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Calcaneogenesis: the use of tibial bone transport for treatment of massively infected hindfoot defects

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Massive hindfoot defectswhich result after sequestrectomy of chronic osteomyelitis (COM) or Trauma or after tumors resection is a real challenge to the treating surgeons with either amputation or other reconstructive plastic procedures as the only available options, Calcaneal osteomyelitis is a major cause with classical surgical management to cure the infection has limited success in preservation of the hindfoot shape, function, and mechanical stability. The surgical procedure reported with the use of the Ilizarov apparatus for partial or total calcaneal OM is aimed to preserve the Hindfoot. Materials and Methods We retrospectively reviewed 10 patients which were treated by radical debridement of the infected area, Ilizarov frame application and arthrodesis with bone reconstruction by the Ilizarov apparatus using tibial transport for Hindfoot salvage. The mean age at presentation was 33.5 years (range; 24-57) and the mean follow-up was 5.1 years (range; 2-12).Patients clinical and radiographic data were assessed according to the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot score. Results The mean preoperative American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score was 48.3(range; 38-86) while the mean postoperative (AOFAS) was 58.5 (range; 45-73) , p value < 0.01 . Clinically all patients had anatomically stable feet with deformity correction and no signs of infection recurrence. Conclusion The use of Ilizarov distal tibial bone transport to fill massive hindfoot defects proved to be a reliable method for elimination of infection and reconstruction of large defects without the need for bony or soft tissue plastic procedures. The technique also has the ability to produce a rigid limb fixation following debridement and to fill in massive hindfoot defects due to other etiologies as well.

Keywords: Calcanectomy; talectomy; hindfoot defects; Ilizarov technique; tibial bone transport; calcaneogenesis.

INTRODUCTION

Despite the introduction of new surgical techniques and application of modern antimicrobial chemotherapy, chronic osteomyelitis (COM) of

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the calcaneus remains a challenging condition for the orthopaedic and plastic surgeons. It constitutes about 7 to 8% of the total COM cases that develops in the skeletal bones and 5l % from the total number of COM cases that occur in the foot bones *(1)*. This condition usually requires multiple surgical debridement and may result in amputation *(2-5)*. The available reconstructive and plastic operations result in poor outcome in 5 to 20 % of cases with recurrence of the infection process *(6, 7)*.

We have developed a novel technique using Ilizarov method in foot reconstruction utilizing the concept of distraction histogenesis of G Ilizarov *(8)* and bone transport using a circular external fixator *(9)*. According to our knowledge and literature review this technique with distal tibial bone transport and osteotomy of the remaining bony block to create a calcaneus like structure (Calcaneogenesis) had never been reported for reconstruction of hindfoot massive defects after excision of the calcaneus and /or talus and the surrounding soft tissues and with the ability to restore its anatomical shape and limb weight bearing capability. The technique also has the advantage being reproducible.

MATERIALS AND METHODS

This is a retrospective descriptive review of 10 cases with the aim to illustrate a novel technique for reconstruction of massively infected hindfoot defects using the concept of bone transport with some modifications. The study has been approved by our institutional review board (IRB) and all individuals in the study gave informed consent for the purpose of the study and publication. Our inclusion criteria were 1- Total or partial infection of the calcaneum and/or talus or both of them, 2- Treatment in which Ilizarov bone transport technique was used to reconstruct and reshape the hind foot. 3- Follow-up of ≥ two years. Exclusion Criteria were 1- Destruction of the calcaneum and/or talus due to causes other than infection. 2- Treatment that involved techniques other than Ilizarov bone transport 3- Follow-up < two years or patients who are lost to follow-up. The study resulted in 10 patients with neuropathic hindfoot chronic osteomyelitis with 7 males and 3 females and a mean age at presentation of 33.5 years (range; 24-57) and mean follow-up of 5.1 years (range; 2-12) (Table I). They had a mean of 1.5 (range; 0-5) of previous operative intervention to treat their infection without successful results. Eight patients had both calcaneum and talus massively infected while two had calcaneal infection in which they developed multiple defects due to the infection and previous sequestrectomy. Statistical analysis was performed using Excel package 2010. Patient's parameters using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score was calculated as mean ± standard deviation, a p-value less than 0.05 was considered significant.

Surgical management consists of two stages:

1- Radical debridement of the infected areas, Ilizarov frame application,and arthrodesis

2- Bone reconstruction by the Ilizarov apparatus for hindfoot salvage using tibial bone transport.

