

■ CASE REPORT

Calcaneogenesis

M. R. Brinker,
D. P. Loncarich,
E. G. Melissinos,
D. P. O'Connor

From Texas
Orthopedic Hospital,
Houston, Texas, USA

We report a case in which Ilizarov distraction osteogenesis was used to lengthen the portion of calcaneum that remained after a radical debridement for osteomyelitis. The patient was able to walk normally in unmodified shoes at the end of his treatment.

Osteomyelitis of the calcaneum may occur after an open fracture¹ and is difficult to treat. A number of authors have described the use of partial calcanectomy,²⁻⁷ soft tissue flaps,^{5,7-12} arthrodesis,¹³ and various reconstruction procedures to address this problem.¹⁴⁻¹⁷ However, each of these methods has its disadvantages, which include donor site morbidity, failure of the graft, limitation of function and a need for adaptive footwear to allow walking. Ilizarov distraction osteogenesis to restore calcaneal support for the talus has not previously been described. This procedure encourages the formation of new bone under highly controlled conditions, and avoids many of the disadvantages of other treatments. We describe a case in which distraction osteogenesis was used to restore mass to the calcaneum after its debridement for osteomyelitis. We have called this process calcaneogenesis.

Case report

A 67-year-old farmer was involved in a high-speed automobile accident, in which he sustained an open fracture of the right calcaneum with extrusion of bone through the plantar aspect of the heel. That night he underwent operative debridement and internal fixation with two Steinmann pins (Fig. 1). A deep infection occurred two months later, and he had a further debridement with partial excision of the calcaneum. The patient was referred to our hospital 23 days after the second procedure. The patient and the referring surgeon had, by this time, discussed a below-knee amputation as a potential solution.

When we first saw him, there was an open, draining wound measuring 3 cm × 5 cm on the plantar aspect of the hindfoot through which the calcaneum was visible (Fig. 2). His right ankle was in 20° of fixed equinus due to shortening of

the tendo Achillis. The range of movement of his right hip and knee were unaffected. He was unable to walk and using a wheelchair, and required assistance to transfer to and from the chair.

The patient agreed to a staged plan of surgical treatment. The Steinmann pins were removed and three serial debridements were carried out with implantation of antibiotic beads, these were exchanged at each procedure. By then the entire anterior and inferior parts of the calcaneum had been excised, leaving only the posterosuperior aspects and the tubercle (Fig. 3).

A free-flap transfer from the radial part of a forearm was then carried out by a plastic surgeon to gain soft-tissue cover.

Three months later he underwent lengthening of the calcaneum by distraction osteogenesis using an Ilizarov external fixator. Physiotherapy started post-operatively and continued, two to three times per week, until the fixator was removed.

Distraction occurred at a rate of 0.25 mm twice a day, beginning on the tenth day. Initially, it proceeded in an inferior direction for four weeks, then anteriorly for six weeks, after which the fixator was locked down to allow consolidation of the newly formed bone. It was finally removed 141 days after application, when arthrodesis of the subtalar and talonavicular joints was undertaken with cannulated screws, and an iliac crest bone graft and corticocancellous allograft. Arthrodesis was thought to be necessary to avoid further degeneration of the unstable tarsal joints.

After removal of the external fixator, the patient had six weeks of physiotherapy to increase the range of movement of the ankle and then began partial weight-bearing. By ten weeks he was walking without support. He had occasional discomfort but did not need any analgesia.

■ M. R. Brinker, MD, Co-Director, Clinical Professor
■ D. P. Loncarich, MD, Orthopaedic Surgeon
Center for Problem Fractures and Limb Restoration
Fondren Orthopedic Group,
7401 S. Main Street, Houston,
Texas 77030, USA.

■ E. G. Melissinos, MD, Clinical Associate, Professor
University of Texas Medical School-Houston, 6410 Fannin St Ste 1220, Houston, Texas 77030, USA.

■ D. P. O'Connor, PhD, Assistant Professor
University of Houston, 3855 Holman GAR 104, Houston, Texas 77204-6015, USA.

