EXTERNAL FIXATION FOR COMPLICATED TIBIAL FRACTURES

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An account is given of 38 patients with complicated tibial fractures who were treated by the Portsmouth method of external fixation. Twenty-one patients had multiple injuries and 30 had compound fractures of the tibia. Eighteen fracture wounds were infected, 17 cases required bone grafts and 13 had skin grafts. Thirty-four fractures united in an average time of six months; three patients underwent below-knee amputations; one with neurofibromatosis remains ununited.

Those treated primarily by external fixation did better than those in whom external fixation was used after failure of another method. Most fresh fractures united with external callus; and the significance of this in relation to the rigidity of fixation is discussed. The method is easy to use, effective and economical. Improvements to permit adjustment of position and testing for union are suggested. We advise the use of this method of external fixation as the primary treatment for complicated tibial fractures where there is a significant risk of infection or non-union.

Fractures of the tibia frequently occur in association with severe damage to the soft tissues and with injuries elsewhere. Open wounds are common because the tibia has a subcutaneous anteromedial surface; it is precisely this anatomical feature which makes external fixation easy. In complicated tibial fractures external fixation is successful and has definite advantages over conventional methods. The fracture can be reduced and stabilised without sacrificing access to the injured soft tissues and without burying foreign material next to the fracture or under damaged skin.

Ten of these fractures had previously been plated, nine treated in plaster and eight with os calcis traction. In 18 of these secondary cases the wound at the fracture site was already infected.

The apparatus (Figs 1 and 2). The Portsmouth external fixation device consists of a single external bar secured to the tibia by three transfixed pins above the fracture and three below it. Sometimes more pins are used. They

MATERIAL AND METHODS

Between 1975 and 1979 we have used the Portsmouth method of external fixation on 38 patients with complicated tibial fractures (Edge and Denham 1979). The average follow-up from application of external fixation until this review was 20 months. Twenty-eight of the fractures were due to road traffic accidents (16 involving motor cyclists); two were pathological. Twenty-one patients had multiple injuries and 30 had open fractures. In 29 patients the fracture involved the middle or lowermost third of the tibia, and six patients had segmental fractures. Eleven patients were treated by primary application of external fixation within 24 hours of injury; the average interval between fracture and fixation was eight hours. In the remaining 27 patients external fixation was applied secondarily after failure of another method of treatment; the average interval between fracture and fixation was six months.

Fig. 1

Figure 1—Components of the Portsmouth external fixation device.

Fig. 2

Figure 2—Primary external fixation of a compound comminuted fractured tibia in a woman aged 77 years.

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are inserted through the subcutaneous anteromedial surface of the tibia and fastened with acrylic cement to mobile carriages on the external bar; the position of the carriages is governed by the locking nuts. Compression can be applied across the fracture at any time. In 34 cases compression was applied when the fixation was first applied and 21 had additional compression added at a later date. Compression was not used where, because of comminution or loss of bone, the external fixation was being used to maintain length. In three cases low amplitude springs were used between the locking nuts and the carriages, so that the compression was acting across the fracture intermittently, during activity (Fig. 3).

**Technique.** The external fixation device was applied under general anaesthesia using open or closed reduction as described elsewhere (Edge and Denham 1979). The policy was to try to obtain accurate reduction of the bone fragments, except in those few cases where the degree of comminution or of bone loss was so severe that no greater stability would have resulted and where the interference might have further jeopardised the blood supply (Figs 4 and 5). In 22 cases the fractures were reduced under direct vision.

Whichever method was used it was considered vitally important to achieve as perfect a reduction as possible before cementing the pins to the external bar. Check radiographs in both planes were always taken before applying the cement, since no adjustment of position is possible once the cement has hardened.

**Skin care.** With fresh fractures careful debridement and early skin cover were priorities of treatment. The object was to avoid infection which seemed to be the most important factor influencing the final outcome. If the skin was deficient split-skin grafts were applied (Figs 6 to 8) but neither releasing skin incisions nor skin flaps were employed as their outcome was thought to be unpredictable in these severely injured limbs. In many cases the original wound was extended slightly in order

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**Figure 3**

The method of securing the carriage on to the external bar using springs.

**Figure 4**—This 17-year-old motorcyclist, with a compound comminuted fracture, was treated by closed reduction and external fixation. He was in hospital for 12 days. Figure 5—The fracture united at seven months and he returned to work at 10 months. There was 2.5 centimetres of shortening and 12 degrees of backward angulation.

**Figure 6**—A 51-year-old woman hit by a motorcycle sustained this fracture of the tibia with skin loss. Figures 7 and 8—She was treated by open reduction and primary external fixation with split-skin grafting. The fracture united in seven months.
to obtain sufficient access for accurate open reduction. Most fractures were held reduced with bone clamps until the external bar and compression had been applied; the clamps were then removed.

In segmental fractures the middle segment often needed additional support by further transfixing pins; otherwise, with compression, the middle segment might bow or become displaced (Figs 9 to 11).

