Capsuloligamentotaxis and definitive fixation by an ankle-spanning Ilizarov fixator in high-energy pilon fractures

S. K. Kapoor, H. Kataria, S. R. Patra, T. Boruah

From Dr Ram Manohar Lohia Hospital & PGIMER, New Delhi, India

Open reduction and internal fixation of high-energy pilon fractures are often associated with serious complications. Various methods have been used to treat these injuries, with variable results. A total of 17 consecutive patients with pilon fractures of AO/OTA type 43-B3 (n = 1), type C2 (n = 12) and type C3 (n = 4) were treated by indirect reduction by capsuloligamentotaxis and stabilisation using an ankle-spanning Ilizarov fixator. The calcaneal ring was removed at a mean of 3.7 weeks (3 to 6). A total of 16 patients were available for follow-up at a mean of 29 months (23 to 43). The mean time to healing was 15.8 weeks (13 to 23). Nine patients had pin-track infections but none had deep infection or osteomyelitis. Four patients (25%) had malunion. Fair, good or excellent ankle scores were found in 14 patients. External fixation with a ring fixator achieves stable reduction of the fractured fragments without additional trauma to soft tissues.

With minimum complications and good healing results, the Ilizarov apparatus is particularly useful for high-energy pilon fractures.

High-energy pilon fractures are among the most challenging orthopaedic problems, as they are frequently open and contaminated, with severe damage to the soft tissues, have marked comminution of the articular surface and metaphysis and are often associated with fracture of the fibula. They may result from an axial compression force alone, or have a rotational or angulatory component. This fracture can be a low-energy type, as in sporting injuries such as skiing or high-energy when caused by a fall from a height or in a motor vehicle accident.

Recommended treatments range from closed reduction and casting to calcaneal pin traction, percutaneous Kirschner-wire fixation, external fixation, isolated lateral pillar stabilisation by a fibular plate, limited open reduction of key fragments, open reduction and internal fixation (ORIF), biological plating, primary arthrodesis and even early amputation. The most promising results have been achieved by following the principle of osteosynthesis with ORIF of the fibula to restore length, anatomical reconstruction of the plafond, primary grafting and fibular buttress plating, followed by early movement and prolonged non-weight-bearing. However, most of these cases do not clearly correlate their results with factors such as fracture classification and soft-tissue involvement, which greatly influence the nature of the injury.

Studies reporting good or excellent results with ORIF often involved low-energy fractures. Open reduction of pilon fractures, particularly if high-energy with a traumatised soft-tissue envelope, may develop devastating complications. An open wound will delay proceeding with internal fixation, and by the time the limb becomes suitable for surgery, a satisfactory reduction becomes extremely difficult. The search continues for an alternative treatment that can be used for all pilon fractures, irrespective of fracture type, soft tissue and wound conditions and time from injury, which can minimise complications and secondary procedures and give a good functional outcome.

In order to address these well-known pitfalls we have used Ilizarov ring fixators for indirect reduction by capsuloligamentotaxis and definitive stabilisation of the fractures.

Patients and Methods
A total of 17 patients (16 men, one woman, mean age 42 years, 26 to 70) presenting with 17 intra-articular pilon fractures were studied prospectively. They were treated using ankle-spanning Ilizarov ring fixators (Table I) between August 2005 and June 2007. The fractures were classified as AO/OTA type B3 (n = 1), type C2 (n = 12) and type C3 (n = 4). Of the open fractures three were grade I (two C2 and one C3 type) and three were grade II open
Table I. Data sheet of patients with pilon fractures

