Ilizarov bone transport versus vascularized fibular graft in reconstruction of post-traumatic tibial bone defects

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Background

Traumatic bone defects may be primary, following open fractures, or secondary to an aseptic or septic nonunion. The traditional procedures to bridge segmental bone defects include autogenous bone grafting, the open bone grafting (Papineau) technique, posterolateral bone grafting of the tibia, transplantation of allograft bone, and fibula protibia procedures. However, these procedures usually require multiple surgical procedures, no weight bearing during treatment, and have limited extent of bone defect reconstruction. Vascularized bone grafts and bone transport according to the Ilizarov technique show much better results. However, each has its advantages and disadvantages.

Patients and methods

Between April 2001 and September 2008, we treated 32 patients with post-traumatic tibial bone defects at the El-Hadra University Hospital. The patents were divided into two groups: group 1 consisted of 17 patients who were treated using the Ilizarov bone transport technique; group 2 consisted of 15 patients who were treated by vascularized fibular grafting. The average age of the patients at the time of the surgery was 39.9 years in group 1 and 29.7 years in group 2. The mean length of the bone defect was 4.1 cm in group 1 and 7.6 cm in group 2. The site of the bone defect was proximal in six and two patients and middle in eight and 13 patients of group 1 and group 2, respectively. The distal tibia was affected in six patients of group 1. All patients had undergone surgeries previously (one to four operations). The results were divided into bone and functional results. The bone results were based on five criteria: union, infection, deformity, lower limb deformities, and the cross-sectional area of union of the regenerated bone and docking site. The functional results were based on five criteria: pain, need for walking aids or braces, ankle or knee deformity or contracture, loss of range of ankle and knee motion compared with the preoperative range, and ability to return to normal activities of daily living and/or work.

Results

The mean amount of the filled defect was 4.1 cm with Ilizarov bone transport and 7.6 cm with vascularized fibular grafting. The external fixator time in group 1 was 6.9 ± 1.39 months. The average time to achieve union in group 2 was shorter than that in group 1 (4.8 months, range 3–9 months), whereas the average time to full weight bearing is 8.7 months (range 5–15 months). The average follow-up period was 10.9 months (range 6–24 months) in the bone transport group and 17.6 months (8–24 months) in the vascularized fibular graft group. The bone results and functional results of Ilizarov bone transport were excellent in 64.7 and 29.4%, good in 17.6 and 41.2%, fair in 5.9 and 17.6%, and poor in 11.8 and 11.8% of the patients in groups 1 and 2, respectively, whereas those of vascularized fibular grafting were excellent in 73.3 and 6.7%, good in 13.3 and 73.3%, fair in 6.7 and 13.3%, and poor in 6.7 and 6.7%, respectively. The main problems in Ilizarov bone transport were patient compliance, pin tract infection (all patients), residual deformity in seven patients, and skin sloughing in one patient who was treated using a skin flap. Stress fracture of the transported fibula (eight patients) and need for secondary procedures (10 procedures) were the main problems in the vascularized fibular graft group.

Conclusion

Ilizarov bone transport is a good method for management of post-traumatic tibial defects, especially short bone defects; in addition, bone grafting of the docking site is necessary in all cases to achieve union and to shorten the time of external fixator application. Although the vascularized fibular graft yielded better results in longer bone defects with shorter time for union, non-weight-bearing is mandatory until graft hypertrophy to avoid stress fractures, which were the main problem in our series.

Keywords:

bone defect, bone transport, Ilizarov, vascularized fibular graft

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Introduction

Traumatic bone defects may be primary, following open fractures, or secondary to an aseptic or septic non-union [1]. The traditional procedures to bridge segmental bone defects include autogenous bone grafting, the 4open bone grafting (Papineau) technique [2], poster-olateral bone grafting [3] of the tibia, transplantation of allograft bone [4], and fibula protibia procedures [5]. However, these procedures usually require multiple surgical procedures, no weight bearing during treatment, and have limited extent of bone defect reconstruction.

Vascularized bone grafts [6,7] and bone transport according to the Ilizarov technique [8–16] yield much better results. However, each has its advantages and disadvantages.