**Mobilisation.** After fixation, movements of the knee and ankle were encouraged immediately. There was usually no difficulty, because the fracture was securely held and the calf muscles were not tethered by the transfixing pins. The patients remained in bed only as long as other injuries or the soft tissues made this necessary; they were then mobilised on crutches at an average time of less than four weeks (range one day to 11 weeks).

The external fixation device is not strong enough to take the whole weight of the body, and weight-bearing is prohibited until some force can be transmitted down the tibia. Thus, with a transverse fracture the patient could usually start weight-bearing immediately, whereas with an unstable fracture it was postponed until there was clinical or radiographic evidence of sufficient union.

It was our policy to apply cancellous bone grafts if the fracture showed no sign of progress towards union after three months. We used Harmon's (1945) method of applying the graft posterolaterally to avoid the site of infection. Our fixation device provided excellent access.

**Removal of external fixation.** The device was left on until the fracture was considered solid. It was then easily removed by cutting the tibial pins with bolt cutters or a hacksaw. We found it difficult to assess whether or not a fracture was solid before cutting the pins and in some cases the fracture still felt "springy" after removing the fixation. This presented no difficulty providing the skin wounds had healed and the patients had achieved good movements at the knee and ankle; for it was then safe to apply a walking cast or gaiter, and to retain it until consolidation had occurred. The most recent modification of the Portsmouth external fixation bar can be completely dismantled without cutting the tibial pins. This makes clinical assessment of the state of union much easier.

The average time spent in external fixation was five months. Thereafter 10 of the 34 patients were left entirely unsupported; in the remaining 24 a plaster gaiter was applied for a time, though in only 14 of them was there even a hint of mobility.

**RESULTS**

The results are summarised in Table I. In 34 patients solid union was achieved in an average time of six months. The four failures are analysed in Table II; only one had been treated by primary external fixation and here the severity of the associated injuries to nerves and arteries was responsible for the failure; no blame could be attributed to the fixation.

<table>
<thead>
<tr>
<th>Table I. Results of external fixation (38 patients)</th>
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<tbody>
<tr>
<td>United</td>
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<tr>
<td>Early amputation for vascular insufficiency</td>
</tr>
<tr>
<td>Late amputation</td>
</tr>
<tr>
<td>Non-union</td>
</tr>
<tr>
<td>34</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<td>1</td>
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Seventeen of our patients required bone grafts of which 14 were those treated by secondary external fixation after an average time lapse of six months from injury. The union rate for all fractures treated by
secondary external fixation was 89 per cent. The union rate in those 14 patients with bone grafts was only 79 per cent, with three fractures failing to unite.

Of the 34 tibiae which united 21 did not have a bone graft. It was notable that 18 of these united with radiographic evidence of external bridging callus (Figs 12, 13 and 14); with this external callus solid union was achieved in an average time of five months.

**Table II. Analysis of failures (4 out of 38)**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Reasons for failure</th>
<th>Time in external fixation</th>
<th>Outcome</th>
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</thead>
<tbody>
<tr>
<td>16</td>
<td>Run over by a train Vascular and neurological insufficiency Infection</td>
<td>11 days</td>
<td>Below-knee amputation at 11 days</td>
</tr>
<tr>
<td>70</td>
<td>Infected non-union</td>
<td>6 months</td>
<td>Below-knee amputation at 25 months</td>
</tr>
<tr>
<td>64</td>
<td>Multiple injuries including neurological deficit Infected non-union</td>
<td>13 months</td>
<td>Below-knee amputation at 15 months</td>
</tr>
<tr>
<td>6</td>
<td>Non-union Inadequate stability Neurofibromatosis</td>
<td>5 months</td>
<td>Fibrous non-union</td>
</tr>
</tbody>
</table>

Only in the first case was the external fixation applied from the start. In the other three it was applied secondarily.

The average time before the patient, with his fixation device, was up and about, was less than four weeks; but in any individual case the time was largely determined by the state of the soft tissues and the nature of any other injuries. Patients were allowed to go home with the fixation device in position and wearing normal clothes. Those with experience of both methods found the device less inconvenient than wearing a plaster cast.

Twenty-one patients returned to their normal work in an average time of 11 months after the application of external fixation. There was no case of refracture after the device was removed.

**COMPLICATIONS**

The complications in the 38 patients are listed in Table III.

**Malunion.** This, the commonest complication, occurred in 21 cases. Our criteria were stringent: any tibia with angulation or rotation deformity of over five degrees, or shortening of over one centimetre, was included.

There were three reasons for malunion: the initial reduction and external fixation was sometimes imperfect; compression sometimes caused the tibia to bow or displace, and since the bar was on the medial side bowing, if it occurred, was always into varus; and removal of the fixation device when the fracture was still mobile sometimes led to angulation while the fracture was consolidating in plaster.

It would have been helpful if we could have adjusted the reduction after the external fixation bar had been fitted. However, with experience this problem was anticipated and overcome by fixing the fracture in slight valgus and by splaying out the tibial pins so that there was less bending movement imparted to the fracture when compression was applied.