<table>
<thead>
<tr>
<th>Number</th>
<th>Age</th>
<th>Gender</th>
<th>Fracture type</th>
<th>Wound grading</th>
<th>Time since Articular reduction weeks</th>
<th>Weight-bearing partial/full (weeks)</th>
<th>Ankle movement dors/flexion/planter flexion</th>
<th>Complications</th>
<th>Ankle outcome score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>M</td>
<td>C3</td>
<td>Closed</td>
<td>23 days</td>
<td>Poor</td>
<td>3</td>
<td>5/13</td>
<td>17/35°</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>M</td>
<td>C3</td>
<td>Gr I comp.</td>
<td>2 days</td>
<td>Fair</td>
<td>3</td>
<td>4/12</td>
<td>12/35°</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>5 days</td>
<td>Fair</td>
<td>3</td>
<td>4/15</td>
<td>0/30°</td>
</tr>
<tr>
<td>4</td>
<td>51</td>
<td>M</td>
<td>C3</td>
<td>Closed</td>
<td>3 days</td>
<td>Fair</td>
<td>4</td>
<td>4/14</td>
<td>10/25°</td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>1 day</td>
<td>Fair</td>
<td>5</td>
<td>6/13</td>
<td>5/25°</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>M</td>
<td>C2</td>
<td>Gr. I comp.</td>
<td>1 day</td>
<td>Good</td>
<td>4</td>
<td>5/13</td>
<td>10/30°</td>
</tr>
<tr>
<td>7</td>
<td>45</td>
<td>M</td>
<td>C2</td>
<td>Gr. II comp.</td>
<td>6 hours</td>
<td>Good</td>
<td>5</td>
<td>6/14</td>
<td>15/35°</td>
</tr>
<tr>
<td>8</td>
<td>70</td>
<td>M</td>
<td>C2</td>
<td>Gr. II comp.</td>
<td>14 hours</td>
<td>Fair</td>
<td>6</td>
<td>7/15</td>
<td>0/15°</td>
</tr>
<tr>
<td>9</td>
<td>26</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>12 hours</td>
<td>Good</td>
<td>3</td>
<td>4/12</td>
<td>15/30°</td>
</tr>
<tr>
<td>10</td>
<td>42</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>2 days</td>
<td>Good</td>
<td>4</td>
<td>5/13</td>
<td>15/35°</td>
</tr>
<tr>
<td>11</td>
<td>38</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>10 hours</td>
<td>Fair</td>
<td>3</td>
<td>4/12</td>
<td>5/25°</td>
</tr>
<tr>
<td>12</td>
<td>48</td>
<td>M</td>
<td>C2</td>
<td>Gr. I comp.</td>
<td>9 hours</td>
<td>Good</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>13</td>
<td>39</td>
<td>M</td>
<td>B3</td>
<td>Closed</td>
<td>13 days</td>
<td>Fair</td>
<td>3</td>
<td>3/12</td>
<td>10/40°</td>
</tr>
<tr>
<td>14</td>
<td>49</td>
<td>M</td>
<td>C3</td>
<td>Closed</td>
<td>2 days</td>
<td>Fair</td>
<td>4</td>
<td>5/13</td>
<td>10/25°</td>
</tr>
<tr>
<td>15</td>
<td>34</td>
<td>M</td>
<td>C3</td>
<td>Gr. I comp.</td>
<td>1 day</td>
<td>Good</td>
<td>3</td>
<td>4/14</td>
<td>15/35°</td>
</tr>
<tr>
<td>16</td>
<td>38</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>10 hours</td>
<td>Fair</td>
<td>3</td>
<td>5/13</td>
<td>10/40°</td>
</tr>
<tr>
<td>17</td>
<td>41</td>
<td>M</td>
<td>C2</td>
<td>Closed</td>
<td>2 days</td>
<td>Fair</td>
<td>4</td>
<td>5/12</td>
<td>10/35°</td>
</tr>
</tbody>
</table>

* fracture classification as per AO/OTA scheme

(all C2 type), according to the Gustilo and Anderson classification. The mechanism of injury was a road traffic accident in 11, a fall from a height in five, and one occurred during a game of volleyball. The mean interval between injury and operation was 3.4 days (six hours to 23 days). All patients had fractures of the fibula, except one who had a type B3 fracture.

All the patients were operated on within six hours of presentation at our Trauma Centre after giving written informed consent. The variable interval between injury and operation was due to delayed referral from the primary care hospitals. All patients with an open fracture underwent wound debridement and thorough lavage with normal saline, hydrogen peroxide and povidone-iodine before surgery. The fractures were evaluated by anteroposterior, mortise and lateral radiographs. Distal tibial fractures without involvement of the articular surface were excluded. Other exclusion criteria were inability to walk, a neuropathic joint and an established neurovascular deficit. The only woman, who had a type C2 pilon fracture (open grade II) and associated fractures of the pelvis, femur and ribs, with large wounds around the knee, underwent surgical fixation but later died from other injuries and was excluded. The wound grading, local oedema, fracture blisters or contamination of the wound were not criteria for exclusion.