The advantages of bone transport include minimal soft-tissue trauma, the fact that large bone defects can be treated with the same bone diameter, gradual correction of deformities, limited donor-site morbidity, and minimization of soft-tissue coverage operations. The disadvantages include requirement of patient compliance during the long process of bone transport, multiple clinic visits, and frequent complications [9–13].

Although these disadvantages are not present in the vascularized fibular graft technique, it is not without disadvantages. Problems with vascularized bone grafts include lengthy remodeling time and a high fracture rate, compromised vascularity, infection, nonunion of the graft–host junction sites, and fatigue fracture of the graft. Donor-site complications may add to these problems [6,7].

The best long-term treatment method to both salvage the limb and restore the longitudinal bone loss depends on multiple factors, including the size and anatomical location of the bone deficit, the soft-tissue envelope, blood supply, and history of local infection. Multiple treatment techniques, such as conventional repetitive bone grafting, vascularized bone grafts, and bone transport, should be considered as reconstruction options. Therefore, the physician must be aware of all the advantages and disadvantages of each procedure to achieve an optimal result and determine the optimal treatment regimen for each patient [17].

Patients and methods

Between April 2001 and September 2008, we treated 32 patients with post-traumatic tibial bone defects at the El-Hadra University Hospital. The patients were divided into two groups: group 1 consisted of 17 patients who were treated using the Ilizarov bone transport technique; group 2 consisted of 15 patients who were treated by vascularized fibular grafting. The youngest patient in group 1 (bone transport) was 24 years old and the oldest was 60 years old; the average age of the patients in group 1 was 39.9 years, whereas the average age in group 2 (vascularized fibular grafting) was 29.7 years (11–51 years). Ten patients (56.8%) in group 1 (bone transport) and 11 patients (73.3%) in group 2 (vascularized fibular grafting) were male. The bony defect was mainly in the middle tibia segments in both groups (eight in group 1 and 13 in group 2). The proximal tibia was affected in six patients of group 1 (bone transport) and two patients of group 2 (vascularized fibular grafting), whereas three of 17 patients of group 1 (bone transport) had a bone defect in the distal tibia. All patients had undergone surgeries previously (one to four operations).

The results were divided into bone and functional results. The bone results were based on five criteria: union, infection, deformity, lower limb deformities, and the cross-sectional area of union of the regenerated bone and docking site. The functional results were based on five criteria: pain, need for walking aids or braces, ankle or knee deformity or contracture, loss of range of ankle and knee motion compared with preoperative range, and ability to return to normal activities of daily living and/or work (Table 1). The average period of follow-up was 9.2 and 17.3 months, respectively.

Group 1 (Ilizarov bone transport)

(1) Acute shortening was performed in three patients with middle segment defects (3–4 cm), in whom the Ilizarov technique and proximal tibial corticotomy had been performed for lengthening; further, acute shortening was performed in a patient with a proximal tibial defect (4 cm) by distal tibial osteotomy to compensate for limb-length inequality.
(2) Bone transport was performed in 13 patients: to replace a defect in the middle tibia in five patients and in the distal tibia in three with bifocal transport from the proximal tibia; in five patients the defect was in the proximal tibia, with transport from the distal to proximal tibia.
(3) The assembled frame was formed of four rings, with two rings in each segment of the middle tibial defect in the case of proximal defects and one ring in the short segment and three in the other in the case of distal defects.
(4) Bone grafting in the docking site was performed routinely in all patients with internal bone transport on reaching the docking site.

