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Gradual fibular transfer by ilizarov external fixator in post-traumatic and post-infection large tibial bone defects

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Abstract

Introduction Several reconstructive procedures have been used in management of large tibial bone defects including bone graft, bone transport (distraction osteogenesis) using various external fixators, and vascularized bone graft. Each of these procedures has its limitations and complications. The study describes gradual medial fibular transfer using Ilizarov external fixators in management of patients with large tibial defect, either following infection or trauma.

Patients and methods Between May 2011 and June 2013, 14 patients were prospectively included in the current study. The inclusion criteria were large tibial defect due to trauma or infection with severe soft tissue compromise, and small or poor tibial bone remnants making bone lengthening difficult. Exclusion criteria were patients with vascular or nerve injuries. The average age of the patients was 31.64 (±6.5) years. Medial fibular transfer was done for all patients using Ilizarov at a rate of 0.5 mm twice daily. Iliac bone graft was used in all patients after the transfer.

Results The average segmental bone defect of the tibia was (13.2±2.6), ranging between 8 and 18.6 cm. Union was achieved in all patients with average fixator time was 32.42 (±4.32) weeks. Average follow-up after removal of the fixator was 40.5 (±6.9) months.

Conclusion Gradual fibular transfer by Ilizarov external fixator is a reliable technique in management of post-traumatic and post-infection large tibial bone defects with good clinical outcome, and with few complications.

Keywords Tibial defect · Illizarov · Fibular transefer

Introduction

Open tibial fractures are very common in developing countries because of high rates of road traffic injuries with consequent osteomyelitis and large tibial bone defects [1]. The reconstruction of large bone defects in post-infection environment is still a big challenge for limb salvage because of disturbances in bacterial flora and resistance, and poor vascularity of scarred tissue [2].

Several reconstructive procedures have been used in management of large tibial bone defects including bone graft, bone transport (distraction osteogenesis) using various external fixators, and vascularized bone graft. Each of these procedures has its limitations and complications [3].

Fibular transport is another option that was first presented by Huntington (1905) who performed a muscle pedicle fibular graft by medializing the osteotomized fibula with its muscle attachment to treat post-osteomyelitis tibial defect [4]. A much less invasive technique is a gradual, transverse

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fibular transport using Ilizarov external fixator that was presented by Catgani in 2006 with good results [5]. However, after 10 years, very few case series published about such technique. The aim of the current study was to assess the outcome of gradual fibular transfer using Ilizarov external fixator in management of large tibial defect.

Patients and methods

Between May 2011 and June 2013, 15 patients were included in the current study. One patient lost to follow-up during the second stage and was excluded. The inclusion criteria were large tibial defect due to trauma or infection with severe soft tissue compromise, and small or poor tibial bone remnants making bone lengthening difficult. Exclusion criteria were patients with vascular or nerve injuries, and patients who did not complete 2 years' follow-up. The study was approved by the ethical committee of the University.

Preoperatively, all patients were assessed clinically and the general condition of the patient and associated comorbidities (e.g., diabetes, anemia, etc.) were controlled. The local soft tissue condition, scarring, draining sinuses, knee and ankle range of motion, and the neurovascular status were recorded. The technique was explained to the patients, and all patients have signed an informed consent.

Plain radiographs were obtained and anteroposterior view (AP) was used to measure the defect (using the other side as reference). CT angiography was obtained to detect the site of entry of the peroneal artery into the fibula to avoid injury of the artery during the fibular osteotomy.

Surgical technique

The procedure was designed to be done in three stages:

Stage one Removal of hardware and necrotic bone in cases of chronic osteomyelitis then fixation by uniplanar Hoffman external fixator or Ilizarov external fixator till soft tissue healing. Primary uniplanar Hoffman external fixator was used in cases of acute trauma with long-segmental tibial loss and severe soft tissue compromise.

Stage two After skin and soft tissue healing in both types of segmental tibial loss, the uniplanar fixator was removed with application of Ilizarov external fixator. The fixator was composed of two constructs, proximal and distal to the defect, the proximal part consisted of two complete rings of suitable size connected to each other by slotted sockets, and fixed to the proximal tibia above the defect by six crossing wires. The distal part consisted of two complete rings connected to each other by serrated rods, and fixed to the tibia distal to the bone defect by six crossing Ilizarov wires, three on each ring. The proximal and distal constructs were connected to each other by four serrated rods.

