on the characteristics of the foot malunion and to evaluate the suggested treatment strategies.

Methods: This retrospective review of data from patients with posttraumatic midfoot malunion categorized each foot deformity into one of three types based on the foot arch and then separated these categories into one of three subtypes based on the forefoot deformity. According to the types of malunion, fascio-cutaneous flap, osteotomy, joint arthrodesis or realignment was used to correct the deformity. Patients were assessed before surgery and at 12 and 24 months postoperation.

Results: Of the 24 patients identified, six had Lisfranc joint injuries, nine had Lisfranc joint complex injuries combined with cuboid compression fractures and nine had Lisfranc joint complex injuries combined with navicular fractures. Overall, eight patients presented with poor soft tissue and massive scar at the dorsal foot. Visual analogue scale and American Orthopaedic Foot and Ankle Society midfoot scores significantly improved over the 24-month study period. At the end of the study, 21 of 24 patients (87.5%) rated their functional outcome as excellent or good.

Conclusion: The classification of the midfoot malunion evaluated in this study may be helpful in the decision making process for surgical intervention.

Keywords

Midfoot injuries, malunion, surgical procedures, fractures

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Introduction

The number of patients with a 'high energy' or violent injury is increasing especially in western countries.[1] These types of trauma often result in lower extremity injuries, such as midfoot fractures, which have a high

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impact on functional outcome.[2,3] For example, in Greece, the annual incidence of midfoot fracture is approximately 1/30 000 people and it accounts for 0.4% of all fractures.[4,5] The midfoot includes the metatarsal base, five small bones (i.e. navicular, cuboid and three cuneiform) and the Chopart joint.[4] The anatomical stability of the midfoot depends on the structure of the ligaments, joint capsules and muscles within the foot. For displaced injuries, treatment options include closed reduction with or without fixation,[6–11] open reduction using various methods of fixation (e.g. Kirschner wires,[6,12–14] different types of screws,[15–18] extra-articular plate fixation,[19,20] or a suture-button device[21,22]), and primary arthrodesis.[23,24] Improper treatment of a foot injury can easily lead to foot malunion, which is characterized by pain, deformity, and dysfunction of the foot.[25] Typically, most patients require surgery to correct the deformity and the choice of surgical approach depends on the type of malunion.[26]

External fixation to treat midfoot malunion has been reviewed,[27] and a thorough anatomical classification scheme has been reported based on the segmental patterns of injury and the forces involved.[9] With the exception of these two published articles, to our knowledge, little information is available on the treatment of midfoot malunion. Therefore, the aim of this retrospective review was to assess a classification system for midfoot injury, which was based on the characteristics of the foot malunion and evaluate our suggested treatment strategies.

Patients and Methods

Patient population and study design

This was a retrospective review of data obtained from patients who had been treated in the Department of Orthopaedics, Tongji Hospital, Tongji University School of Medicine, Shanghai, China between June 2004 and June 2012 for posttraumatic midfoot malunion. The inclusion criteria were a midfoot fracture or dislocation for more than 6 months and an X-ray showing foot residual deformity or joint degeneration. The exclusion criteria were: (i) neurological and/or vascular complications; (ii) diabetes mellitus; (iii) foot neoplasms; (iv) Charcot arthropathy. The type of injury, treatment and time from initial injury to reconstructive surgery were recorded by one of the investigators (C.G.L.). Each foot deformity (malunion) was categorized retrospectively by C.G.L. into one of three types based on the foot arch: Type I, the foot arch was normal; Type II, pes cavus deformity; Type III, flatfoot deformity (Figure 1). Subsequently, based on the forefoot deformity, each type was categorized into one of three subtypes: Type a, forefoot abduction; Type b, forefoot adduction; Type c, normal forefoot.

Prior to the operation, patients had (i) assessed their level of pain using a visual analogue scale (VAS)[28] that ranged from 0 (no pain) to 10 (severe pain); and (ii) assessed their function using the American Orthopaedic Foot and Ankle Society (AOFAS) midfoot scoring scale (0 [poor]–100 [excellent]).[29]

Preoperative weight bearing and non-weight bearing X-ray and computed tomography (CT) scans were measured and the Coleman block test[30] or antiColeman block test[31] performed to determine if the calcaneus had a structural or functional varus deformity.