Stage 1

Proper debridement of the purulent lesion by performing radical sequesterectomy of the affected calcaneus and/or talus which was indentified by injecting methylene blue dye into the sinuses. Skin and soft tissue incision is performed layer by layer on the lateral surface of the foot to access the calcaneus. The cutting line passes through the sinus, and the whole sinus is excised along with its tract. Next, the non-viable surrounding soft tissues are removed (Fig. 1 a) The affected calcaneal bone is separated gently from the subtalar and calcaneocuboid joints and then removed completely. Hemostasis is secured. The wound is washed properly with saline and antiseptic solutions. After removal of the infected tissues, the Ilizarov apparatus is applied on the leg and then to the foot. In both the upper and middle thirds of the tibia two rings are mounted and connected to the bone by wires and to each other by rods , wires are tensioned and fixed on the rings in the tibia and half rings in the foot (Fig. 1 b). The wound is drained and sutured tightly. An interval of one month is necessary for granulation tissue and wound healing and dressing during this time is every 3 days while patients are

given IV antibiotics according to the culture and sensitive results for one 3 weeks.

Stage 2

Next, we proceed to perform arthrodesis of the ankle joint, the surfaces of the joints are exposed and the cartilage is removed carefully using an osteotome. The body of the talus is approximated to the tibial end while the head of the talus to the navicular bone. Bone segments are fixed in the Ilizarov frame with acute compression (Fig. 1 c). In the postoperative period, a supportive compression by 1 mm every 10 days is maintained between the bones of the ankle and talo-navicular junctions to obtain a reliable bony block of the joints. It usually takes from 30 to 40 days. If the surrounding soft tissues are involved into the infection process to a great extent, this phase of the operation can be delayed for four weeks until infection resolve by IV antibiotics and/or serial debridement sessions. Once ankle arthrodesis has been obtained, osteotomies in the proximal tibial metaphysis and at the level of the neck of the talus are performed. To improve the stability of the tibial fragment, two or three extra wires are inserted and two more rings are added (Fig. 1 d)

By proximal Tibial osteotomy and gradual distraction in the upper third of the tibia, the tibia is lengthened while the body of the talus is lowered into the region of the removed calcaneus (Fig. 1 e). The amount of tibial lengthening should be equal to the height of the previously removed calcaneus and /or talus. The rate of distraction is 1.0 mm per day.

After bringing down the distal end of the tibia to the hindfoot defect , the hindfoot shape is modeled.