Proximal and distal fibular osteotomy sites were planned according to the lost segment of the tibia, followed by insertion of two olive wires in the fibula (2–3 cm away from the planned fibular osteotomy site), directed from posterolateral into anteromedial and connected to motor attractor (Fig. 1).

The motor attractor was assembled as the following steps (Fig. 2c):

- Six holes' straight plate is connected to the ring just proximal and distal to the bone defect in anteromedial direction.
- Male support or Rancho cube of a suitable number of holes was connected to each straight plate.
- A long, serrated rod connected at its end to female support was connected to the olive wire that came out on the anteromedial surface of the tibia by wire holder and at the other end, it was connected to the Rancho cube or the male support attached to the ring.
- The lateral end of the olive wires was cut 3–4 cm away from the skin of the lateral surface of the leg to facilitate the wire removal during apparatus removal.

The fibular osteotomy was performed through a lateral incision of about 3 cm length using 2.5 mm drill and sharp osteotome. Fibular transfer began from the third postoperative day, at a rate of 0.5 mm every 12 h, till the fibula come at the axis of the tibia.

Stage three When the fibula was centralized, autogenous iliac graft at both ends of the transferred fibula was done to promote union between the tibial and fibular ends. Additional fixation by wires was performed for fibular segment stability. (Fig. 1).

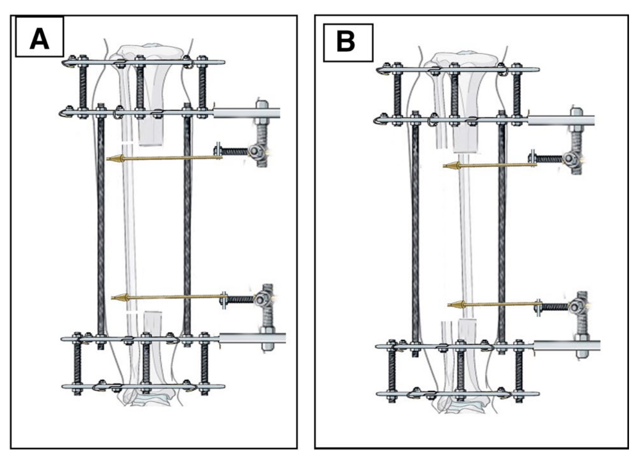

Fig. 1 Illustration presenting the technique of the gradual transefer of the fibula by Ilizarov. **a** The construct of the apparatus and the osteotomy of the fibula with traction by olive wires at the beginning of transfer, the fibular osteotomy was done at the same level of the bone defect in the tibia, (the attractor). **b** Centralization of the fibula at the end of transfer

Fig. 2 **a** Clinical photo shows infected non-united fracture of RT. Tibia with skin ulcer at the antero-medial surface of the leg, bone and plate are exposed. **b** Plane X-ray shows non-united fracture tibia fixed by plate and screws. **c** Clinical photo shows healed skin ulcer and illizarov construct during gradual fibular transfer, with attractor at the antero-medial side to attract the fibula. **d** Plane X-ray shows centralization of the fibula at the end of gradual fibular transefer. **e, f** Clinical photos show complete healing of skin ulcer and after complete bone healing and the patient is standing. **g** Plane X-ray shows complete union of the transported fibula at proximal and distal ends with hypertrophy of the fibular cortices. **h** C.T. Angiography shows the arteries of the RT. leg and the peroneal artery branches enter the transferred fibular segment

Follow-up

In the first stage, follow-up was every 2 weeks monitoring the soft tissue healing, then every week in the second stage to check the process of fibular transfer till it was completed. AP and lateral radiographs were obtained at every visit. In the third stage, the follow-up radiographs were obtained monthly till union.

Partial weight bearing was allowed in the third stage till union, then complete weight bearing was allowed. Removal of the apparatus was done after bone healing at both ends of the transferred fibular segment, followed by application of above knee cast. The cast was changed every month till complete thickening of the transferred fibula was achieved.

At final follow-up, duration of each stage, knee and ankle range of motion (ROM), limb length discrepancy, any malalignment, the need for walking aids, satisfaction of the patients, and possible complications were recorded. Postoperative CT angiography was done to assess fibular vascularity.