This study was approved by the Ethics Committee of Tongji Hospital and complied with the Declaration of Helsinki. All patients provided written informed consent.

Surgical techniques

Continuous spinal or epidural anaesthesia had been induced with the patient in a supine or lateral position. According to the types of malunion, a fascio-cutaneous flap, osteotomy, joint arthrodesis or realignment had been chosen to correct the deformity. A pneumatic tourniquet was used during surgery and one or more longitudinal incisions were made as

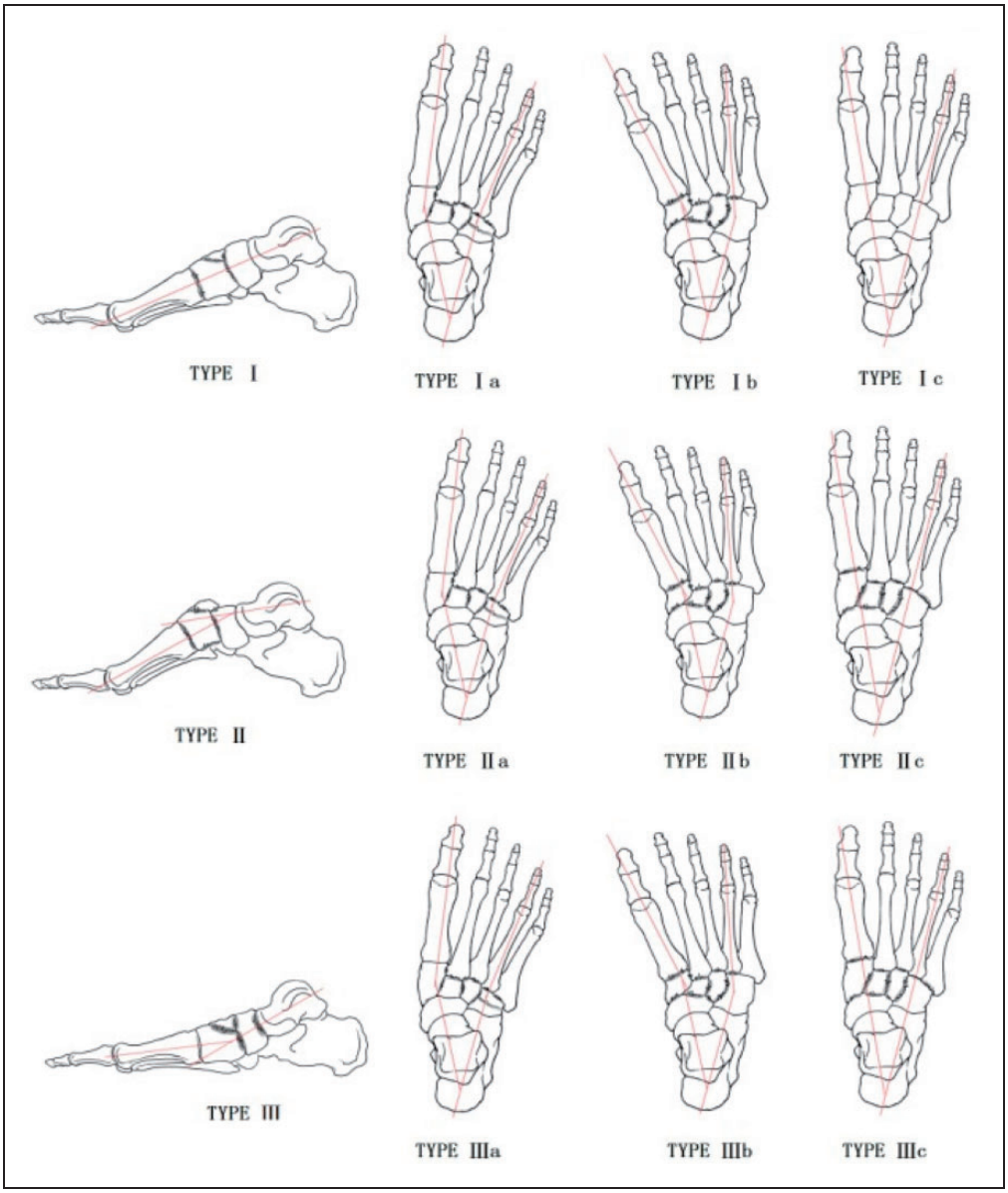

Figure 1. Categorization of midfoot malunion. Each foot deformity was categorized into one of three types based on the foot arch and then these were further categorized into one of three subtypes based on the forefoot deformity. The types were: Type I, the foot arch was normal; Type II, pes cavus deformity; Type III, flatfoot deformity. The subtypes were: Type a, forefoot abduction; Type b, forefoot adduction; Type c, normal forefoot.

required. A single dorsal incision in the interspace between the first and second metatarsal was made for the fusion of the first and second tarso-metatarsal joints.

