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ORIGINAL ARTICLE

Amputation versus functional reconstruction in the management of complex hind foot injuries caused by land-mine explosions: a long-term retrospective comparison

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Abstract The purpose of this study is to compare the long-term clinical outcomes of patients who were treated with either hind foot reconstruction or amputation in complex hind foot injuries accompanied with bone and soft tissue loss due to land-mine explosions. Between 1994 and 2004, all patients with hind foot complex injuries due to land-mine explosion, who were operated in our clinic, were enrolled to the study. All patients were evaluated with Short-Form 36 (SF-36), Foot and Ankle Disability Index (FADI) and Body Image Quality of Life Inventory (BIQLI) after a mean of 15.1 ± 2.2 (range 9–19) years of follow-up. Demographic characteristics, number of operations, necessity of psychiatric treatment and all complications were compared between groups. There were a total of 42 patients [21 in reconstruction group (Gr I) and 21 in amputation group (Gr II)]. The mean age at the time of final follow-up was 38.4 ± 3.04 years in Gr I and 38.2 ± 4.24 years in Gr II ($p = 0.732$). The mean follow-up duration was 15.7 ± 2.07 years in Gr I and 14.57 ± 2.29 years in Gr II ($p = 0.081$). The number of operations was significantly higher in Gr I (8.66 ± 10.2 times vs. 4.42 ± 7.7 times, respectively, $p = 0.001$). The mean FADI score at the final follow-up was 64.3 ± 18.1 in Gr I. In amputation group, more patients needed psychotherapy due to major depression (12 patients vs. 4 patients, $p = 0.012$). Major complications in Gr I were musculocutaneous flap atrophy in calcaneal region ($n = 8$ patients), limited ankle motion ($n = 11$) and painful osteophytes on plantar region ($n = 6$). In Gr II, stump problems were dominating (pain and tenderness $n = 10$, ulcer $n = 2$, allergic skin lesions $n = 7$, painful neuroma $n = 10$, bony spur $n = 5$, paresthesia $n = 1$, excessive sweating $n = 12$). At the final visit, although SF-36 scores were similar between groups ($p = 0.182$), extremity reconstruction group had significantly higher BIQLI scores than the amputation group ($p = 0.016$). If the dorsalis pedis is intact and midfoot and forefoot is relatively protected, hind foot reconstruction should be attempted. Long-term outcomes of hind foot reconstruction are satisfactory with minor complications and better BIQLI.

Keywords Land-mine injuries · Hind foot · Open calcaneal fractures · Reconstruction · Ilizarov method

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Introduction

In a land-mine injury, extent of tissue damage depends on the amount of energy discharged when the mine is detonated and the part of the body contacting to the mine. Foot, particularly the hind foot and heel, is affected in vast majority of events that usually lead to complex hind foot fractures with significant bone and soft tissue loss [1–3]. The management of these injuries is still a challenge for orthopedic surgeons, which comprises several controversies.

Heel plays an important role in all phases of the normal gait. Therefore, a surgical reconstruction should provide a functional hind foot with sufficient bone and surrounding

soft tissue coverage in such kind of injuries [1, 2]. Recently, limb salvage after land-mine injuries improved greatly parallel to the advancements in reconstructive techniques and technologies [2, 3]. Intact vascular status and mild involvement of midfoot and forefoot can be an indication of limb salvage [1]. However, in severe cases limb salvage necessitates multiple surgical procedures which do not always produce an ideal result. Furthermore, the treatment may be physically, psychologically and financially devastating both for the patient and for the health system [4, 5]. On the other hand, early amputation allows a rapid functional recovery, although stump complications and problems with prosthetic use may ensue later in the long term [4]. In this retrospective study, we aimed to compare the long-term clinical outcomes of Ilizarov distraction osteogenesis and soft tissue reconstruction in patients with defective calcaneal fractures due to land-mine injuries, with the clinical results of below-knee amputation in patients who suffered from similar injuries.

