Ankle fusion for bone loss around the ankle joint using the Ilizarov technique

We present the results of ankle fusion using the Ilizarov technique for bone loss around the ankle in 20 patients. All except one had sustained post-traumatic bone loss. Infection was present in 17. The mean age was 33.1 years (7 to 71). The mean size of the defect was 3.98 cm (1.5 to 12) and associated limb shortening before the index procedure varied from 1 cm to 5 cm. The mean time in the external fixator was 335 days (42 to 870). Tibiotalar fusion was performed in 19 patients and tibiocalcaneal fusion in one. Associated problems included diabetes in one patient, pelvic and urethral injury in one, visual injury in one patient and ipsilateral tibial fracture in five. At the final mean follow-up of 51.55 months (24 to 121) fusion had been achieved in 19 of 20 patients. A total of 16 patients were able to return to work. The results were graded as good in 11 patients, fair in six and poor in three. The mean external fixation index was 8.8 days/mm (0 to 30). One patient with diabetes developed severe infection which required early removal of the fixator. Refractures occurred in three patients, two of which were at the site of fusion and one at a previous tibial shaft fracture site. Equinus deformity of the ankle fusion occurred after a further fracture in one patient. There were two patients with residual forefoot equinus, and one developed late valgus at the fusion site.

Poor consolidation of the regenerated bone in two patients was treated by bone grafting in one and by bone and fibular strut grafting in the other. Residual soft-tissue infection was still present in two patients.

Injuries involving bone loss around the ankle, with either distal tibial or talus loss, are very serious with few options for reconstruction. The problems are compounded by the presence of infection, scarring, osteoporotic bone and shortening, either due to the primary injury or to subsequent surgery.\(^1\) The bone loss and poor condition of the soft tissue, together with infection, contraindicate the use of internal fixation.\(^2\) External fixation with large-diameter pins may be complicated by infection and nonunion.\(^3,4\)

The associated osteoporosis can cause pin loosening, movement at the fusion site and delayed soft-tissue healing.\(^5\)

Possible methods of reconstruction are ankle fusion\(^a\) combined with either bone transport or a vascularised bone graft. The Ilizarov frame can provide stable fixation, correction of deformity, bone transport and compression. Tensioned wires which have good bending and torsional stiffness but low axial stiffness make the Ilizarov apparatus an excellent choice for this difficult problem.\(^5,7,9\)

In this retrospective study we report our results using the Ilizarov technique in the management of these difficult cases.

Patients and Methods

From 1994 to 2004, 20 patients were treated in the authors’ institutions. The cause of the bone defect was post-traumatic in 19 and post tumour resection in one. The mean age of the patients was 33.1 years (7 to 71). There were 17 males and three females. In five patients there were associated fractures of the ipsilateral tibia. Tibiotalar fusion was performed in 19 patients and tibiocalcaneal fusion in one.

The mean size of the bone defect was 3.98 cm (1.5 to 12). Associated shortening was present in four patients before the index procedure and varied from 1 cm to 5 cm (Table I). An all-wire or hybrid Ilizarov frame (SH Pitkar Orthotools, Pune, India) was used in all patients, and a proximal tibial corticotomy in all except one, who had a diaphyseal corticotomy because of an infected nonunion in the proximal tibia. The talus, calcaneum or tibia was denuded of cartilage when the fixator was applied and radical debridement of the necrotic and infected bone and soft tissue was carried out. The standard frame configuration consisted of one or two tibial rings proximal to...
the corticotomy, two rings in the tibial shaft, and in the foot, a half ring with two calcaneal wires and two talar drop wires in the hindfoot. In the forefoot two wires were fixed to connection plates which were attached to a hindfoot half-ring (Fig. 1). Prior to the attempted fusion, six patients had a free vascularised latissimus dorsi or gracilis flap to cover the exposed viable tibia and ankle joint, and one patient had a cross-leg flap. Previous ankle fusion using an Ilizarov fixator had failed in one patient. Infection was present in 17 patients: cultures revealed *Staphylococcus aureus*, *Klebsiella* and *Pseudomonas aeruginosa*. In five patients there was an associated tibial shaft fracture or tibial bone loss at another level. The frame construct was therefore adjusted to stabilise these associated problems (Fig. 2). The patient previously treated elsewhere by tumour resection (patient 6) and a non-vascularised fibular graft had become infected.

After operation, weight-bearing on the operated limb was allowed as tolerated, using crutches.