Results

The average age of the patients was 31.64 ($\pm$ 6.5) years. There were 10 males and 4 females, there were 11 right-sided defects, and 3 left sided. The etiology of the segmental tibial loss was open fractures due to high-energy trauma in eight patients, and chronic osteomyelitis with involvement of most of the diaphysis in six patients. Eight patients were referred to our institution for below or above knee amputations.

The average segmental bone defect of the tibia was (13.2 $\pm$ 2.6), ranging between 8 and 18.6 cm. The average

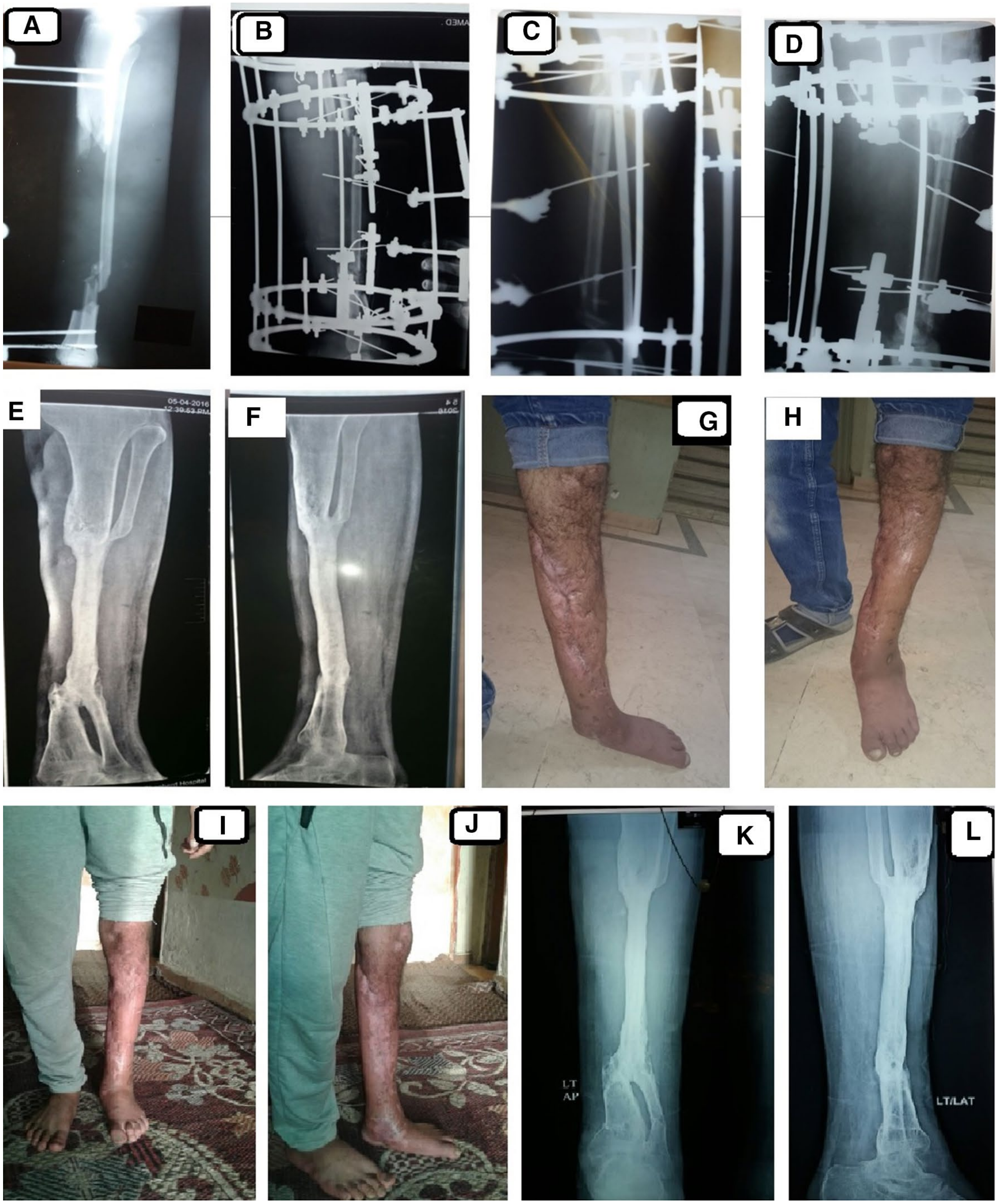

Fig. 3 **a** Plane X-ray shows fracture both bone leg with massive bone loss of the tibia, the fibula is present but fractured distally, and there was primary fixation of the fracture by mono-planner external fixator. **b** Plane X-ray shows removal of mono-planner external fixator, application of illizarov external fixator, fibular osteotomy, beginning of gradual fibular transfer. **c** Plane X-ray shows the centralization of the fibula in between the proximal and distal end of the bone defect. **d** Plane X-ray shows augmentation of the fibular fixation by additional wires and autogenous iliac bone grafting at both ends of the fibula. **e, f** Plane X-rays A-P and lateral views show complete bone healing at both ends of the transferred fibular segment with hypertrophy and thickening of the cortices. **g, h** Clinical photos of the LT. leg of the patient after complete bone and skin healing with scar along the medial side of the leg. **i, j** Clinical photos show the correction of valgus deformity of the LT. ankle by medial closing wedge supra malleolar osteotomy of the tibia. **k, l** X-rays show complete healing of the bone after supra-malleolar osteotomy of the LT. tibia and lower fibula with correction of the limb axis

time of the first stage was 11.4 (± 1.78) weeks, and of the second stage was 2.7 (± 0.5) weeks, while the average time of the third stage was 29.71 (± 4.15) weeks. The average fixator time was 32.42 (± 4.32) weeks. Average follow-up after removal of the fixator was 40.5 (± 6.9) months. CT angiography showed adequate vascularity of the transferred fibula (Fig. 2h).

Union was achieved in all patients. At final follow-up, all patients can fully weight bear on the affected extremity without external support. Hypertrophy of the transported fibula accompanied full weight bearing. The average limb-length discrepancy was 2.76 (± 0.28) cm, and was managed by shoe lift. The average postoperative keen extension were 2.28° (range 0–10) and knee flexion were 135.12 (range 110–140). The average postoperative ankle dorsiflexion was 5.3° (range 0–10) and the average postoperative plantarflexion was 20.9° (range 10–30).

Pin tract infections during the three stages of the procedure were present in seven cases, skin complications as superficial erosion at the docking sites were present in four cases, and it was managed by daily dressing with normal saline and local antibiotic spray.