Operative technique. The patient is positioned supine on a radiolucent operating table. No tourniquet is used. When indicated, fibular plating is performed at the beginning of the operation using a one-third tubular plate and screws. The proximal half of the Ilizarov frame consists of two rings of either 160 mm or 180 mm diameter, depending on the circumference of the limb. The first ring is placed at the proximal third of the tibia perpendicular to its long axis allowing at least two finger breadths between the ring and the skin and more than 90° of flexion at the knee joint. A second ring is placed parallel to the first, just proximal to the fracture. Ilizarov wires, 1.8 mm in diameter, are used for fixation and tensioned up to 120 kg. These two rings are fixed together by three threaded rods. In the next step, a five-eighths ring is applied at the level of the calcaneal tubercle and connected to the previous ring by three threaded rods with a ‘dummy ring’ in between, just proximal to the ankle joint, for subsequent fixation of the articular fragments. At the time of initial construction of the frame the dummy ring is placed between the calcaneal ring and the ring proximal to the fracture, but no wires are inserted through it and it is kept free. After ligamentotaxis is achieved between the proximal half of the construct and the calcaneal ring, reduction of the fracture is checked under image intensifier and the dummy ring is positioned over the major fracture fragments approximately 15 mm above the ankle joint. With the rest of the frame maintaining reduction by ligamentotaxis, multiple wires are inserted through the dummy ring for the final fixation of the fragments. Gentle closed manual manipulation of fracture fragments during distraction helps them to fall into place. Olive wires are used and tensioned up to 30 kg for reduction and compression of larger fragments and the syndesmosis whenever necessary. The distraction is adjusted after fixation of the articular fragments to pre-
vent any gap between the proximal and the reconstructed distal tibia. Once a satisfactory reduction is confirmed by the image intensifier, additional threaded rods are inserted between the rings to augment the stability of the frame. The pin tracks are dressed using antiseptic iodine preparations, and any tenting of the skin is relieved by small incisions. The distal pulses are checked.

The limb is elevated on a Braun frame and active toe movements and range of movement exercises of the knee are started on the second post-operative day. The patients are mobilised non-weight-bearing with crutches. All receive intravenous antibiotics for two to five days, and anti-inflammatory drugs as required.

Follow-up was at weekly intervals for six weeks or up to removal of the calcaneal ring, and then at two- to three-week intervals for up to 18 weeks or full weight-bearing. Thereafter, patients were seen every two to three months, or advised to report to the hospital promptly in case of any complications. They were taught to do daily dressing of the pin tracks at home. The ankle spanning calcaneal frame was kept in place for a mean of 3.7 weeks (three to six). After its removal, rigorous ankle mobilisation exercises were started. Toe-touch weight-bearing began at the earliest radiological evidence of fracture healing. The patients were advised to gradually increase weight on the affected limb, and full weight-bearing was started at a mean of 13.1 weeks (12 to 15) depending on the radiological assessment of union and tolerance of pain. All the frames were dynamised with full weight-bearing for one to two weeks before removal. The mean total duration of fixation was 17 weeks (14 to 24).

We considered that clinical union was achieved when there was no tenderness at the fracture site and the patient had no pain at the site of injury on walking. Radiological union was defined as evidence of healing in at least three cortices in anteroposterior and lateral views. Articular reduction was graded as good (step-off or gap of ≤2 mm), fair (between 2 mm and 4 mm) or poor (>4 mm).

A major complication was defined as an infection requiring surgery, wound breakdown needing cover, neurovascular compromise, malunion, nonunion or amputation.11 Malunion was defined as >10° of angulation in any direction at the time of union. Nonunion was defined as failure of clinical or radiological union more than six months after the injury.11 Pin-track infection was defined as any discharge, induration or pustule formation.

Functional outcome was measured by the modified Mazur ankle scoring system as described by Teeny and Wiss.8 The ankles were scored on a scale of a maximum 100 points and considered excellent (93 or more points), good (87 to 92), fair (65 to 86) or poor (<65).

**Results**

The mean follow-up was 29 months (23 to 43) and the mean time to clinical and radiological union was 15.8 weeks (13 to 23).

There were 12 pin-track infections in nine cases (56%). All healed with antiseptic dressings and oral antibiotics, and nine required removal of the wire. One patient had superficial skin breakdown (1 cm × 4 cm) which healed by epithelialisation without intervention. There was no case of deep infection or osteomyelitis.

There was only one revision operation, when the reduction appeared unsatisfactory on the post-operative radiographs. The patient required readjustment of the fixator and change of the wires, after which he progressed to union in 23 weeks (case no. 7 Fig. 1).