Materials and methods

Patients

This retrospective study was carried out according to the Declaration of Helsinki, and the Local Ethics Committee approved the study protocol. All patients gave informed consent prior to their inclusion in the study. Between 1994 and 2004, all patients with hind foot complex injuries due to land-mine explosion, who were operated in our clinic, were enrolled to the study. All patients had type 3 soft tissue damage according to Ostern and Tscherne classification and type IIIb or type IIIc open calcaneal (Gustillo-Anderson classification) or combined calcaneal and talar-comminuted fractures with bone loss at the initial admission (Fig. 1) [6]. All patients' data were assessed from the clinic database, and patients were divided into two groups; Group I *(reconstruction group)* consisted of patients with severe Gustillo-Anderson Grade IIIb or IIIc defective calcaneal fractures treated with soft tissue reconstruction and distraction osteogenesis with Ilizarov external fixator. Group II *(amputation group)* consisted of patients who were treated with below-knee amputation due to similar injuries.

Limb salvage and hind foot reconstruction surgical technique

Intact dorsalis pedis artery, relatively protected mid- and forefoot were indications of limb salvage and reconstruction. Initially, a meticulous debridement was carried out, and patients received proper course of antibiotics. Soft tissue

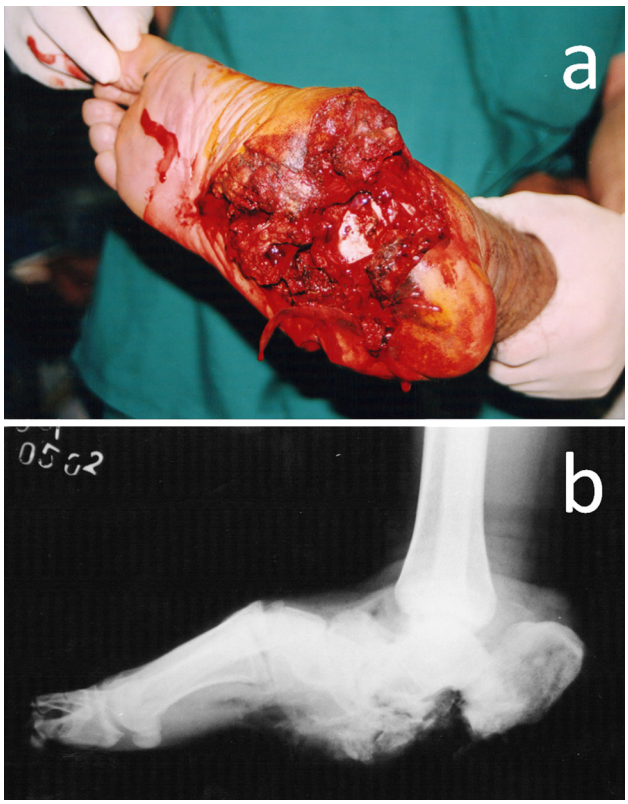

Fig. 1 Clinical appearance of 21-year-old male patients with complex hind foot injury (**a**). Lateral radiograph shows comminuted calcaneal, talar and navicular fractures (**b**)

defects were reconstructed with free musculocutaneous flaps on an average of 24.7 days (range 5–76) from the initial injury. Rectus abdominis and latissimus dorsi musculocutaneous free flaps were used in case of severe heel pad, plantar region and posterior leg soft tissue injuries. Prior to bony reconstruction, patients with wound infection were treated with sequential debridement to eradicate the infection at least 2 weeks before applying the external fixator. The technique and components of the apparatus for the reconstruction of the hind foot in the presence of large osseous defects are previously described by Ilizarov [7]. We performed all operations according to the previous descriptions and technique. After applying the fixator, an oblique osteotomy was performed from the distal tibia or posterior talus [1]. Proximal and distal sites of the osteotomy were fixed with at least two or three K-wires. With distraction osteogenesis, osteotomy site was rotated on the sagittal plane 1 mm/day to fill the calcaneal defect (Fig. 2).

All patients were allowed for partial weight bearing on postoperative third day and full weight bearing on 12th day. Distraction was continued till the level of distal osteotomy fragment had reached the level of first metatarsal head on the lateral radiographs. After the soft callus was seen on the osteotomy site, external fixators were dynamized along 2 or 3 weeks and consequently removed.