For simple Lisfranc joint fractures and dislocations (i.e. the first to fifth tarso-metatarsal joint fracture or dislocation) the affected joint was reduced and the first

tarso-metatarsal joint was fused. The second and third tarso-metatarsal joints were fused or fixed according to the dislocation and articular cartilage damage, and in cases where the fourth and fifth tarso-metatarsal joints were dislocated, open reduction was performed under direct vision and fixation was performed with a 2 mm Kirschner wire. In cases where there was significant degeneration of the lateral column and persistent pain, fusion of the fourth or fifth tarso-metatarsal joint was required.

For severe Lisfranc joint complex injuries, in patients with mild abduction deformity, and when the therapeutic effects of talo-first metatarsal angle reduction were not satisfactory, the affected joints were fused after medial osteotomy. In patients with severe abduction deformity, medial and lateral incisions were made followed by medial wedge osteotomy and lateral column lengthening. The bone from the medial osteotomy could have been used to prolong the lateral column and, if required, autologous iliac bone could have been used. The principles of midfoot joint fusion were to ensure joint stability and retention of the talonavicular and calcaneocuboid joint function as much as possible. If severe degeneration, preoperative impairment of activities and/or persistent pain were present, the talonavicular and calcaneocuboid joints could be fused simultaneously. Other tarsal joint instability was also treated with arthrodesis.

For patients with poor soft tissues and massive scars at the dorsal foot, fasciocutaneous flap grafting was performed followed by fracture/dislocation reduction by simple fixtures. In the event that the foot structure and morphology recovered poorly, osteotomy and rigid fixation were undertaken.

Following all surgery, patients were immobilized in a neutral position by a plaster cast for 2 weeks. Patients were encouraged to do partial weight bearing activities using a postoperative brace for 6 weeks. Full weight bearing was delayed for 10 to 14 weeks after fracture healing was confirmed by radiological examinations.

Patients had been assessed preoperation and thereafter at 12 and 24 months. Anteroposterior, lateral and oblique X–rays had been taken to assess the integration of joint morphology and healing. At 12 and 24 months, patients had been assessed using the VAS to assess weight bearing and walking pain and the AOFAS midfoot score to assess functional outcome. At 24 months, patients were categorized into different groups according to their AOFAS midfoot scale score for functional outcome (i.e. 90–100, excellent; 75–89, good; 50–74, fair; < 50, poor).[29] Patient satisfaction with surgery was assessed as the patient being able to return back to work and the treatment having no impact on their daily activities.

Statistical analyses

All statistical analyses were performed using the SPSS® statistical package, version 17.0 (SPSS Inc., Chicago, IL, USA) for Windows®. Paired *t*-tests were used to compare data and a *P*-value < 0.05 was considered to be statistically significant with a 2-tailed test. No allowance was made for multiple testing.

Results

Twenty-four patients (21 men and three women) with posttraumatic midfoot malunion were treated between June 2004 and June 2012. Their ages ranged from 16 to 65 years with a mean $\pm$ SD age of 37.8 ± 7.5 years. The cause of injury was direct violence in 15 cases and indirect violence in nine cases. According to the site of injury, there were six Lisfranc joint injuries, nine Lisfranc joint complex injuries combined with cuboid compression fractures and nine Lisfranc joint complex injuries combined with navicular fractures. In eight patients, large area scars formed due to severe soft tissue injury.

Table 1. Visual analogue scale (VAS) and American Orthopaedic Foot and Ankle Society (AOFAS) midfoot scores preoperation and postoperation in patients ($n = 24$) with posttraumatic midfoot malunion.