Table 1 The criteria of assessment of bone and functional results

Bone results	Functional results
Union	Pain
Infection	Need for walking aids or braces
Deformity	Ankle or knee deformity or contracture
Lower limb deformities	Loss of range of ankle and knee motion compared with preoperative range
The cross-sectional area of union of the regenerated bone and docking site	Ability to return to normal activities of daily living and/or work

Group 2 (vascularized fibular graft)

(1) In all cases, the fibula was harvested as an osteoseptocutaneous flap with inclusion of skin.
(2) Sites of fibular osteotomy were determined, leaving at least 6 cm of the fibula distally to maintain ankle stability and 3–4 cm proximally to maintain lateral stability of the knee.
(3) Thereafter, the harvested fibular flap was trimmed to the desired length, taking into consideration the length needed for bone doweling (telescoping the fibula inside the tibial medullary cavity). Both ends of the fibula were fixed to the recipient bones either by intramedullary doweling with or without transfixing screws or by using a small plate with end-to-end compression and two screws on each side.
(4) The construct was augmented by a fixation method that bridged the gap (the main method of fixation). The selection of the main method of fixation was made on an individual basis according to the anatomical site, length of the defect, and the type of reconstruction (mobile or arthrodesis).
(5) Using an operating microscope and a 10/0 suture, the peroneal artery and one or two venae comitantes were sutured to the prepared artery and veins at the recipient site. The anterior tibial artery was the recipient artery in all patients with post-traumatic tibial defects.

Postoperative follow-up

Group 1

The postoperative period is divided into the latency period (12 days) and the distraction phase at a rate of 1 mm/day (1/4 mm every 6 h). Distraction was continued until the gap was filled when revision of the docking site and bone grafting were performed for all patients of the bone transport group.

In the four patients in whom acute compression was performed, followed by lengthening, distraction was continued until the length of the limbs was equal. The third phase is the consolidation phase, in which the patient was followed up monthly until full union of the defect site and consolidation of the distraction site were achieved. After that, the frame was removed under general anesthesia and a long leg cast was applied for 1 month, to be followed by physiotherapy of the knee and ankle and functional assessment at the end of the follow-up period.

Group 2

Postoperative follow-up was divided into early, intermediate, and late periods. Graft viability could not be determined during the early period (up to 6 weeks). Simultaneous transfer of a skin paddle helped identify blood-flow problems.

During the intermediate period (up to 6 months), union of the graft–host junction sites was evaluated clinically and radiographically.

During the late postoperative period (after 6–8 months), the graft was observed for evidence of hypertrophy. Adequate hypertrophy of the graft is a prerequisite for full weight bearing without support.

Results

The mean size of the filled defect was 4.1 cm with Ilizarov bone transport and 7.6 cm with vascularized fibular grafting. The external fixator time in group 1 was 6.9 ± 1.39 months. The average time to achieve union in group 2 was shorter than that in group 1 (4.8 months, range 3–9 months), whereas the average time to full weight bearing was 8.7 months (range 5–15 months; Figs. 1–3).

The average follow-up period was 10.9 months (range 6–24 months) in the bone transport group and 17.6 months (range 8–24 months) in the vascularized fibular graft group. The bone and functional results of the Ilizarov bone transport technique were excellent in 64.7 and 29.4%, good in 17.6 and 41.2%, fair in 5.9 and 17.6%, and poor in 11.8 and 11.8% of patients in groups 1 and 2, respectively, whereas those of vascularized fibular grafting were excellent in 73.3 and 6.7%, good in 13.3 and 73.3%, fair in 6.7 and 13.3%, and poor in 6.7 and 6.7%, respectively (Table 2).

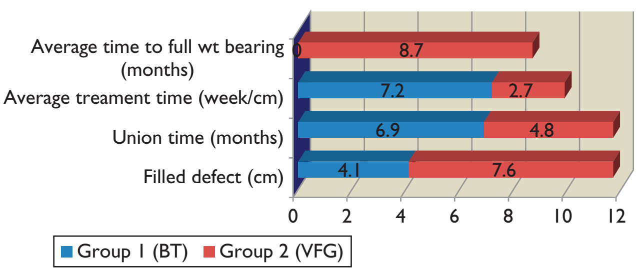
Discussion

Post-traumatic segmental bone defects resulting from injuries of the extremities can have a severe negative long-term impact on patients' lives and present complex treatment challenges.

Established methods of managing post-traumatic segmental bone defects to restore limb function include limb shortening, autologous nonvascularized cancellous bone grafting, bone transport distraction osteogenesis, and vascularized fibular grafting. Each method has its advantages and disadvantages.