Twenty patients had angulation deformity of more than five degrees, but in only two was this severe enough to need osteotomy. Three patients had rotation deformity of more than five degrees and four had shortening of over one centimetre; none of these needed osteotomy.

**Wound infection.** Thirty patients had compound fractures and 18 of these developed infection at the fracture site. Three of the 10 compound fractures treated by primary external fixation became infected. All these united. Of our four failures three were infected when fixation was started. In two of these, infection was thought to be the main reason for non-union.

Union by bridging callus was twice as frequent in the non-infected cases, and it was necessary to apply bone grafts twice as often to patients with infected wounds.

**Pin track infection.** This occurred in 16 patients. It was associated with loosening of the pins, but we have not determined which condition came first. In no case was the infection severe enough to require removal of the fixation device. Antibiotics were given but usually some infection persisted until the device was finally removed.

Thirty-four pins became infected out of a total of 249 pins used. All healed spontaneously except one, which did not do so until after the track had been curetted.

**Table III. Complications in 38 patients**

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<table>
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<tbody>
<tr>
<td>Non-union</td>
<td>3</td>
</tr>
<tr>
<td>Malunion</td>
<td>21 (2 required correction)</td>
</tr>
<tr>
<td>Imperfect control of fracture position</td>
<td>9</td>
</tr>
<tr>
<td>Infected pin track</td>
<td>15</td>
</tr>
<tr>
<td>Pin fracture</td>
<td>1</td>
</tr>
<tr>
<td>Bent pins</td>
<td>1</td>
</tr>
</tbody>
</table>

**Joint stiffness.** Residual joint stiffness occurred in five knees and 11 ankles. There was invariably a predisposing factor, such as injury of the affected joint, nerve damage, or spasticity from a coincidental head injury.

**Failure of fixation.** The external fixation device was considered at fault in failing to hold the original reduction in nine patients. In one, a tibial pin fractured, presumably a fatigue fracture. In another, the patient had a second accident in which he redisplaced his tibial
fracture and bent three tibial pins at one end of the fixation. In the remaining seven patients excessive mobility occurred at the fracture site because of loosening of the tibial pins at the interface between pin and bone. This was associated with infected pin tracks in five patients; in the remaining two the number of pins was inadequate. At least three pins are needed above the fracture and three below it; additional pins are sometimes needed with a segmental fracture. Osteoporotic bone also needs more than three pins, and better fixation is achieved if these are splayed rather than all in one line (Fig. 13).

DISCUSSION

In the treatment of fractures it is not known what degree of rigidity is optimal for bone healing. It is recognised clinically that the amount of external callus formed is related to the amount of movement of the fractured ends. It has been shown that rigid internal fixation can inhibit external callus completely (Anderson 1965; Schenk and Willenegger 1967). In delayed union and non-union of the hypertrophic type, increased rigidity of fixation is required to achieve bony union (Hicks 1977).

However, union by a bridge of external callus has definite advantages, especially in severe injuries such as those for which we have been using external fixation. It can bridge gaps due to missing bone or devitalised fragments, and is the most rapid variety of bone healing.

Austin (1977) has pointed out that all grades of tibial fracture take longer to unite if treated by rigid internal fixation than they do with conservative non-rigid methods; moreover, the difference is most marked in the severe group of fractures, which also have the highest incidence of non-union. It seems logical, therefore, particularly when treating complicated fractures, to encourage this natural healing process and not to suppress it by rigid internal fixation or by completely rigid external fixation.

The Portsmouth external fixation device is less rigid than most other external fixation devices (Campbell and Kempson, personal communication). It gives more secure fixation than a plaster cast but is not so rigid as internal fixation, which may in any case be contraindicated by the risk of infection.

More research is needed to determine the optimal degree of stiffness in an external fixation device. Our clinical experience suggests that we should not strive for total rigidity, since in most cases we can expect union by bridging callus; and with severe injuries such as we are considering, simply to obtain union is something of an achievement.

The virtues of non-rigidity, with consequent external callus, have been well described by McKibbin (1978).

CONCLUSIONS

External fixation of complicated tibial fractures using the Portsmouth device has proved safe and effective. The overall union rate was 90 per cent and no refractures occurred after the device was removed.

With these difficult fractures union with external callus (the most rapid method) is desirable and is promoted by movement. Our method permits sufficient movement to stimulate callus while affording sufficient stability to prevent serious malunion. When the device was applied late for patients with delayed union or non-union, the results were less satisfactory, even when bone grafts were added. It seems that these late cases need more rigidity, which could perhaps be achieved with thicker transfixing pins.
Infection is an important cause of failure. Its avoidance must have a high priority in the initial treatment. Malunion was severe enough to need correction in only two patients. Small degrees of malunion were more frequent and it would be an advantage if the position could be altered soon after the initial fixation.

The method is extremely cost effective. The bar is inexpensive, patients can go home with it in place and, after removal, it can be used again.

REFERENCES