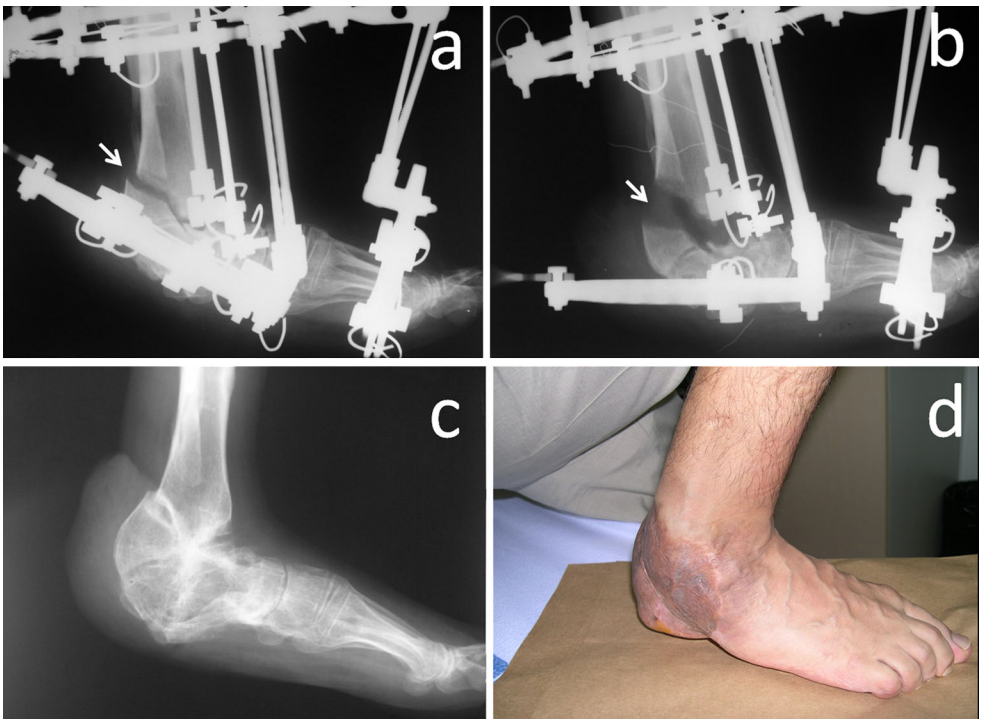

Fig. 2 **a** Oblique osteotomy from the distal tibia (*white arrow*). **b** Sagittal rotation of the osteotomy to fill the calcaneal bone defect. Note the distraction (*white arrow*). **c**, **d** Final radiographic and clinical appearance of the patient

Amputation technique

Patients with severe calcaneal fracture accompanying irreparable tibialis posterior and dorsalis pedis arterial injury and extensive soft tissue loss underwent below-knee amputation. Amputation was performed 13–14 cm distal to the knee joint line. If the posterior muscle (gastrocnemius and soleus) is intact, posterior flap technique was used for amputation. Fish mouth amputation technique was used in case of severe posterior tibia compartment muscular injury.

Evaluation of functional results and quality of life

All patients were invited to the hospital at the final follow-up. Both groups were evaluated with physical examination and radiologic study throughout the follow-up period. Quality of life quality and functional outcomes were evaluated using Short-Form 36 (SF-36), Foot and Ankle Disability Index (FADI) and Body Image Quality of Life Inventory (BIQLI) [8, 9]. All complications were screened and recorded, including psychiatric treatments.

Statistical analysis

Continuous variables were stated as mean and standard deviation and categorical variables as percentages and frequency distributions. Mann–Whitney *U* test was used to compare the means of independent groups. Chi-square test was used to analyze the distribution of categorical data. A p value <0.05 was considered statistically significant.

Results

There were a total of 42 patients (21 in Group I and 21 in Group II). The mean age at the time of final follow-up was 38.4 ± 3.04 years in Gr I and 38.2 ± 4.24 years in Gr II ($p = 0.732$). The mean follow-up duration was 15.7 ± 2.07 years in Gr I and 14.57 ± 2.29 years in Gr II ($p = 0.081$). The number of operations was significantly higher in Gr I (8.66 ± 10.2 times vs. 4.42 ± 7.7 times, respectively, $p = 0.001$). The mean external fixator application time was 5.07 ± 3.1 (range, 1.5–15) months in Gr I. The mean FADI score at the final follow-up was 64.3 ± 18.1 in Gr I. In amputation group, more patients needed psychotherapy due to major depression (12 patients vs. 4 patients, $p = 0.012$). Major complications in Gr I were musculocutaneous flap atrophy in calcaneal region ($n = 8$ patients), limited ankle motion ($n = 11$) and painful osteophytes on plantar region ($n = 6$). In Gr II, stump problems were dominating (pain and tenderness $n = 10$, ulcer $n = 2$, allergic skin lesions $n = 7$, painful neuroma $n = 10$, bony spur $n = 5$, paresthesia $n = 1$, excessive sweating $n = 12$) (Fig. 3). At the final visit, although SF-