Refracture at proximal part of the transported fibula occurred in two cases after 15 and 18 months postoperatively, and it was managed by putting the injured limb in a long leg cast for 3 months till union. Valgus ankle deformity developed in three patients, the mean angle was 16.7° (± 12.6), which was associated with pain. One patient had supra-malleolar corrective osteotomy, and the other two patients refused any further surgical deformity correction. All patients were satisfied with the procedure and recommend it for other patients. CT angiography showed adequate vascularity of the transferred fibula.

Case presentation

Patient 1

Male patient, 40 years old, presented with as infected non-united fracture of middle third of the right tibia. The fracture was fixed by plate and screws with chronic skin ulcer with the bone and plate exposed (Fig. 2).

The procedure was done by removal of plate and screws and the sequestrated bone. The defect was about 8 cm. Ilizarov external fixator was applied, and he had repeated daily dressing till soft tissue condition improved and infection subsided after about 9 weeks.

Osteotomy of the fibula was done and medial transfer began on the third day post-operative by a rate of 0.5 mm every 12 h. When the fibula was centralized (after about 3 weeks), open autogenous iliac graft was performed at both ends of the transferred fibula. Union was achieved and fixator removed after about 23 weeks. A waking cast was then used for 3 months.

Patient 2

Male patient, 29 years old, presented by open fracture both bone leg Gastillo type IIIB with loss of most of the tibial

Table 1 summery of different case series using medial fibular transfer by Ilizarov

Study	AL-sayyed [9]	Shiha et al. [10]	Yin et al. [8]	Catagni et al. [5]	Current study
Procedure	Medial fibular transport using Ilizarov in children and adolscents	Medial fibular transport using Ilizarov in children	Medial fibular transport using Ilizarov	Gradual fibular transport by illizarov	Medial fibular transport using Ilizarov
No of cases	Six children (average of age 8 years)	Two children	Nine patients (average age of 32.22 years)	Seven patients (average age 40.8 years)	14 patients (average age of 31.6 years)
Average bone defect in cm	9.8 cm (range 8–11)	11, 12 cm	15.67 cm (range 13–25)	15.14 cm (range 7–28)	13.2 cm (range 8–18.6)
Methodology	Infection in four patients, and high energy trauma in two patients	One due to massive bone infection The 2nd patient had open fracture grade 3B	One patient had bone sarcoma Eight patients had motor car accident	High energy trauma in four patients Infected nonunited tibia in two patients, one patient had chronic osteomyelitis	High energy trauma in eight patients, and chronic osteomyelitis with involvement of most of the diaphysis in six patients
Mean time of fixator application	11 months (range 7–17)	2 and 3.5 months	11.6months (range 9–14)	11.14 months (range, 6–18)	8 months (range 6.5–10)
Results	Union was achieved in all patients	Union was achieved in both patients	Union was achieved in all patients	Union was achieved in all patients	Union was achieved in all patients
Complications	Pin tract infection in four cases	Pin tract infection in both cases	Pin tract infection in six cases	Pin tract infection in two cases	Pin tract infection in seven cases