Progressive compression of the fusion site was performed at the rate of 1 mm/day. Distraction at the corticotomy site started at seven to ten days after operation and continued until the bone ends had docked or limb-length discrepancy had been equalised. The frame was removed when the ankle fusion had united and the regenerated bone matured.

Antibiotics were given at the time of the index procedure depending on culture and sensitivities for a period of five to seven days. Any pin track infections which developed were treated with appropriate antibiotics. After removal of the frame a patellar tendon bearing cast was applied in all patients. One of the indices used at follow-up to evaluate the results was the external fixation index which was calculated by dividing the entire time for which the external fixator was in place by the amount of shortening or bone loss corrected by bone transport. Results were classified as good, fair or poor using the criteria described by Hawkins et al. A good result was acceptable function with solid ankle fusion and a plantigrade foot. A fair result was when the fusion had united but with deformity or pain. Failure of ankle fusion or persistent infection was classed as a poor result.

### Results

The mean follow-up was 51.55 months (24 to 121). Successful fusion was achieved in 19 of 20 patients. The mean time in the ring fixator was 335 days (42 to 870) (Table I). The mean external fixation index was 8.8 days/mm (0 to 30) (Table I). Union was not obtained in one patient (patient 5; Table I) who was a diabetic; the frame had to be removed at six weeks owing to severe pin track infection and septicaemia.

Refractures occurred in three patients. Two were at the fusion site and one at the previous fracture site in the tibial shaft. Of the two patients who sustained a further fracture at the fusion site, one united in equinus and the other in a good position in a below-knee walking cast. In the patient who sustained a further fracture of the shaft, the fracture remains ununited. Equinus deformity of the ankle occurred in one patient following a further fracture, but in two patients forefoot equinus was probably due to the unopposed action of the plantar flexors after removal of the frame as a result of loss of the toe dorsiflexors in the initial

### Table I. Details of the length of the bone defect and or associated shortening.

<table>
<thead>
<tr>
<th>Case</th>
<th>Bone defect (cm)</th>
<th>Shortening (cm)</th>
<th>Period in ring fixator (days)</th>
<th>EFI* (days/mm)</th>
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<tr>
<td>1</td>
<td>2.5</td>
<td>2.5</td>
<td>150</td>
<td>6</td>
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<td>0</td>
<td>3</td>
<td>150</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0</td>
<td>330</td>
<td>6.6</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>5</td>
<td>42</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
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<td>7</td>
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<td>0</td>
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<td>9</td>
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<td>11</td>
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<tr>
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<td>0</td>
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<td>0</td>
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<tr>
<td>17</td>
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<td>0</td>
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</tr>
<tr>
<td>Mean</td>
<td>3.98</td>
<td>0.58</td>
<td>335.05</td>
<td>8.8</td>
</tr>
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</table>

* EFI, external fixation index
injury. One patient developed delayed collapse and valgus deformity at the fusion site eight months after removal of the frame.

Problems with bone transport were seen in nine patients and included delayed consolidation and deformity of the regenerate bone. In one patient (patient 6) this was due to removal of the frame before full consolidation of the regenerate bone (Table I). In another patient, in whom follow-up was erratic, the regenerate bone consolidated, re-osteotomy of the regenerate bone was then necessary, resulting in delayed consolidation and deformity. One patient required bone grafting of the regenerate bone. Another patient in whom consolidation of the regenerate bone failed, was treated by fibular bypass grafting, which was successful. One patient developed further infection and sequestration of 7.5 cm of tibial shaft in the Ilizarov frame, and further bone transport was required to close this gap. Four patients had a mean residual shortening of 3 cm (2 to 5). Residual infection was present in two patients.

Of the 20 patients, 16 returned to work, but two changed their occupation. Of the four who did not return to work, three had a successful ankle fusion. One did not return to work because of severe urethral and bladder injuries, another because of severe deformity of the regenerate bone and one because of nonunion following further fracture at the site of a previous tibial shaft fracture.

In nine patients further surgery following the index procedure was required to change infected wires, re-align the docking site, apply bone graft at the docking or bone regeneration site, and to further debride and resect necrotic bone.

Overall, 11 patients (55%) had a good result, six (30%) a fair and three (15%) a poor result.

Discussion

Loss of the distal tibia or the talus as the result of injury or subsequent infection is a very serious problem, and ankle fusion is the only alternative to amputation. The choices for reconstruction using fusion are bone transport with external fixation or a vascularised bone graft.