Correspondence should be sent to Professor M. R. Brinker; e-mail: mb53@fondren.com

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Fig. 1a

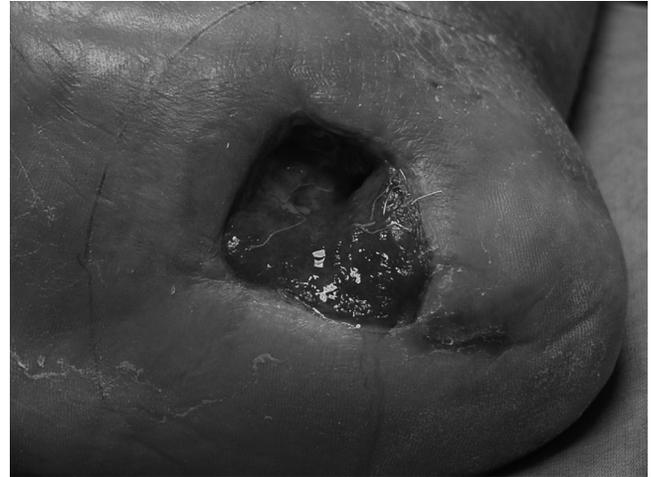


Fig. 2

Clinical photograph of the patient upon presentation with an open, draining wound and exposed calcaneal bone, approximately three months after injury.



Fig. 1b

Lateral radiograph of a) the original injury showing a comminuted open fracture of the calcaneum and b) following open reduction and internal fixation with two Steinmann pins.

The talonavicular arthrodesis failed to unite and a further talonavicular arthrodesis was undertaken a year later with two partially-threaded cancellous screws, a dynamic compression staple, local autogenous bone graft and corticocancellous allograft. This arthrodesis united solidly at eight months.

One year after revision of the talonavicular arthrodesis, the patient's hindfoot ached occasionally but without the need for analgesics. He could walk fully weight-bearing in normal shoes (Fig. 4) and had returned to work as a farmer. His functional outcome scores¹⁸⁻²² were all substantially improved (Table I).

Discussion

Osteomyelitis of the calcaneum is a severe problem which may lead to amputation if the infection cannot be eliminated.¹ Most cases are either the result of chronic heel ulcers secondary to diabetes mellitus, or to prolonged

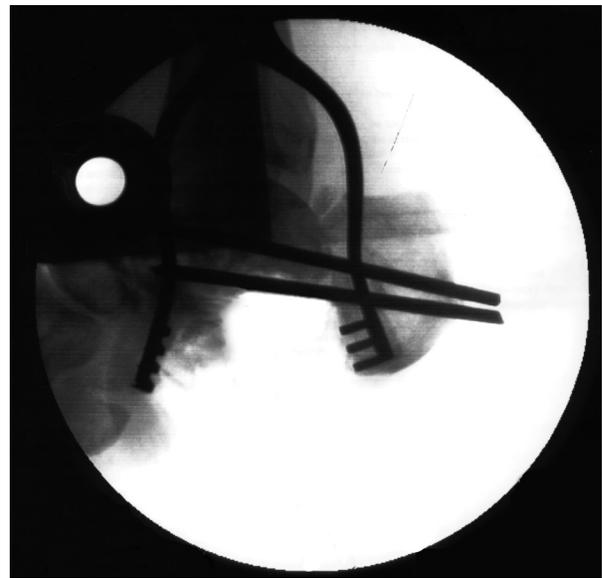


Fig. 3

Intra-operative lateral fluoroscopic image following debridement of the anterior and inferior calcaneum and immediately prior to the free flap transfer to obtain soft-tissue coverage.

immobilisation or injuries from land mines or other military weapons.^{2,3,6,7,12,23-30} Osteomyelitis has also been described as a complication of open fractures of the calcaneum.^{1,2,5,6,13,14}

Ilizarov distraction osteogenesis can restore length and substance to the calcaneum after a radical debridement for osteomyelitis. In our patient's restoration of the calcaneum, particularly of its anterior part and the sustentaculum tali, we partially restored the longitudinal arch of the foot, which allowed him to resume a normal gait in standard



Fig. 4a



Fig. 4b



Fig. 4c

a) Lateral radiograph and (b) and (c) clinical photographs at the time of the final follow-up, two years after distraction osteogenesis and one year after subtalar and talonavicular arthrodesis.

footwear. Restoration of the calcaneal bone mass obviated the need for amputation and allowed us to fuse the subtalar and talonavicular joints to restore mid- and hindfoot stability. Without restoration of the calcaneum arthrodesis would not have been possible, and the patient would have experienced degeneration of the talonavicular joint, subsidence of the talus and loss of the structural integrity of the foot.

The use of this technique depends on the quantity and location of infected bone in the calcaneum rather than the cause of the infection. It is indicated when there is insufficient residual calcaneum to support the talus and bear weight.