The articular reduction was good in five cases, fair in ten and poor in a C3 fracture presenting 23 days after injury (Fig. 2). All four type C3 fractures had a fair or poor reduction, whereas all type C2 fractures had a good or fair reduction.

Malunion was seen in four patients (25%). Two had posterior angulation of approximately 20° but refused corrective surgery. Two had valgus angulation of 10° and 25°, respectively. There was no case of nonunion, arthrodesis or amputation.

A total of 12 patients (75%) regained ankle dorsiflexion of 10° or more; two achieved dorsiflexion between 5° and 10°, and two had none (12%). Plantar flexion was 30° or more in 11 patients (69%), 20° to 30° in four and <20° in one.

The mean functional ankle score was 79.8 (56 to 93). All four type C3 fractures had fair results; six of the 12 type C2 fractures had good or excellent results, and two type C2 fractures had poor results. The only type B3 fracture had a fair result. Three of five patients with an open fracture achieved fair results, one was poor, and one with a grade I fracture had an excellent result. Three patients who had immobilisation of the ankle for more than four weeks had fair or poor results. Four of five fractures with good articular reduction had good or excellent results.

**Discussion**

The variables that influence the outcome of these complicated injuries are the quality of the bone stock, the type of fracture, especially if open, soft-tissue involvement, the time from injury, surgical technique, the quality of articular reduction, the incidence of infection and post-operative rehabilitation. Of these, the type of fracture, quality of reduction and soft-tissue management are the most important predictors of outcome.4,8,12

Until recently the standard protocol for the management of pilon fracture has been according to the AO principles of ORIF, as popularised by Ruedi and Allgöwer,6 who demonstrated excellent results in 73% of cases. However, most of their fractures were rotational low-energy skiing injuries with minimal soft-tissue compromise, and therefore more amenable to open reduction and internal fixation.7-10,13,14

Ovadia and Beals,9 in a study of 145 pilon fractures, recommended rigid internal fixation in most cases. In fractures not amenable to accurate reduction, they pre-
ferred fibular fixation and application of a cast followed by early mobilisation, and occasionally primary arthrodesis.

Watson et al.\textsuperscript{15} described 107 pilon fractures, of which 36 were treated with ORIF and 58 with external fixation. They observed late complications such as osteoarthritis and arthrodesis in both groups, but the incidence of unplanned secondary procedures was higher in the ORIF group, which the authors attributed to extensive stripping of soft tissue during open reduction. They recommended external fixation for high-energy pilon fractures.
In general, the results of high-energy pilon fractures treated by ORIF have not been promising with frequent complications such as wound breakdown, infection and osteomyelitis.\textsuperscript{11,16} Teeny and Wiss\textsuperscript{8} questioned the protocol of open reduction and plate osteosynthesis when they observed at least one major complication such as skin slough, wound dehiscence, infection, nonunion, malunion or implant failure in more than 50% of a series of 60 plafond fractures, 27 of which were Ruedi type II and 30 were type III. They observed that the infection rate correlated more closely with the fracture pattern than to whether the fracture was closed or open.

Some have favoured two- or three-stage procedures for the management of type C3 pilon fractures, with variable results.\textsuperscript{1,12,17} A newer method of internal fixation aimed at reducing iatrogenic soft-tissue injury is minimal invasive plate osteosynthesis, which has given encouraging results.\textsuperscript{9,18,19} However, this ‘biological plating’ method is more demanding technically and is only suitable in selected cases.\textsuperscript{9} Its use in compound fractures is controversial and wound breakdown, although minimised, is not eliminated.\textsuperscript{18}

External fixation is a recognised alternative treatment for high-energy pilon fractures.\textsuperscript{7,15,16} McDonald et al\textsuperscript{7} observed no deep infection or osteomyelitis with a high rate of fracture healing and good functional recovery after external stabilisation of 13 pilon fractures, 12 of which were Ruedi type II or III.\textsuperscript{6} Marsh et al\textsuperscript{16} observed no wound breakdown and only two cases of infection of the fibular plating site. Bone et al,\textsuperscript{20} in a study of 20 high-energy open pilon fractures managed with ankle spanning external fixators, found that these fractures are better managed by external fixation with or without minimal internal fixation than with plate osteosynthesis. They had no infections.