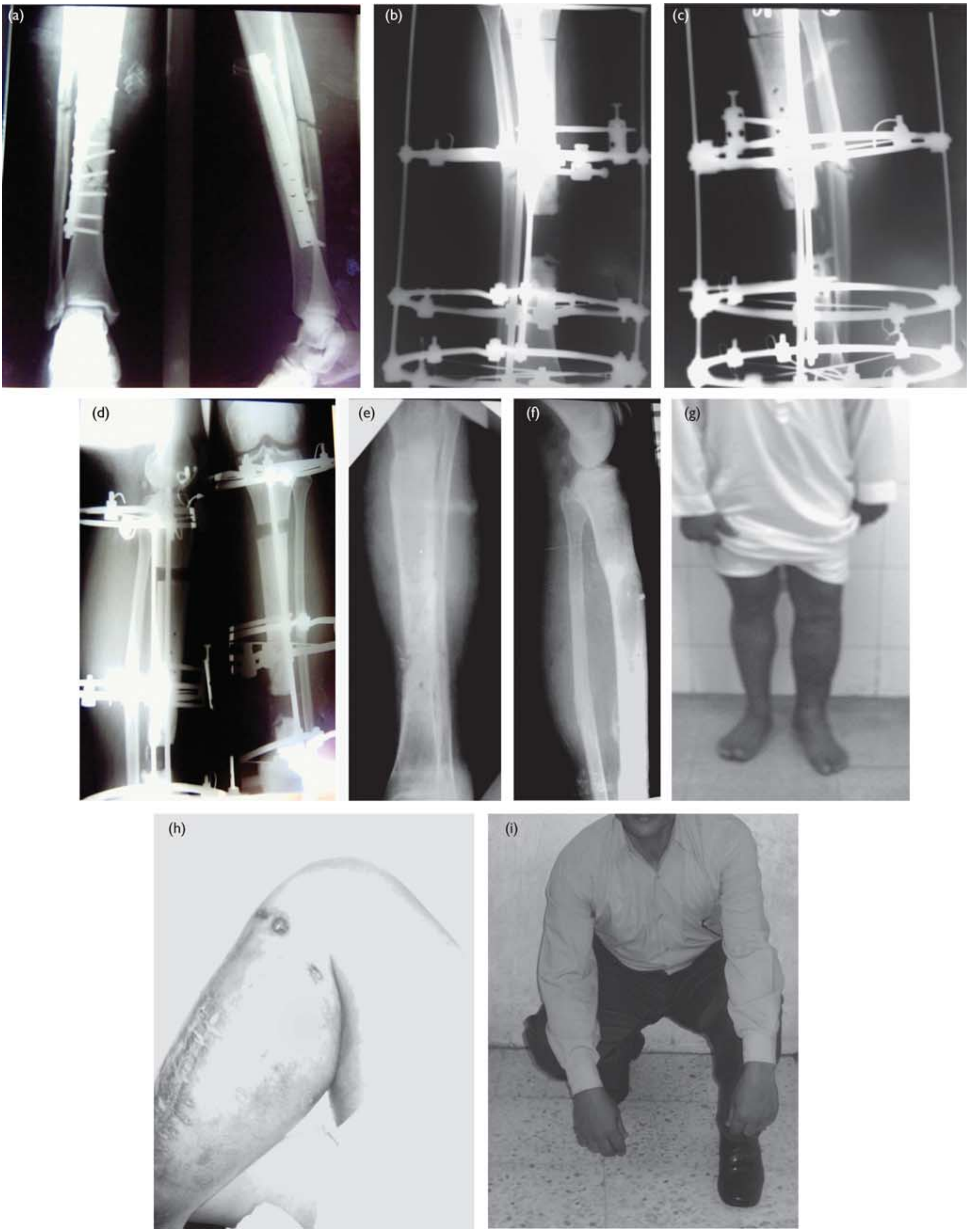
In this study, we compared the management of post-traumatic tibial defects using two different methods of treatment: Ilizarov bone transport and vascularized