Surgical methods other than calcaneogenesis may be used when an adequate amount of the calcaneum remains to allow weight-bearing. For example, some cases of calcaneal osteomyelitis involve extensive debridement of the surrounding soft tissues, such that partial calcaneotomy may be performed to reduce the volume of the hindfoot to allow for wound closure. Because partial resection of the calcaneum does not usually destabilise the mid- or hindfoot, no attempt at its restoration is usually attempted. Partial calcaneotomy is reported to have good results, with most patients recovering the ability to work although a substantial number require orthoses or prescrip-

Table I. The outcome scores improved substantially from the time of presentation to the time of final follow-up

Outcome score	At time of presentation	At time of final follow-up
AAOS* Lower limb core scale	19.3	84.8
Short-form 12		
Physical component scale	20.5	26.4
Mental component scale	39.9	47.3
Brief pain inventory†		
Intensity	2.3‡	2.3
Interference	7.9	1.8

* AAOS, American Academy of Orthopaedic Surgeons

† all brief pain inventory scores are stated on a scale of 0 (no pain) to 10 (worst)

‡ the patient was taking narcotic pain medication on a daily basis at the time of presentation but was taking none at the time of final follow-up

tion shoes.² The presence of diabetes mellitus may be a risk factor for subsequent amputation.^{23,26}

Soft-tissue reconstructions using free flaps, vascularised flaps and neurocutaneous flaps have also been described.^{5,7-12,15} The goal of these procedures is to obtain cover and closure of the wound in the heel rather than restoration of the calcaneum.

We did not believe that either partial calcaneotomy or soft-tissue reconstruction alone were appropriate for our patient. The extensive debridement necessary to eliminate infection in the bone removed the entire anterior and inferior parts of the calcaneum, including the sustentaculum tali. This left no bony support under the talus, disrupted the longitudinal arch and destabilised the midfoot. It is unlikely that he would have been able to walk as well as he did without restoring the back of the calcaneum by distraction osteogenesis.

Various procedures for reconstruction following extensive loss of bone from the calcaneum have also been described, including block arthrodesis using allograft,¹³ vascularised iliac osteocutaneous flaps,^{16,17,31} and vascularised double-barrel rib autograft with free serratus anterior muscle flaps.¹⁴ We were able to restore the calcaneum using distraction osteogenesis, which has no associated morbidity of a donor site. It does not preclude subsequent reconstruction with bone grafting using an osteocutaneous flap if this should prove to be necessary. The autogenous bone graft from the iliac crest from the subsequent talonavicular arthrodesis in this particular patient did not cause symptoms but could have potentially led to problems.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. Heier KA, Infante AF, Walling AK, Sanders RW. Open fractures of the calcaneus: soft-tissue injury determines outcome. *J Bone Joint Surg [Am]* 2003;85-A:2276-82.
2. Bollinger M, Thordarson DB. Partial calcaneotomy: an alternative to below knee amputation. *Foot Ankle Int* 2002;23:927-32.
3. Isenberg JS, Costigan WM, Thordarson DB. Subtotal calcaneotomy for osteomyelitis of the os calcis: a reasonable alternative to free tissue transfer. *Ann Plast Surg* 1995;35:660-3.