	Preoperation ($n = 24$)	12 months postoperation ($n = 24$)	24 months postoperation ($n = 24$)
VAS	$9.0 \pm 1.0^{*\dagger}$	$2.5 \pm 1.3^{\ddagger}$	2.0 ± 1.4
AOFAS	$42.4 \pm 7.0^{*\dagger}$	$81.5 \pm 7.5^{\ddagger}$	83.9 ± 7.3

Values presented as mean ± SD.
AOFAS[29] is scored 0 (poor)–100 (excellent). VAS[28] ranged from 0 (no pain) to 10 (severe pain).
$^{*}P < 0.05$ compared with 12 months postoperation; paired *t*-test.
$^{\dagger}P < 0.05$ compared with 24 months postoperation; paired *t*-test.
$^{\ddagger}P < 0.05$ compared with 24 months postoperation; paired *t*-test.

With the exception of two patients who were misdiagnosed and not initially treated, the remaining 22 patients had been treated (i.e. three with closed reduction and cast immobilization; four with closed reduction and percutaneous Kirschner wire fixation; seven with open reduction and internal fixation with Kirschner wire; eight with open reduction and rigid fixation). The mean ± SD time from initial injury to the reconstruction operation was 13.5 ± 5.4 months (range 10–25 months).

Of the 24 patients with midfoot malunion, two were Type Ia, four were Type Ic, nine were Type IIa, two were Type IIb, four were Type IIIa and three were Type IIIc. The mean ± SD preoperative VAS score for all patients was 9.0 ± 1.0 (range 7–10) and the mean ± SD score for AOFAS midfoot scoring was 42.4 ± 7.0 (range 33–56).

The mean ± SD time to union was 12.9 ± 1.2 weeks (range 12.0–13.9 weeks). Patients were followed up for a mean ± SD of 34.7 ± 6.3 months (range 25–53 months). VAS and AOFAS midfoot scores improved over the 24 months. By comparison with preoperative values, the improvement in both scores was statistically significant at 12 and 24 months ($P < 0.05$ for all comparisons) (Table 1). The difference between VAS and AOFAS midfoot scores at 12 and 24 months was also significant ($P < 0.05$). At 24 months, based on AOFAS midfoot scale scores for functional outcome, seven patients (29.2%) rated treatment as excellent (i.e. 90–100), 14 patients (58.3%) rated treatment as good (i.e. 75–89) and three patients (12.5%) rated treatment as fair (i.e. 50–74). Therefore, 87.5% (21 of 24) patients rated treatment as providing excellent or good functional outcome.

According to radiographs taken at 24 months, the foot morphology for all patients was much closer to anatomical status than it had been preoperatively. At the end of the study, the mean ± SD talus-first metatarsal angle was $13.2 \pm 0.4^{\circ}$, and the mean ± SD calcaneus-fourth metatarsal angle was $11.5 \pm 1.5^{\circ}$ (Table 2). These values were significantly different compared with the preoperative values ($P < 0.05$ for both comparisons). In 11 cases that had a cavus arch and seven cases that had flatfoot preoperatively, the talus axis and metatarsal axis were now at the same level. Three typical clinical cases are shown in Figures 2, 3 and 4.

After 12 months, five (20.8%) patients had moderate pain (VAS ≥ 4), 13 (54.2%) patients had occasional mild pain (VAS = 2 or 3) and six had no pain. Most of the pain

Table 2. Comparison of radiographic measurements preoperation and 24 months postoperation in patients ($n = 24$) with posttraumatic midfoot malunion.

Parameters	Preoperation ($n = 24$)	24 months postoperation ($n = 24$)	Variation[a]	Statistical significance[b]
Talus-first metatarsal angle, degrees	33.7 ± 8.8	13.2 ± 0.4	20.5	$P < 0.05$
Calcaneus-fourth metatarsal angle, degrees	31.4 ± 6.6	11.5 ± 1.5	19.9	$P < 0.05$

Values presented as mean ± SD.
[a]Variation was the difference between the preoperation mean angle and the 24 month mean postoperation angle.
[b]Paired *t*-test.

occurred on the 2nd or 3rd tarso-metatarsal joints. At 24 months, two (8.3%) patients still had moderate pain, 14 (58.3%) patients had occasional mild pain and eight had no pain. None of the patients had a recurrent malunion. Twenty (83.3%) patients were satisfied with the outcome and returned to their previous work and activities, two (8.3%) patients had changed their occupation and worked part-time and two (8.3%) had not resumed work.