Fig. 3 **a** Lateral foot radiograph of a 38-year-old patient who complain about painful osteophytes (*white arrows*). **b** Clinical appearance of the patient. **c** Pedography shows the increased pressure points over the heel (*black circle*)

Table 1 Summary of results

	Group I amputation ($n = 21$)	Group II reconstruction ($n = 21$)	Significance (p value)
Age at final follow-up (mean ± SD) years	38.2 ± 4.24	38.4 ± 3.04	0.732
Follow-up (mean ± SD) years	14.57 ± 2.29	15.7 ± 2.07	0.081
Side of involvement (right vs. left)	14 right, 7 left	14 right, 7 left	0.628
Number of operations (mean ± SD)	4.42 ± 7.7	8.66 ± 10.2	0.001
Psychotherapy requirement (number of patients)	12 patients	4 patients	0.012
SF-36 (mean ± SD)	93.5 ± 24.4	103.3 ± 17.9	0.182
BIQLI (mean ± SD)	−8.4 ± 19.8	5.7 ± 15.8	0.016

36 scores were similar between groups ($p = 0.182$), extremity reconstruction group (Gr I) had significantly higher BIQLI scores than the amputation group (Gr II) ($p = 0.016$). Results are summarized in Table 1.

Discussion

The current study investigated the clinical results of Ilizarov distraction osteogenesis and soft tissue reconstruction in patients with defective calcaneal fractures due to land-mine injuries, with the clinical results of below-knee amputation in patients with similar injuries. We have found that hind foot reconstruction and limb salvage yielded higher BIQLI scores as compared with amputation group.

There is no standard protocol in the treatment for massive hind foot injuries which consist of severe soft tissue and bony defects. While Sanders and Heier propose open reduction and internal fixation in type 1 and 2 open calcaneal fractures, they prefer meticulous soft tissue reconstruction prior to bone osteosynthesis in type IIIb fractures as the early bony fixation is highly associated with infection and osteomyelitis [3, 10, 11]. They proposed extensive debridement and prompt soft tissue coverage as soon as possible in type III open fractures, especially in type IIIB open fractures [10]. However, open calcaneus fractures due to land mines are mostly associated with some destructive complications. These injuries are blast induced, and restoration of normal hind foot function is not warranted with

the use of standard calcaneus fracture management protocols as in civilian events. Soft tissue damage is occurred with "outside-in" mechanism due to blast effect, and the bone communition is extended to the subtalar joint surface that often makes it non-reconstructable [3]. Additionally, these fractures are frequently bilateral and often accompanied by neurovascular injuries which make it difficult to make a treatment decision [3]. In case of open calcaneal fractures with massive soft tissue destruction that requires flap coverage, some authors offer early amputation [3, 4]. They state that most patients who undergo flap reconstruction for an open calcaneus fracture end up with a delayed elective amputation due to poor functional outcome or chronic infection [3]. On the contrary, Ozturk et al. [2] reported satisfactory long-term results in massive open calcaneal fractures due to land mines treated with musculocutaneous free flaps. They found that muscle flaps with overlying skin grafts supplied sufficient and durable tissue in long-term follow-up. Also, authors preferred shoe modifications and orthotics to correct load distribution and pressure points underneath the reconstructed feet [2]. Similarly, Ulusal et al. [12] reported satisfactory results in type IIIb open calcaneus fractures treated with free musculocutaneous flaps. In the current study, we have reconstructed the soft tissue defects with free musculocutaneous flaps on average of 24.7 days after meticulous wound care. None of our patients were complicated with infection or flap failure on short-term follow-up. However, on long-term visits, eight of 21 patients had musculocutaneous flap atrophy that has mostly caused pain on heel strike. With proper orthotics and shoe modifications, none of these patients required late amputation.