In this retrospective study we used bone transport with an Ilizarov ring fixator in all patients. In the early patients an all-wire frame was used, but later the frame construction was modified with the introduction of half pins. A proximal metaphyseal corticotomy was used in all except one patient in whom a mid-diaphyseal corticotomy was required because of infection of a proximal tibial fracture. We did not use acute compression in this series for fear of causing neurovascular compromise, but relied on

![Fig. 1a](image1a.jpg)

A 20-year-old man showing application of the ring fixator following trauma and failed infected internal fixation, a) lateral view and b) plantar view.
progressive compression and bone transport to obtain closure of the defect.

There are few reports of the Ilizarov procedure using a bifocal mode (with corticotomy) to achieve ankle fusion. In 1994, Hawkins et al.9 reported its use in ten patients, with successful fusion in eight. Sakurakichi et al.1 achieved excellent results in six cases of ankle fusion with Ilizarov ring fixation. In some he used an interlocking nail after removal of the fixator, which facilitated early removal. Ilizarov, Rozbruch and Blyakhert10 reported a series of ankle fusions with distal tibial and talar bone loss in seven patients where the average bone loss was 5.8 cm and the
mean time in the frame was 8.5 months. Union was achieved in four after initial treatment, and in a further two after repeat frame application.

Kotnis et al11 reported a single case after septic loosening of a total ankle replacement successfully treated by bone transport and Ilizarov ring fixation. Katsenis et al12 reported two cases of infected nonunion treated by resection of the necrotic bone, acute compression, deformity correction and proximal lengthening, and achieved union in both.

Vascularised autogenous bone graft has also been applied successfully in obtaining ankle fusion in the presence of bone loss.13,14 A theoretical possibility would be the use of allogenic vascularised bone transfer with immunosuppression, as reported by Hofmann et al.15 However, the problem of obtaining such allografts and the presence of infection do not make this an attractive option.

The use of fibular grafts supplemented by Ilizarov ring fixation has been reported by Shalaby, Shalaby and Bassiony.16 The combination of these allows early weight-bearing, which can stimulate graft hypertrophy. They used three vascularised and three non-vascularised grafts, and achieved union in five of six patients with an osteosarcoma.

Residual deformity of the ankle was present in four patients in our series: ankle equinus in one, ankle valgus in one and forefoot equinus in two. The cause of the forefoot equinus was not clear, but we presume that it could be due to loss of the dorsiflexors of the toes in the initial injury, and unopposed action of the plantar flexors. These deformities developed after removal of the frame. In the patient with ankle valgus this developed at the fusion site eight months after removal of the frame.

Problems occurred in bone transport in nine of our 20 patients (Table II). Regenerate bone deformity occurred primarily because of delayed regenerate and patient demands for frame removal before consolidation.

The mean external fixation index in this series was 8.8 mm/day (0 to 30). Sakurakichi et al1 reported a mean fixation index of 9.1 days/mm and Katsenis et al12 a mean fixation index of 6.9 days/mm.

Neither the bacterial type nor the severity of the infection seemed to have an adverse effect on ankle fusion in our series. We believe that radical resection of all necrotic infected bone and soft tissue was the key to the eradication of infection and successful fusion. We did not use antibiotics for prolonged periods as described by Cierny, Cook and Mader17 but relied on the regenerative properties of bone and soft tissue to eradicate infection, as described in the principles of the Ilizarov technique: “Osteomyelitis burns in the fire of regeneration”.18 Increased blood flow has also been suggested by Sakurakichi et al1 as a factor in eradicating infection and achieving fusion. However, residual infection due to sequestra or of soft-tissue origin was still present in two patients at latest follow-up. Similar experience has been reported elsewhere5,8,17,19-23 with the presence of infection in association with diabetes causing the greatest concern.

The one patient in our series who needed an early frame removal for severe infection was a diabetic with neuropathy. We allowed all our patients to bear weight with crutches as soon as this was tolerated. It has been shown that axial micromovement in the fixator helps union5,7,8,24 but acknowledge others have not done so.20,22 The combined technique using a circular fixator and an intramedullary nail appears an attractive option to reduce the time in the fixator and maintain alignment.25 However, in infected cases eradication of infection would be required before an intramedullary nail could be added.

Amputation is a swift alternative to reconstruction in these patients but the cost of a lifetime of prosthetic fitting, particularly in countries where prosthetic services are poor, makes reconstruction an attractive option in these cases whenever possible.26-28

Conclusion
In our series ankle fusion was obtained in 19 of 20 patients (95%), of whom 16 returned to work, but the learning curve and the complication rate for this procedure are high.29

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