Figure 1



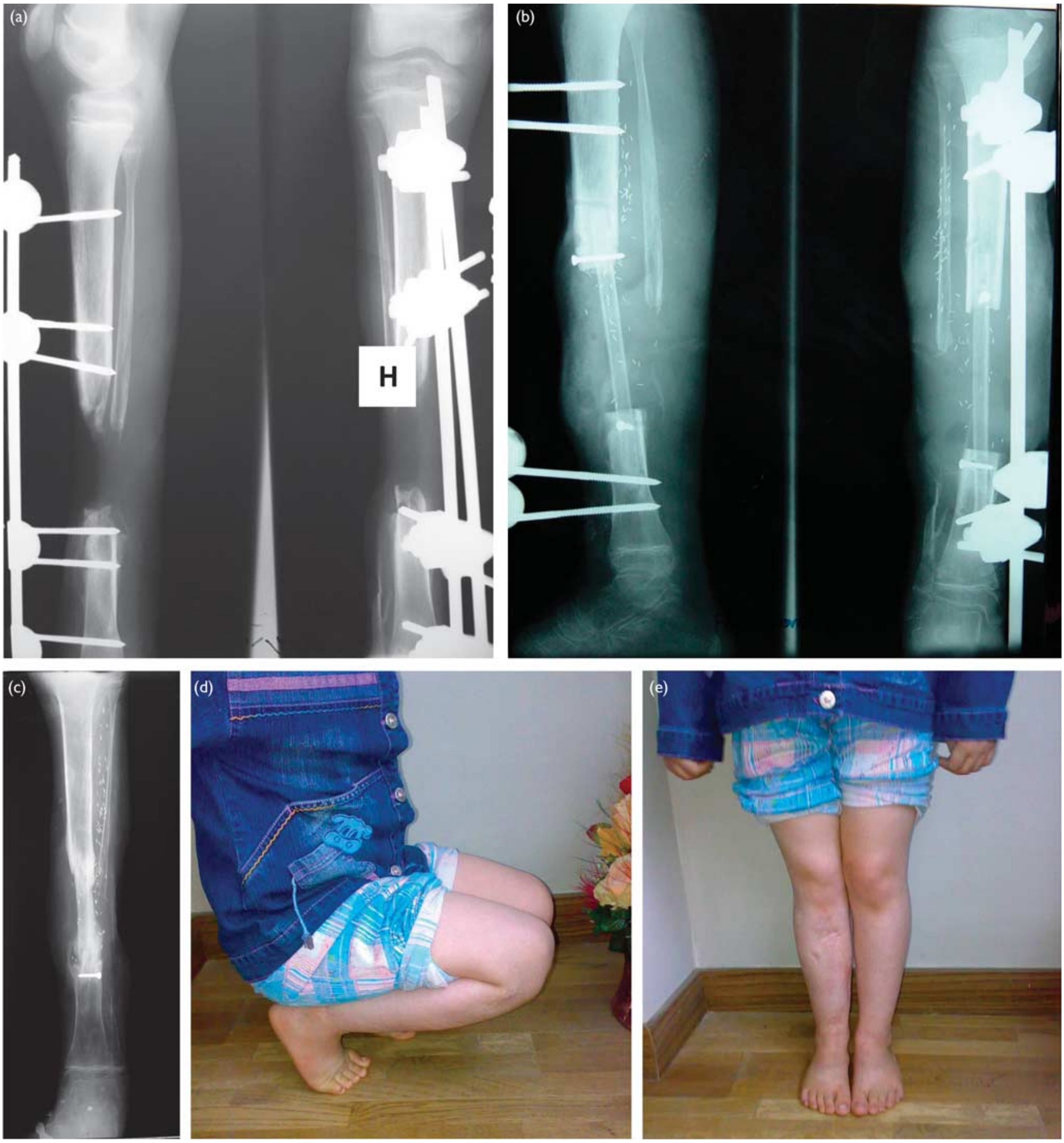
Comparison between group 1 (bone transport) and group 2 (vascularized fibular grafting) in terms of four parameters: size of the filled defect, union time, average treatment time, and the average time to full weight bearing.