One of the other major controversies on massive defective calcaneal fractures is fixation type. Even in closed low-energy calcaneal fractures, wound problems are a common complication in surgical management [13, 14]. Several authors suggested Ilizarov method a good alternative to traditional methods for the management of intra-articular calcaneus fractures with fewer secondary problems [1, 15]. On the other hand, on war wounds, severe contamination and difficulties in coverage of blast-induced wounds pin down the military orthopedic surgeons to choosing staged soft tissue management and applying ring-type external fixators because open reduction and internal fixation with plate osteosynthesis is associated with high rates of osteomyelitis and frequent subsequent amputations in acute phase of the surgery. Heier et al. [10] did not prefer open reduction and internal fixation in type IIIb open calcaneus fractures as first-line treatment. They recommended the use of external fixation to stabilize the fracture and to allow the soft tissues to heal. Even in type II non-medial wound and type IIIa fractures, they bewared of open reduction and internal fixation and they reported fair to poor results in these types of fractures. Similarly, Gur et al. [1] reported excellent results using Ilizarov ring fixator in massive calcaneal fractures due to land mine with minimal complications. In the current study, calcaneal reconstruction with the use of Ilizarov ring fixator after proper soft tissue reconstruction did not have major complications regarding bony fixation. Moreover, patients were allowed for full weight bearing on postoperative 12th day that contributed to the fast rehabilitation process. Major patient complaints were due to flap atrophy and distraction osteogenesis eliminated the requirement of using bone grafts on the fracture zone, which may cause infection and soft tissue complications. In all cases, symptoms related to flap atrophy and calcaneal spurs were overcome with proper shoe modifications and padding.

Recently, many seriously injured limbs due to combat wounds are salvaged and reconstructed appropriately in parallel with developments in orthopedic, plastic and vascular surgical techniques. In the combat fields, limb salvage or amputation decision is performed soon after the patient is initially evaluated in field hospitals [3]. Unfortunately, many scoring systems that were created to aid the trauma surgeon for deciding limb salvage or amputation generally failed in the literature [16, 17]. However, the most objective criteria for deciding amputation in a mangled lower extremity seem as transection of the tibial nerve and irreparable vascular injury [18]. Moreover, some principles are useful for deciding limb reconstruction despite the lack of trauma scoring systems. First, the limb salvage decision should not affect the patient's general state of health and life. Second, it is important to recognize the increased lower-extremity amputation rate in the presence of multilevel segmental foot and ankle injuries [3]. Despite these, controversy exists between limb salvage and amputation. Dagum et al. [19] reported that patients in the amputation group had lower physical functional outcome scores than patients in the successful salvage group. Mental and pain outcome scores were similar in both groups. However, Georgiadis et al. [20] concluded in their study that patients with type IIIb and IIIc injuries who had limb salvage fared worse than those with an early below-knee amputation. More patients in limb salvage group felt themselves disabled. Ebrahimzadeh et al. [4] investigated long-term outcomes of patients undergoing war-related amputations of the foot and ankle. They stated that patients with lower-extremity amputation due to wartime injuries had more long-term physical and psychological problems. These problems had influenced patients' overall health and quality of life. They concluded that wartime amputations should be evaluated in terms of not only phantom pain but also low back pain, contralateral knee pain and vocational and psychosocial problems that also affect patient. In the current study, patients with open hind foot injuries

accompanied with severe defective calcaneus fractures, treated with limb reconstruction according to strict criterions, an intact dorsalis pedis artery and preserved midfoot region. When we have evaluated and compared treatment methods, complications and end-stage functions of patients between two groups, both groups were similar in terms of age, gender and etiology of injury. While patients with successful limb reconstruction experienced more operations and hospital stay than primary amputation group, they have significantly higher functional outcomes than the amputation group at final follow-up. However, they mostly complained about long hospital stay and repeated surgeries. While the amputated patients had a significant shorter treatment time and return to work, they needed more physiotherapy than the limb reconstruction group as they stated they felt themselves disabled for limb amputation.

In conclusion, there is no standard treatment protocol for the complex hind foot injuries with soft tissue and bone loss. In light of our findings and experience, if the dorsalis pedis is intact and midfoot and forefoot are relatively protected, hind foot reconstruction should be attempted. Ilizarov external fixation and distraction osteogenesis is a good alternative treatment method for this purpose. Bone defects can be reconstructed, and a stable plantigrade foot with properly aligned foot in axial, sagittal and coronal planes can be achieved.