The management of high-energy pilon fractures by an ankle-spanning Ilizarov fixator has the advantages of indirect reduction by ligamentotaxis, minimal invasive
surgery, and a stable and definitive fixation. It requires only small stab incisions and allows additional interfracture fixation of the larger articular fragments before the final stabilisation is achieved by a dummy ring over the ankle joint. The most significant advantage of ring fixators is their ability to achieve stability with minimal soft-tissue dissection. However, due to their cumbersome construction, surgeons and patients may find them to be uncomfortable and therefore some authors have used hybrid fixators with a peri-articular ring connected to a unilateral fixator. This hybrid fixator has the inherent problem of cantilever bending, which is eliminated by the circular construction of the Ilizarov frame, thereby making it a better instrument. A circular fixator also provides the option of bone transport. In our opinion the Ilizarov fixator is superior in strength and stability to the hybrid type and allows early weight-bearing. This helps in preventing peri-articular osteopenia, and the tensioned wires allow axial micromovement, which is known to promote bony union.

The timing of surgery is of the utmost importance. An operation performed through severe intradermal oedema and fracture blisters greatly increases the risk of wound breakdown, tissue necrosis and infection. Marsh et al recommended an average delay of six days (0 to 28) for definitive fixation of pilon fractures, to allow soft-tissue swelling to subside and pre-operative planning to be completed. Sirkin and Sanders considered that thin wire external fixators with or without minimal internal fixation should be the preferred treatment within the first 72 hours. It is our experience that the usefulness of ring fixators is rarely influenced by the interval between injury and surgery.

The use of an ankle-spanning external fixator has been criticised for causing loss of movement in the ankle joint. However, considering the severity of these injuries, other methods have their own problems and an ankle-spanning fixator with a good hold on both sides of the joint appears a better option during the early stages of healing. There is also no published evidence to show that fixation on the same side of the ankle joint is better than cross-ankle stabilisation.

The mean duration of immobilisation of the ankle in our patients was 3.7 weeks (three to six). Kim et al removed the foot mounting between six and ten weeks, and reported good functional recovery in 15 of 21 patients. Kapukaya et al recommended the calcaneal frame to be retained for an average of four weeks. Conversely, Bacon et al retained an ankle spanning fixator for six to eight weeks.

It is believed that approximately 10° of dorsiflexion of the ankle is required for an adequate functional gait. Of the 16 patients in our study group, 12 (75%) regained this dorsiflexion or more, and only two (12%) had plantar flexion < 25°. However, in their study of 39 pilon fractures, Wyrsch et al concluded that loss of tibiotalar movement does not always correspond to poor performance. The average duration of external fixation was reported to be 15 weeks by McDonald et al and Leung et al, whereas in our series the apparatus was removed at a mean of 17 weeks (14 to 24).

Closed reduction and stabilisation of pilon fractures by percutaneous Ilizarov wires is technically demanding, with a steep learning curve. The main requirement is a thorough knowledge of anatomy so as to pass the wires safely through anatomical planes. Although ligamentotaxis is a rational approach for indirect reduction of the fracture fragments, type C pilon fractures frequently have small impacted articular segments devoid of capsuloligamentous attachment, and therefore cannot be reduced by ligamentotaxis alone. In our series we occasionally used small incisions to facilitate direct mobilisation and reduction of fragments devoid of ligamentous attachment, using Kirschner-wires as levers and fixing them definitively with interfragmentary screws whenever necessary. The most common disadvantage of the Ilizarov method is the incidence of pin-track infection, which may warrant removal of the wire or its replacement during treatment. Percutaneous wires can also be painful, and patients need to be warned to take care of the apparatus as well as the limb. Prolonged use of this cumbersome device can cause psychological and social difficulties. Our series has weaknesses, such as the study population and the short follow-up. The principle of capsuloligamentotaxis for indirect reduction of pilon fractures appears sound, but its long-term outcome needs to be compared with those of other methods of treatment. There is no agreement worldwide about a definitive protocol to deal with these devastating injuries. Prospective randomised studies will not be possible, because the skill and expertise of an investigator in a particular technique will always make the study biased.

With all this uncertainty, it is important to choose a primary treatment which is less likely to cause serious complications. Although ligamentotaxis with the Ilizarov apparatus does not always achieve an accurate anatomical reduction, its value is least influenced by the time from injury or soft-tissue involvement. It achieves a stable construct through a minimally invasive technique and minimises the incidence of serious complications. It significantly reduces peri-operative morbidity, allows early mobilisation and weight-bearing, and often leads to good or fair results.

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