4. **Martini M, Martini-Benkeddache Y, Bekkechi T, Daoud A.** Treatment of chronic osteomyelitis of the calcaneus by resection of the calcaneus: a report of twenty cases. *J Bone Joint Surg [Am]* 1974;56-A:542-8.
5. **Wellisz T, Rechnic M, Dougherty W, Sherman R.** Coverage of bilateral lower extremity calcaneal fractures with osteomyelitis using a single split free gracilis muscle transfer. *Plast Reconstr Surg* 1990;85:457-60.
6. **Woll TS, Beals RK.** Partial calcaneotomy for the treatment of osteomyelitis of the calcaneus. *Foot Ankle* 1991;12:31-4.
7. **Yildirim S, Gideroglu K, Akoz T.** The simple and effective choice for treatment of chronic calcaneal osteomyelitis: neurocutaneous flaps. *Plast Reconstr Surg* 2003;111:753-60.
8. **Attinger C, Cooper P.** Soft tissue reconstruction for calcaneal fractures or osteomyelitis. *Orthop Clin North Am* 2001;32:135-70.
9. **Fish DN, Goulet JA, Stevenson T.** Chronic osteomyelitis of the calcaneus: treatment with a vascularized muscle flap. *Orthopedics* 1993;16:81-5.
10. **Stockarova D, Pilnacek J, Rubin J, Kolarik M.** Musculocutaneous flaps for the treatment of chronic osteomyelitis of the heel. *Acta Chir Plast* 1991;33:12-21.
11. **Anderson RB, Foster MD, Gould JS, Hanel DP.** Free tissue transfer and calcaneotomy as treatment of chronic osteomyelitis of the os calcis: a case report. *Foot Ankle* 1990;11:168-71.
12. **Sparmann M, Ahmadi A, Kreusch-Brinker R, Lumplesch R.** The forearm flap as a free neurovascular flap for treatment of an extensive bone/soft-tissue defect in the calcaneal part of the foot. *Arch Orthop Trauma Surg* 1987;106:263-7.
13. **Molloy AP, Myerson MS, Yoon P.** Symptomatic nonunion after fracture of the calcaneum: demographics and treatment. *J Bone Joint Surg [Br]* 2007;89-B:1218-24.
14. **Brenner P, Zwipp H, Rammelt S.** Vascularized double barrel ribs combined with free serratus anterior muscle transfer for homologous restoration of the hindfoot after calcaneotomy. *J Trauma* 2000;49:331-5.
15. **del Pinal F, Herrero F, Cruz A.** A technique to preserve the shape of the calcaneus after massive osteomyelitis. *Br J Plast Surg* 1999;52:415-17.
16. **Stevenson TR, Greene TL, Kling TF Jr.** Heel reconstruction with the deep circumflex iliac artery osteocutaneous flap. *Plast Reconstr Surg* 1987;79:982-6.
17. **Stanec Z, Krivic A, Stanec S, Zir R, Budi S.** Heel reconstruction with an iliac osteocutaneous free flap: 10-year follow-up. *Ann Plast Surg* 2004;53:174-7.
18. **Ware J Jr, Kosinski M, Keller SD.** A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. *Medical Care* 1996;34:220-33.
19. **Ware JE Jr, Kosinski M, Keller SD.** SF-12: how to score the SF-12 physical and mental health summary scales. Boston: The Health Institute, New England Medical Center, 1995.
20. **Torrance GW.** Utility approach to measuring health-related quality of life. *J Chronic Dis* 1987;40:593-603.
21. **Johanson NA, Liang MH, Daltroy L, Rudicek S, Richmond J.** American Academy of Orthopaedic Surgeons lower limb outcomes assessment instruments: reliability, validity, and sensitivity to change. *J Bone Joint Surg [Am]* 2004;86-A:902-9.
22. **Daut RL, Cleeland CS, Flanery RC.** Development of the Wisconsin Brief Pain Questionnaire to assess pain in cancer and other diseases. *Pain* 1983;17:197-210.
23. **Crandall RC, Wagner FW Jr.** Partial and total calcaneotomy: a review of thirty-one consecutive cases over a ten-year period. *J Bone Joint Surg [Am]* 1981;63-A:152-5.
24. **Giacalone VF, Gregory JL, Krych SM.** Calcaneotomy for the treatment of calcaneal osteomyelitis: a case report. *J Am Podiatr Med Assoc* 1991;81:88-92.
25. **Horwitz T.** Partial resection of the Os calcis and primary closure in the treatment of resistant large ulcers of the heel, with or without osteomyelitis of the Os calcis. *Clin Orthop* 1972;84:149-53.
26. **Smith DG, Stuck RM, Ketner L, Sage RM, Pinzur MS.** Partial calcaneotomy for the treatment of large ulcerations of the heel and calcaneal osteomyelitis: an amputation of the back of the foot. *J Bone Joint Surg [Am]* 1992;74-A:571-6.
27. **Weisenfeld LS, Flannery D, Luzzi A, Picciotti J.** Partial calcaneotomy for the treatment of osteomyelitis of the os calcis. *J Foot Surg* 1990;29:226-30.
28. **Selmanpakoglu N, Guler M, Sengezer M, et al.** Reconstruction of foot defects due to mine explosion using muscle flaps. *Microsurgery* 1998;18:182-8.
29. **Celikoz B, Sengezer M, Isik S, et al.** Subacute reconstruction of lower leg and foot defects due to high velocity-high energy injuries caused by gunshots, missiles, and land mines. *Microsurgery* 2005;25:3-14.
30. **Ozturk S, Bayrum Y, Mohur H, Devenci M, Sengezer M.** Evaluation of late functional results of patients treated with free muscle flaps for heel defects caused by land-mine explosions. *Plast Reconstr Surg* 2005;116:1926-36.
31. **Wei FC, Chen HC, Chuang CC, Noordhoff MS.** Reconstruction of Achilles tendon and calcaneus defects with skin-aponeurosis-bone composite free tissue from the groin region. *Plast Reconstr Surg* 1988;81:579-89.