Twenty-one patients had a stable midfoot both subjectively and clinically. Two further patients had superficial infection at the dorsal foot incision. The remaining patient presented with poor soft tissue and a massive scar on the dorsal foot and 6 weeks after the operation, the X-ray showed malalignment. Rigid fixation was removed and arthrodesis was conducted.

Out of the 24 patients, two patients had a slight limp when walking. One patient presented foot pain when walking 3 years after fusion of medial and middle column.

Discussion

The nonoperative treatment of midfoot fractures may result in malunion, which may in turn lead to long-term disability for some patients.[32] The goals of any midfoot reconstruction, which is generally accomplished with arthrodesis and realignment, are to create a painless, functional, plantigrade foot with a good appearance. Therefore, not only is correction of the midfoot deformity important but also any coexisting forefoot and hindfoot deformities need to be rectified. Indeed, a hindfoot deformity is critical because if the heel is left in valgus, it can cause increased pronation and abduction of the midfoot and so further deformity may develop. Moreover, if the hindfoot is left in equinus, it can cause pressure on the midfoot and deformity associated with medial column instability can reoccur.[33]

Due to the heterogeneity of midfoot deformity, it is difficult to formulate a routine protocol for treatment. However, the main principles are to correct foot abduction and adduction, any rotation deformity and any arch anomaly in order to achieve realignment. In addition, foot stability must be maintained by restoring foot length through bilateral osteotomy or open osteotomy techniques. Open midfoot injuries often cause large scars on the dorsal foot. On occasions where there is a lack of accurate reduction and rigid fixation at the first surgical stage, scar contracture can aggravate the deformity. In this present study, there were eight patients with a large area of foot scar formation. We are

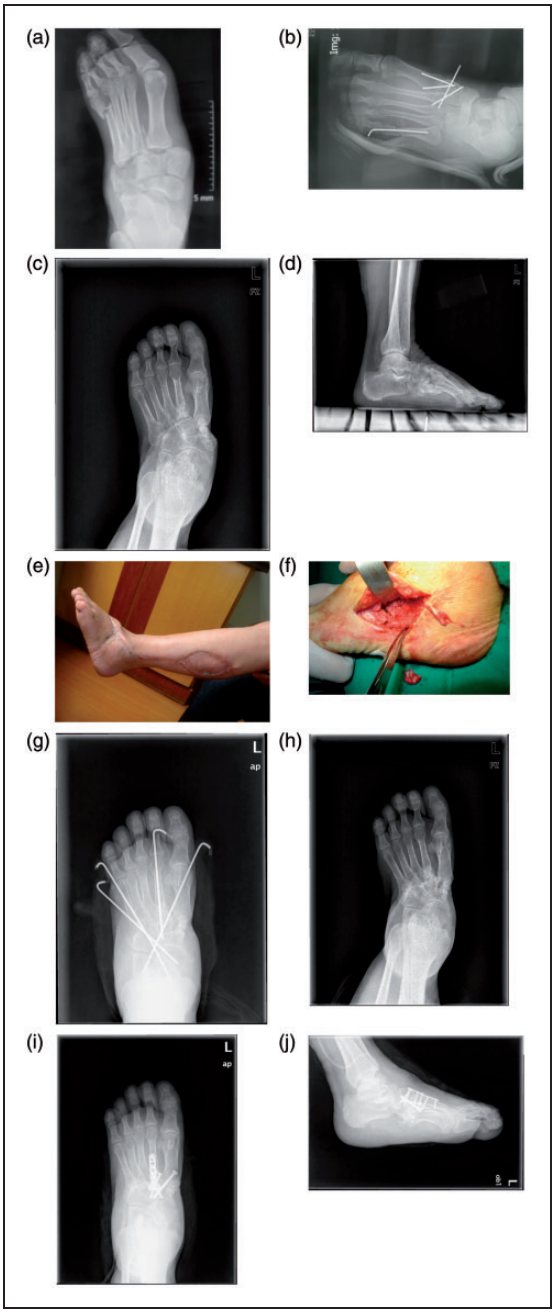

Figure 2. Case study: a 30-year-old man admitted to our hospital after 12 months following a foot injury caused by a car accident. Anteroposterior X-ray of the initial injury (a); X-ray following the initial surgical treatment at a local hospital (b); X-ray images showing the injury after 12 months illustrating the cavus of the foot arch (c) and forefoot abduction deformity (d); a photograph showing the results of surgery to resect the scar following a fasciocutaneous flap (e); a photograph that was taken after the second stage of surgery to solve the dislocation by joint arthrodesis showing significant dislocation at the lateral column (f); X-ray after simple fixation and Lisfranc fusion has been applied (g); X-ray showing that the abduction deformity has not been corrected (h); X-ray images showing the results after the third stage of surgery and the rigid internal fixation of the medial and middle columns, realignment and recovery of the foot arch (i and j).