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Conflict of interest Authors have no conflict of interest to disclose.

References

1. Gür E, Ateşalp S, Başbozkurt M, Aydoğan N, Erler K (1999) Treatment of complex calcaneal fractures with bony defects from land mine blast injuries with a circular external fixator. Foot Ankle Int 20(1):37–41
2. Oztürk S, Bayram Y, Möhür H, Deveci M, Sengezer M (2005) Evaluation of late functional results of patients treated with free muscle flaps for heel defects caused by land-mine explosions. Plast Reconstr Surg 116(7):1926–1936
3. Tintle SM, Keeling JJ, Shawen SB (2010) Combat foot and ankle trauma. J Surg Orthop Adv 19(1):70–76
4. Ebrahimzadeh MH, Rajabi MT (2007) Long-term outcomes of patients undergoing war-related amputations of the foot and ankle. J Foot Ankle Surg 46(6):429–433
5. Hoogendoorn JM, van der Werken C (2001) Grade III open tibial fractures: functional outcome and quality of life in amputees versus patients with successful reconstruction. Injury 32(4):329–334
6. Oestern HJ, Tscherne H (1983) Pathophysiology and classification of soft tissue damage in fractures. Orthopade 12(1):2–8
7. Ilizarov GA, Frankel VH (1988) The Ilizarov External Fixator, a physiologic method of orthopaedic reconstruction and skeletal correction. A conversation with Prof. G. A. Ilizarov and Victor H. Frankel. Orthop Rev 17(11):1142–1154
8. Martin RL, Burdett RG, Irrgang JJ (1999) Development of the foot and ankle disability index (FADI). J Orthop Sports Phys Ther 29:A32–A33
9. Cash TF, Fleming EC (2002) The impact of body image experiences: development of the body image quality of life inventory. Int J Eat Disord 31(4):455–460
10. Heier KA, Infante AF, Walling AK, Sanders RW (2003) Open fractures of the calcaneus: soft-tissue injury determines outcome. J Bone Joint Surg Am 85-A(12):2276–2282
11. Dellinger EP, Miller SD, Wertz MJ, Grypma M, Droppert B, Anderson PA (1988) Risk of infection after open fracture of the arm or leg. Arch Surg 123(11):1320–1327
12. Ulusal AE, Lin CH, Lin YT, Ulusal BG, Yazar S (2008) The use of free flaps in the management of type IIIB open calcaneal fractures. Plast Reconstr Surg 121(6):2010–2019
13. Folk JW, Starr AJ, Early JS (1999) Early wound complications of operative treatment of calcaneus fractures: analysis of 190 fractures. J Orthop Trauma 13(5):369–372
14. Harvey EJ, Grujic L, Early JS, Benirschke SK, Sangeorzan BJ (2001) Morbidity associated with ORIF of intra-articular calcaneus fractures using a lateral approach. Foot Ankle Int 22(11):868–873
15. Ali AM, Elsaied MA, Elmoghazy N (2009) Management of calcaneal fractures using the Ilizarov external fixator. Acta Orthop Belg 75(1):51–56
16. Bosse MJ, MacKenzie EJ, Kellam JF et al (2001) A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores. J Bone Joint Surg Am. 83-A(1):3–14
17. Brown KV, Ramasamy A, McLeod J, Stapley S, Clasper JC (2009) Predicting the need for early amputation in ballistic mangled extremity injuries. J Trauma 66(4 Suppl):S93–S97 Discussion S97–S98
18. Dougherty PJ (2007) Open tibia fracture: amputation versus limb salvage. Opinion: below-the-knee amputation. J Orthop Trauma 21(1):67–68
19. Dagum AB, Best AK, Schemitsch EH, Mahoney JL, Mahomed MN, Blight KR (1999) Salvage after severe lower-extremity trauma: are the outcomes worth the means? Plast Reconstr Surg 103(4):1212–1220
20. Georgiadis GM, Behrens FF, Joyce MJ, Earle AS, Simmons AL (1993) Open tibial fractures with severe soft-tissue loss. Limb salvage compared with below-the-knee amputation. J Bone Joint Surg Am 75(10):1431–1441