Figure 2



(a) Case 1 (bone transport): a 38-year-old patient with a simple tibial fracture treated by lateral tibial plating. Infection and wound dehiscence occurred. Extraction of the plate and excision of the sequestrated bone was performed, leading to a 4 cm defect in the middle of the tibia. (b, c) Ilizarov bone transport with bifocal bone transport was carried out after proximal corticotomy. (d) Radiograph of the leg during bone transport. (e, f) Radiograph at the end of follow-up showing full union of the defect site and the distraction site. (g, h, i) Photographs of the patient at the end of follow-up.

Figure 3



(a) Case 2 (VFG): an 11-year-old patient with open fractures of grade IIIb in both bones of the leg that were treated with an external fixator and resulted in post-traumatic bone loss of the middle tibia (5 cm) with infection and skin loss (5 × 4 cm). (b) Postoperative radiograph after transplantation of the contralateral fibula as a vascularized graft with a skin pedal to cover the skin loss. (c) Radiograph at the end of follow-up showing full union of the graft and its hypertrophy. (d, e) Images of the patient at the end of follow-up. VFG, vascularized fibular graft.

fibular grafting, aiming to establish a protocol for managing this complex problem.

On comparing both groups we found that, although the filled defect size was larger in group 2 [vascularized fibular grafting; 7.6 vs. 4.1 cm in group 1 (bone transport)], we had achieved satisfactory functional results (excellent and good) in 70.6% of patients in group 1 and in 80% of patients in group 2; hence, the results were better in patients treated by vascularized bone grafting with respect to function. Further, the average union time (6.9 months in group 1 vs. 4.8 months in group 2) and the average treatment time (7.2 weeks/cm in group 1 vs. 2.7 weeks/cm in group 2) were shorter in group 2; however, the main advantage of treatment by Ilizarov bone transport was the immediate allow of

Table 2 Comparing bony and functional results between group 1 (bone transport) and group 2 (vascularized fibular grafting)

	Bone results (%)		Functional results (%)	
	Group 1 (BT)	Group 2 (VFG)	Group 1 (BT)	Group 2 (VFG)
Excellent	64.7	73.3	29.4	6.7
Good	17.6	13.3	41.2	73.3
Fair	5.9	6.7	17.6	13.3
Poor	11.8	6.7	11.8	6.7

BT, bone transport; VFG, vascularized fibular grafting.

postoperative weight bearing, in comparison with vascularized fibular grafting in which weight bearing was not allowed except after hypertrophy of the vascularized fibular graft that took an average of 8.7 months.

A literature review revealed many studies reporting on the management of post-traumatic tibial defects by either Ilizarov bone transport or vascularized fibular grafting, but there are few studies comparing Ilizarov bone transport with vascularized fibular grafting.

Ilizarov bone transport

Green *et al.* [9] reviewed 17 patients with segmental skeletal defects who were managed by Ilizarov intercalary bone transport. On average, the regenerated new bone measured 5.14 cm, corresponding to the creation of new osseous tissue equivalent to 13.7% of the original length of the bone; the average time for fixation was 9.6 months, including 4.8 months to transport the bone fragment throughout the limb.

Dendrinos *et al.* [15] reported on 28 patients with infected nonunion of the tibia treated by the Ilizarov technique. The mean bridged bone defect was 6 cm. Sixty-four percent of the patients revealed excellent to good functional results, compared with 70.6% in our study.

Paley and Maar [13] studied 19 patients with tibial bone defects caused by osteomyelitis or tibial fractures treated by the Ilizarov bone transport method. They reported a mean of 2.9 operations per patient. The mean external fixator time was 16 months for a mean bone defect of 3.9 cm and a mean transport gap of 10.7 cm compared with 6.9 months for the 4.1 cm bone defect in our study. The healing index reported in their study was 1.7 months/cm, compared with 1.68 months/cm in our study with a final mean leg-length discrepancy of 1.6 cm compared with 0.8 cm in our study.

Cattaneo *et al.* [8] reported on 28 patients with infected nonunions or segmental bone defects of the tibia. Extremities healed in all of them. The mean length of the regenerated bone was 6 cm. The overall mean time of treatment using the apparatus was 9 months for full segmental bone loss.