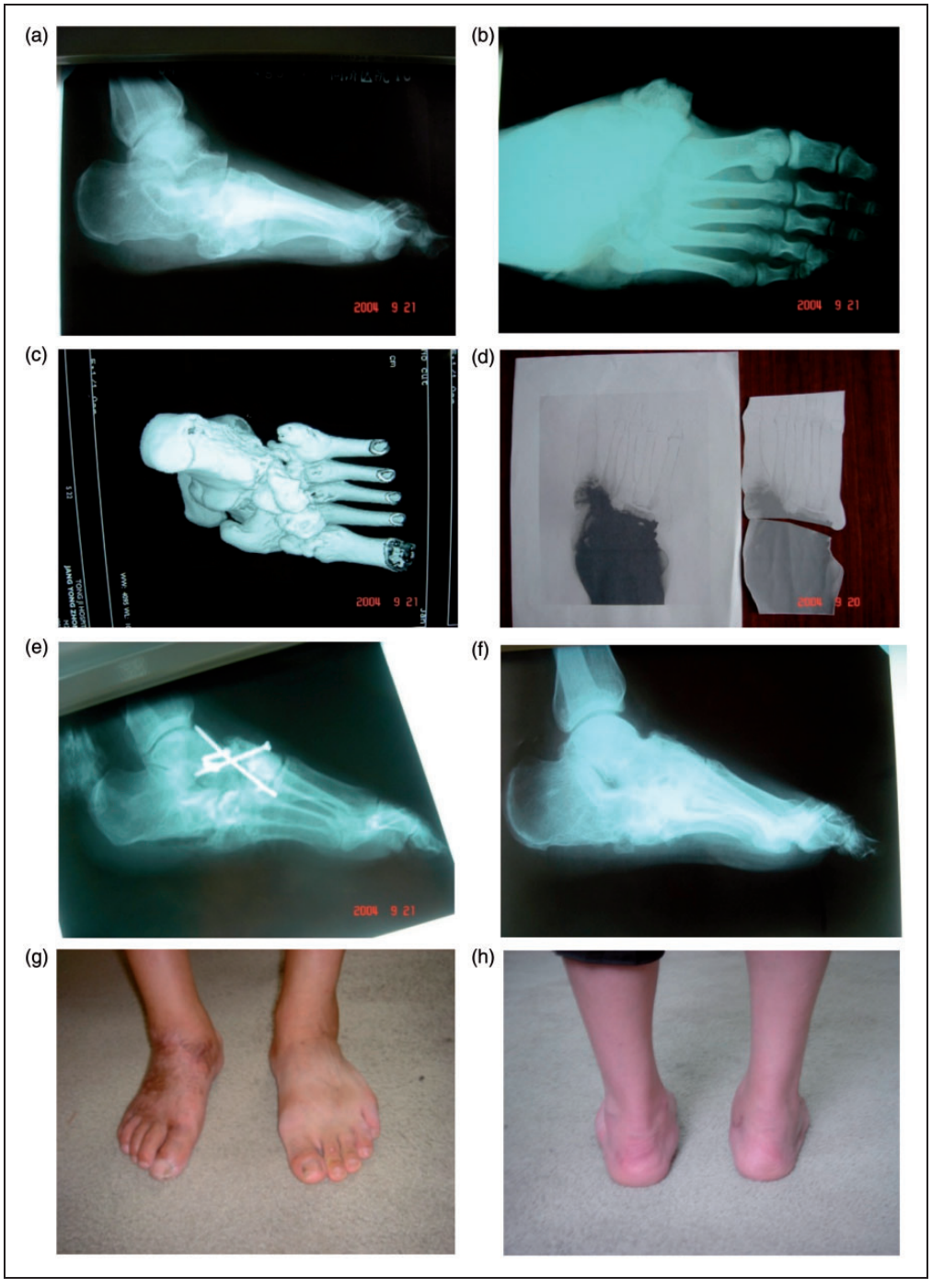

Figure 3. Case study: a 25-year-old man admitted to our hospital after 25 months following a foot injury. Images showing the flatfoot deformity (a–c); the preoperative design in order to decide the osteotomy width; the paper copy shows a 1:1 proportion foot X-ray print (d); X-ray following surgery to correct the collapsed arch (e); the clinical results at 12-months postoperation after removing internal fixation and arch restoration (f–h).