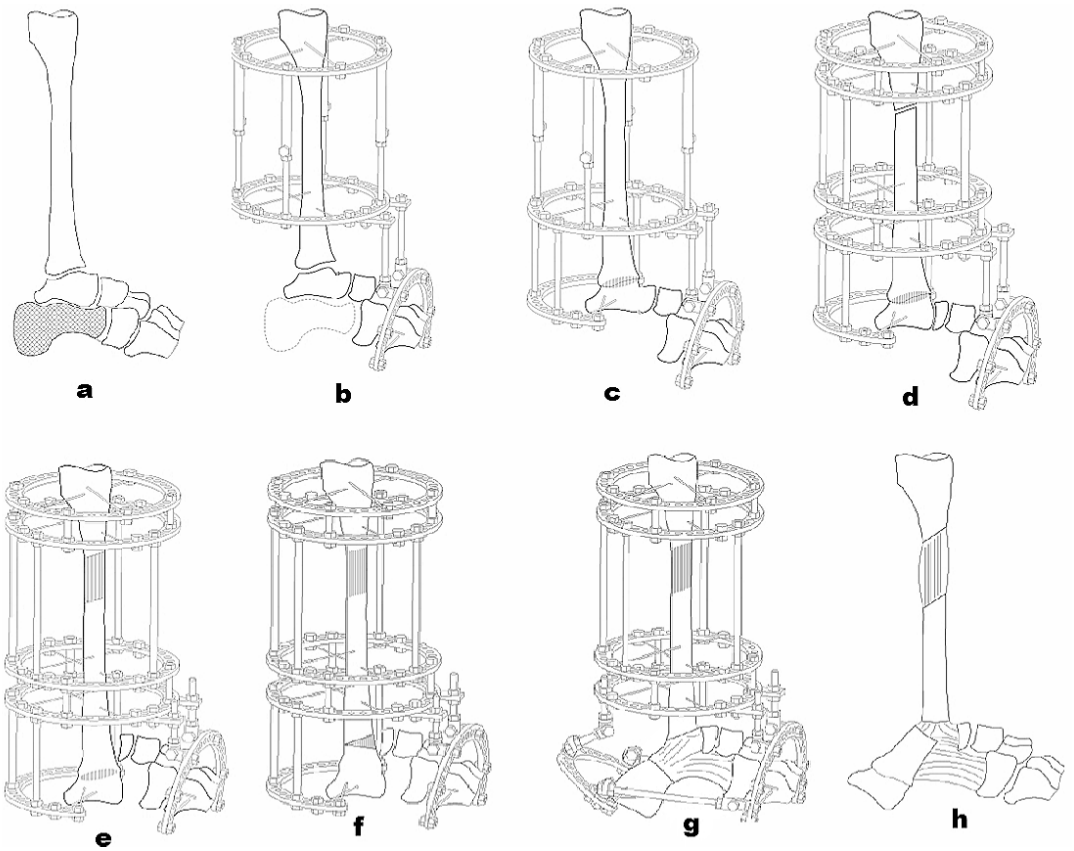

Figure 1. — Schematic drawing for calcaneogenesis (a) before surgery (b) after debridement and calcanectomy(c) tibio-talar arthrodesis (d) high tibial osteotomy for bone transport(e) distraction osteogenesis in the upper tibia (f) lower tibial osteotomy at the level of the ankle joint (g) backward tilting of the distal tibo-talar block (h) Dismounting of the apparatus after complete consolidation of the distal osteotomy.

To achieve this, two parallel wires in the frontal plane are inserted in the distal end of the tibio-talar block which are perpendicular to the axis of the tibia. Next, a tibial osteotomy is performed in the lower third at the level of the fused ankle joint in the horizontal plane (Fig. 1 f). In the postoperative period, a gradual backward tilting transport of the distal fragment)tibio-talar block) with a rate of 0.5 or 1.0 mm per day is performed to shape the arch of the foot (Fig. 1 g).

Once a proper anatomical shape and size of the hindfoot had been achieved fixation in the frame should be continued until the regenerated bone is reorganized into a mature bony tissue and the union of the distal tibial fragment with the mid-foot is completed to form the Tibio-cuboid fibrous union. This junction with the above mentioned fusion creates a bony block which is resistant to static and dynamic loads and is free of osteomyelitic lesions. It should also correspond to the hindfoot height and shape (Fig. 1 h). Upon apparatus removal, further immobilization of the limb is commonly not required but physical exercises are necessary to develop a new gait stereotype. A clinical case example is shown in (Figure 2) .

Post-operative course Patients are advised and recommended for gradual increase of load on the foot. Such regime is maintained until ilizarov frame removal. In our study no patient needed pain medication as all patients were neuropathic. wound dressing is done with gauze soaked in antiseptic solution daily for 5 days, then every other day until end of the second week, then the dressing is carried out once weekly until frame removal. In cases of infection around the wires, dressing was done with rifampicin solution, and gauze is changed daily with local injection of Lincomycinonce for three days.

Figure 2./1 — Clinical case (a) Preoperative clinical photo of 21 year old woman with totally infected Lt) calcaneus (b) sinogram showing the extent of the infection (c) debridement, radical excision of the calcaneus and application of the Ilizarov apparatus (d) ankle arthrodesis.

Figure 2.2 — (e) Proximal tibial corticotomy and distraction to fill the hindfoot void fixed to forefoot ring (f) distal tibial corticotomy to redirect Tibio-talar block to replace the calcaneus with addition of two Posterior half rings with healed arthrodesis and fibrous cuboideo-talar junction (g) after completion of backward tilting of the block(h) one year follow-up with complete consolidation of the regenerate (i) Clinical appearance after 3 year without any signs of infection

After frame removal patients are recommended to wear ankle foot orthosis (AFO) or custom made orthotics for 1 month with gradual increase of load with crutches. Also patients are recommended to do massage sessions to enhance blood supply to the limb and physiotherapy exercises to develop a new gait pattern after a long standing period of infection and disuse atrophy.

RESULTS

All patients had satisfactory results and have their feet reconstructed in a shapely manner and without any signs of infection recurrence either clinically in the form of sinuses, or radiological in the form of any bony changes, laboratory results of complete blood count CBC and C- reactive protein CRP were all negative at last follow-up for all patients. (Table I) shows the microbes isolated which were treated according to the results of culture and sensitivity.