Vascularized fibular graft

Tu and Yen [18] reported on 267 patients who underwent free vascularized fibular grafting for reconstruction of segmental long-bone defects caused by lower-extremity osteomyelitis at the authors' institutes, with 240 followed up for at least 5 years (range 5–14 years; mean, 7.5 years). The age range of the 201 male and 39 female patients was 14 to 69 years (mean, 45.3 years). The primary success rate of free vascularized fibular grafting carried out by the authors was 92.9% (223/240). The average recovery interval required for radiographic bone union in the tibia was 4.3 months (range 3.5–9 months). The average interval needed for radiographic bone union was 4.7 months. In patients who had undergone tibial reconstruction, full weight bearing was commenced at an average of 8.5 months (range 6–14 months) after solid union and positive hypertrophy of the grafted bone had been established.

Lin *et al.* [19] conducted a study on 61 survivors with composite vascularized fibular graft flaps; of them, 50 (82%) showed primary union of the grafts, and another nine showed union after conventional bone grafting, giving an overall union of 97% (59/61). Minami *et al.* [20] obtained good results with primary bone union without additional surgery in 26 of 33 patients with traumatic defects (79%).

Han *et al.* [21] investigated a larger sample of patients ($n = 160$) undergoing free iliac crest or fibula transfer. The indications for the procedure were skeletal defects, including nonunion, as a result of tumor resection, traumatic bone loss, osteomyelitis, or congenital anomaly. They reported that defects associated with chronic noninfected nonunions demonstrated the highest union rate compared with all other etiologies [76% (19/25) primarily and 92% (23/25) overall]. Weiland *et al.* [22] reported a series of 32 fibula transfers in the lower limb, with an apparently successful clinical outcome in 28 of them (87.5%).

Comparison between bone transport and vascularized fibular grafting

Yokoyama *et al.* [23] reported the results of Ilizarov bone transport and vascularized fibular grafting for post-traumatic tibial bone defect. They found that there were no differences in the results between the two groups. Because each group had a small number of patients, their studies were limited for drawing this conclusion. Two of their four patients who had undergone Ilizarov bone transport had nonunion at the docking site. One of the four patients with a vascularized fibular graft had a septic nonunion after the fracture of a grafted fibula. The cause of the septic nonunion was not explained clearly, and they assumed that vascular failure due to venous congestion was the contributing factor.

Song *et al.* [24] compared internal bone transport with vascularized fibular grafting for femoral bone defects. The mean size of the filled defect was 8.4 cm with internal bone transport and 8.9 cm with vascularized fibular grafting. The external fixation index was 1.4 months/cm with internal bone transport and 1 month/cm with vascularized fibular grafting. The functional results of internal bone transport were good in 45% with no excellent results, whereas those of vascularized fibular grafting were good in 47% with no excellent results; however, these achieved results were for femoral defects and they were much lower than those achieved for tibial defects.

From this study we can report that the use of Ilizarov bone transport has some limitations in patients with large bone defects and in those with soft-tissue loss. In those patients, vascularized fibular grafting would be a better option. However, vascularized fibular grafting had limitations in patients with limb-length inequality and in those with severe infection; better results could be achieved by Ilizarov bone transport in such patients.

We faced many problems in both groups. Pin tract infection was the main complication in group 1 (100%), and refracture of the graft was the most common late postoperative complication in group 2. Previously, other authors have found the incidence of fracture to be 20–40% [25,26]. In our series, fractures occurred in 53.3% of patients without affecting the final results. In addition, 10 (66.7%) secondary procedures (bone graft, plate fixation, skin graft, etc.) were needed in group 2.

Conclusion

Ilizarov bone transport is a good method for management of post-traumatic tibial defects, especially short defects; further, bone grafting of the docking site is necessary in all cases to achieve union and to shorten the time of external fixator application. Although the vascularized fibular graft gave better results in longer bone defects with shorter time needed for union, non-weight-bearing is mandatory until graft hypertrophy in order to avoid stress fractures, which were the main problem in our series.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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