Table 2 Clinical data of different studies managing large tibial defects by different techniques

Study	Tuli [11]	kovoor et al. [12]	Gulan et al. [13]	Current study
Procedure	Tibialization of fibula by two stage proximal then distal fibular transfer	Free vascularized fibular graft harvested from contralateral side	Central bone grafting using cancellous iliac bone graft	Gradual medial fibular transport using Ilizarov
Tibio-fibular Fixation technique	Screws or pins or calcaneal pin	One or two AO cortical screws, supplemented by a monolateral external fixator	Above knee cast in eight cases and external fixator in two cases	Transfixing wires
No of cases	21 (average age 43), 2 children 3 and 6 years	15 patients (average age 33.7 years)	10 patients	14 patients (average age of 31.6 years)
Average bone defect in cm	9.8 cm (range 8–11)	14.5 cm (range 6.5–20 cm)	4 cm (2–7)	13.2 cm (range 8–18.6)
Mean time of immobilization	6–8 months' non-weight bearing	8–12 weeks' non-weight bearing then partial weight bearing in cast	9 months (range 7–12) no-weight bearing, then partial weight bearing	Partial weight bearing started after surgery
Complications	Screw cut through tibiofibular synostosis in three patients Shortening and limitation of ankle and knee movement	Ten stress fractures occurred in seven patients Stiff knee in two cases, ankle in one case Infection with draining sinus in one case	Infection in two patients Non-union in one patient	Pin tract infection in seven cases Stress fractures in two patients
Advantage	Easy operation, need no special equipments	Suitable in large defects	Easy operation, need no special equipments	Easy operation could be done in any hospital Immediate weight bearing
Disadvantage	Prolonged immobilization Not suitable in infection	High complication rates Need special instrument, two teams, microvascular skills	Suitable for small defects Risk of neurovascular injury Large soft tissue dissection not suitable in infection	Need experience with Ilizarov external fixator

shaft (Fig. 3). Initially, the fracture was fixed by a mono planner Hoffman external fixator.

After healing of skin and soft tissue (in 10 weeks), Ilizarov external fixator was applied and fibular osteotomy was done. The segmental tibial loss was about 16 cm. The fibular transfer began 3 days post-operative, and take about 3 weeks. When the fibula was centralized, an autogenous iliac graft was performed at docking sites. Union was achieved after about 30 weeks, and the fixator removed and a walking cast was applied for about 3 months. Valgus ankle of 30 degree was managed by supra-malleolar corrective osteotomy and casting for another 3 months.

Discussion

Many procedures have been described for treatment of large tibial bone defect which results from high energy trauma, osteomyelitis or tumors. Bone transport by Ilizarov fixator offers one of the best options, however, it requires healthy metaphysis to perform the osteotomy, so it is not suitable for cases with poor tibial bone remnants. Another limitation is, cases with severe soft tissue scarring that is adherent to the proximal tibia with the risk of bone penetration during distraction. In such cases, vascularized fibular graft is the recommended option [6].

Vascularized fibular graft is a complex procedure that requires a microvascular surgeon in specially equipped centers. The need for two surgical teams, donor site morbidity, and the difficulty of vascular anastomosis in severe infection are another limitation. Moreover, many complications were reported in up to 50% of cases [7]. In the technique presented in the current study, we combined the bone transport (but in a transverse rather than longitudinal direction) of a vascularized fibular graft with good clinical outcome.

The technique of gradual fibular transfer by Ilizarov external fixator allows a safe transfer of the fibular graft with its vascular and muscle attachment. This biological fibular transfer allowed graft hypertrophy and tibialization of the transferred fibular graft. Such technique is adequate in cases of massive tibial defects with small or poor remnants and low regeneration potentials, or with adherent scars making bone transport inadequate. Therefore, the transferred fibular segment was used to replace the tibial defect.