Figure 4. Case study: a 30-year-old man admitted to our hospital after 18 months following a foot injury. X-ray showing the forefoot abduction deformity (the black line indicates the medial osteotomy bone that can be used as a bone-block to prolong the lateral column) (a); X-ray showing the results following correction of the abduction deformity with bilateral plates (b); the clinical results at 12 months postoperation showing that the injured foot is in good shape (c–e).

of the opinion that it is best to remove the dorsal scar and make a calf perforator flap or free flap autograft. After flap survival, reduction of the involved joints should occur with simple fixtures to minimize irritation of the skin and soft tissues. Although simple fixations provide stability they may not provide strength and so full weight bearing should be delayed until the fracture has healed. In the event of bone infection, the fixation should be removed promptly. One study recommended that dermal matrix

allograft transplantation should be used to promote bone healing if there was nonunion of the talonavicular joint after arthrodesis.[34] However, there were no nonunion cases in this present study.

To facilitate the classification of the midfoot deformity for clinicians and to assist in the selection of an appropriate treatment, this present study proposed a categorization system according to the characteristics of the foot malunion. Subsequently, according to the types of malunion observed, the appropriate procedure (i.e. fascio-cutaneous flap, osteotomy, joint arthrodesis or realignment) was selected to correct the deformity. For example, for patients with Type I (i.e. normal arch), only forefoot adduction or abduction deformity was corrected. For Type Ia, according to the degree of abduction, the foot length determined the osteotomy method. If the abduction angle was $< 25^{\circ}$, closed or open wedge osteotomy based on foot length and soft tissue contracture was considered; if the abduction angle was $\geq 25^{\circ}$, bilateral osteotomy was required and the medial closing wedge osteotomy and lateral cuboid open wedge osteotomy were chosen. Type Ib was treated with medial open wedge osteotomy or lateral closing osteotomy according to the severity of the deformity and soft tissue contracture. Type Ic was mainly foot instability or osteoarthritis and *in situ* fusion was used for this. For patients with Type II cavus arch anomalies, foot dorsal closing wedge osteotomy was required and attention to retain sufficient foot length was taken. For patients with Type III flatfoot deformities, the joint had to be stabilized and plantar side closed osteotomy conducted to correct the collapsed arch. Of the 24 patients with midfoot malunion in this present study, two were Type Ia, four were Type Ic, nine were Type IIa, two were Type IIb, four were Type IIIa and three were Type IIIc. In this present study, VAS and AOFAS midfoot scores significantly improved over the 24-month study period and at the end of the study 87.5% patients rated their functional outcome as excellent or good. In addition, radiographs showed that the foot morphology for all patients was much closer to anatomical status than it had been preoperatively.

The study had several limitations. First, the sample size was small and so there were few patients with each type of midfoot malunion. Therefore, further studies with more patients are required to confirm the classification system and the therapeutic effects of the suggested surgical therapies. Secondly, because of the relatively long follow-up period of this study, different types of implants were used in the patients. Patients who were enrolled early in this study had their joints fixed with screws, whereas those who enrolled later had their joints fixed with plates and screws. Future studies should specify the type of internal fixation for the different types of foot deformity.

In conclusion, this study confirms that the surgical management of midfoot malunion provides effective and good results by stabilizing injured joints, improving alignment and restoring the foot arch. Classification of the midfoot malunion introduced in this study may be helpful in the decision making process for surgical intervention. The morphology of the malunited midfoot can be restored by salvaging the tarso-metatarsal joint. In addition, we recommend restoring the foot arch by reconstructive osteotomy and primarily fusing or fixing the midfoot malunion.

Declaration of conflicting interests

The authors declare that there are no conflicts of interest.

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had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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