The mean time spent in external fixation was 10.9 months (range; 8-14). The mean follow-up time was 5.1 years (range; 2-12). The mean preoperative American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score was 48.3(range; 38-86) while the mean postoperative (AOFAS) was 58.5 (range; 45-73) , with a p value < 0.01 which is considered significant. since all patients are neuropathic with senseless feet the pain the score didn't change very much pre and postoperatively, the painless foot together with the stiffness they had will contribute to the small change in the

Table I. — Demographic and clinical features

Patient	Sex	Age	Side	Bone	Previous operations	Microbe Isolated	Time in frame(months)	Follow-up in years
1	W	27	L	Calcaneus	5	St. Aureus	12	5
2	W	24	L	Calcaneus, talus	0	Pseudomonas	11	2
3	W	32	R	Calcaneus, talus	3	MRSA	9	6
4	M	56	L	Calcaneus, talus	0	St. Aureus	14	5
5	M	57	R	Calcaneus	0	Pseudomonas, Enerococcusfecalis	8	2
6	M	29	R	Calcaneus, talus	2	Pseudomonas	9	4
7	M	34	R	Calcaneus, talus	1	St. Aureus	11	5
8	M	27	R	Calcaneus, talus	0	MRSA	12	12
9	M	24	L	Calcaneus, talus	3	St. Aureus	10	3
10	M	25	R	Calcaneus, talus	1	MRSA	13	7

functional score. However, at the end of treatment all patients had stable feet, the function at the Hindfoot will resemble those with a tibio-talar and Pan-arthrodesis, which is a sufficient gain for the patients. Three patients reported complications in the form of Pin Tract Infections (PTIs) which were treated by oral and/or IV antibiotics depending on the severity as mentioned above by the protocol.

DISCUSSION

Chronic hindfoot infections whether calcanean or talar or both are a management dilemma with causative agent, patient comorbidities and condition of local tissues further making treatment options a complex one. Until recently, few surgical techniques have been used to fill in the bone and soft tissue defects in the foot, some authors advocated total or partial calcanectomy or talectomy as an alternative to amputation *(2, 4, 5, 6)* .Other technically demanding procedures such as free fasciocutaneous perforator (FCP) or free muscle flaps, fibular and composite grafts *(4, 10, 11, 12, 13),* have also been reported. Some authors have used bony allograft and membrane induced osteogenesis for reconstruction *(14, 15)* most of these techniques require delayed or partial postoperative weight bearing period and result in donor site morbidities and with a possibilty to repeat the procedure in case of recurrence. defects filling with various other materials like bone cement mixed with various antibiotics, hydroxyapatite, calcium sulphate, or organic materials have been used with different success rate *(16, 17, 18)*. The use of external fixators to address such conditions have been reported but their use was limited to fixation of the affected segment only, without any further reconstructive or restorative procedures *(14, 19)*.

With regard to foot and ankle stability in the postoperative period, most of the reported methods use various types of splints which do not provide adequate stability, On the other hand the ilizarov technique provides a stable construct which patients are advised to weight bear on the second postoperative day even in the presence of large defects, it also enables the generation of osseous and other tissues and to mobilize these segments simultaneously, the technique is also a minimally invasive one with less blood loss and almost no donor site morbidity by utilizes the concept of distacrtion bone transport to fill the defects. It is important to mention that with regard to patients with neuropathic foot infections with ulcers, it is better to avoid amputation as much as possible as they are more prone to stump ulcers and hence difficulty in wearing prosthetics *(20, 21)*. while most of the reported procedures covered partial or complete defects of calcaenum, none of them were used to treat massive defects including the situation of talocalcanectomy which were treated successfully using our technique. With regard to adverse effects of our method, this includes pin tract infections [PIT] which could be avoided by meticulous follow

up and dressing around wires. In our series most of the wires infections were superficial with only erythema at the pin-skin interface which responded by anti-septic solution soaked gauze change, only three cases developed purulent infection around one wire which necessitated removal of that wire, so we advocate for increasing the frame stability by increasing the number of inserted wires to enhance the construct *(22)* and to compensate in case we need to remove any wire which might be needed just before the scheduled removal to dynamize the frame. Some patients developed minor skin wounds during treatment course which were treated by dressing and Antibiotics, it is worth mentioning that proper placement of wires will prevent skin invaginations that may be associated with such procedures. Another disadvantage is a relatively long duration in the fixator compared with other techniques although when other techniques fail, patients usually will have enlargement of the bony defects due to repeated debridement or even a limb loss *(6)* in addition to another donor site morbidity, We believe that patient's compliance and cooperation are necessary to achieve satisfactory results.

CONCLUSION

Calcaneogenesis technique is based on the Ilizarov method for management of massively infected Hindfoot defects due to chronic osteomyelitis. It is feasible to use Ilizarov distraction osteogenesis to fill in the bone and soft tissue defects for the treatment of calcaneal and/or Talar osteomyelitis. The technique has the ability to produce a rigid limb fixation following debridement and to fill in massive hindfoot defects due to other etiologies as well.

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