Reviewing the literature, only few case series of medial fibular transfer could be found [5, 8–10] with most of them using the technique in children [9, 10]. The current series represent the largest series of 14 patients with results comparable to other series (Table 1). Union was achieved at an average of 8 ($\pm$ 1.1)months, which is much shorter than time reported by Catagni [5] or Yin [8] that was 11.14 and 11.6 months respectively. This could be explained by our routine use of cancellous bone graft at the docking sites that ensured union in all our cases in a shorter time.

The results obtained in our study are comparable to those obtained in other case series using different techniques in managing large tibial defects [11–13] (Table 2). The complications reported in our case series and similar Ilizarov fibular transfer series were minimal including pin tract infections. No neurovascular complications or compartment syndrome were reported. On the other hand, complications were reported in up to 50% of cases of vascularized fibular graft including; thrombosis of the feeding artery, peroneal nerve injury, stress fracture of the fibula, and infection over the metal ware used in fixation [7, 14]. Other open techniques are not feasible with persistent infection and bad soft tissue conditions, and required prolonged periods of non-weight bearing.

Conclusion

Gradual fibular transfer by Ilizarov external fixator is a reliable technique in management of post-traumatic and post-infection large tibial bone defects with good clinical outcome, and with few complications.

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Compliance with ethical standards

Conflict of interest All authors have no conflict of interest to disclose.

Ethical approval The study was approved by ethical committee of Benha University and were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study. All patients signed an informed consent after clear explanation of the surgical procedure.

References

1. Peden M, Hyder A (2002) Road Traffic injuries are a global public health problem. Br Med J 324(7346):1153
2. Mauffrey C, Barlow B, Smith W (2015) Management of segmental bone defects. J Am Acad Orthop Surg 23(3):143–153
3. Keating J, Simpson A, Robinson C (2005) The management of fractures with Bone Loss. J Bone Jt Surg Br 87(2):142–150
4. Huntington T (1905) Case of bone transference. Use of a segment of fibula to supply a defect in the tibia. Ann Surg 41:249–251
5. Catagni M, Camagni M, Combi A, Ottaviani G (2006) Medial fibula transport with the Ilizarov frame to treat massive tibial bone loss. Clin Orthop Relat Res 488:208–216

6. Yokoyama K, Itoman M, Nakamura K, Tsukamoto T, Saita Y, Aoki S (2001) Free vascularized fibular graft vs. Ilizarov method for posttraumatic tibial bone defect. J Reconstr Microsurg 17(1):17–25
7. Arai K, Toh S, Tsubo K, Nishikawa S, Narita S, Miura H (2002) Complications of vascularized fibula graft for reconstruction of long bones. Plast Reconstr Surg 109(7):2301–2306
8. Yin P, Zhang L, Li T, Xie Y, Li J, Liu J, Zhang L, Zhang Q, Tang P (2015) Ipsilateral fibula transport for the treatment of massive tibial bone defects. Injury 46(11):2273–2277
9. Al-Sayyad M (2015) Ipsilateral medial fibular transport using a circular external fixator for reconstruction of massive tibial bone defects in children and adolescents. Egypt Orthop J 50:25–30
10. Shiha A, Khalifa A, Assaghir Y, Kenawey M (2008) Medial transport of the fibula using the Ilizarov device for reconstruction of a massive defect of the tibia in two children. J Bone Jt Surg Br 90(12):1627–1630
11. Tuli S (2005) Tibialization of the fibula: a viable option to salvage limbs with extensive scarring and gap nonunions of the tibia. Clin Orthop Relat Res 431:80–84
12. Kovoor C, Jayakumar R, George V, Padmanabhan V, Guild A, Viswanath S (2011) Vascularized fibular graft in infected tibial bone loss. Indian J Orthop 45(4):330–335
13. Gulan G, Jotanović Z, Jurdana H, Sestan B, Rapan S, Rubinić D, Ravlić-Gulan J (2012) Treatment of infected tibial nonunion with bone defect using central bone grafting technique. Coll Antropol 36(2):617–621
14. Pederson W, Person D (2007) Long bone reconstruction with vascularized bone grafts. Orthop Clin North Am 38(1):23–35