LOCKED INTRAMEDULLARY NAILING OF OPEN TIBIAL FRACTURES

C. M. COURT-BROWN, M. M. McQUEEN, A. A. QUABA, J. CHRISTIE

From the Royal Infirmary, Edinburgh

We report the use of Grosse-Kempf reamed intramedullary nailing in the treatment of 41 Gustilo type II and III open tibial fractures. The union times and infection rates were similar to those previously reported for similar fractures treated by external skeletal fixation, but the incidence of malunion was less and fewer required bone grafting.

The role of exchange nailing is discussed and a treatment protocol is presented for the management of delayed union and nonunion.

We have previously discussed the treatment of closed and type I (Gustilo and Anderson 1976) open tibial fractures using a reamed locking intramedullary nail and have shown that excellent results can be obtained (Court-Brown, Christie and McQueen 1990a). Our success with these fractures, coupled with our disquiet about the results of external skeletal fixation in the management of type III open fractures (Court-Brown et al 1990b), led us to extend our use of tibial nailing to all type II and III open fractures. We now report the results of a prospective study of the treatment of type II and III (Gustilo, Mendoza and Williams 1984) open tibial fractures with primary intramedullary nailing using the Grosse-Kempf locked nail with reaming.

MATERIALS AND METHODS

Between July 1987 and January 1990, 41 type II and IIIa and IIIb open tibial fractures were primarily treated with the Grosse-Kempf locking tibial nail. During this period, seven type IIIc open fractures were admitted. Those that were not treated by amputation had external skeletal fixation, which was preferred to nailing because of the speed with which it can be applied.

The 41 fractures were in 39 patients, 31 males and eight females. Their mean age was 39.1 years (range 17 to 89). Road traffic accidents caused the injury in 26 patients (66.6%), 14 were pedestrians and 12 were drivers or passengers on motor cycles or in cars. Seven patients were injured in falls, three in sporting accidents and three at work. Additional orthopaedic injuries were present in 15 (38%) and six (15%) had injuries in other body systems. The fractures were in the middle third in 16 cases, in the distal third in 11, and in the proximal third in two. The remaining 12 fractures were either segmental or comminuted, spanning more than one-third of the bone.

All fractures were treated as soon as possible after admission. The patients were placed on a fracture table with traction applied through a calcaneal pin in the manner already described by Court-Brown et al (1990a). A thorough wound toilet was performed with excision of all devitalised soft tissue and all bone fragments denuded of periosteum. In degloving injuries the skin was resected until dermal bleeding was encountered. The soft-tissue wounds associated with type II fractures were mainly treated by orthopaedic surgeons but plastic surgeons were present for the assessment and treatment of the wounds associated with type III fractures.

Following wound toilet, the tibia was nailed using the technique described by Court-Brown et al (1990a) except that the guide wire was passed across the fracture site under direct vision. To avoid damage to soft tissues, reaming was not undertaken across areas of cortical bone loss. Static locking was used in 40 of the fractures and in one type II proximal tibial fracture we used a proximal dynamic lock. Prophylactic cefuroxime was used in all cases with benzyl penicillin added for the type III fractures. Recently, ceftazadime was added to the
antibiotic regime for type IIIb fractures because of the high incidence of pseudomonas infection (Court-Brown et al 1990b).

Three wounds were closed primarily. One, associated with a type II fracture, was primarily sutured; the other two wounds were in type IIIa fractures and were closed by primary flaps. The remaining 38 wounds were all left open and re-explored 36 to 48 hours after the initial operation, with further soft tissue and bone resection carried out as required. If tissue resection was required at the second operation, another exploration was carried out after a further 48 hours. Once the wound was free of contamination definitive soft-tissue cover was performed. The type of cover was dictated by the size and position of the wound and the type of fracture.

Mobilisation of the patients depended on the type of fracture, the requirement for plastic surgery and the presence of other injuries. Patients with isolated type II and IIIa fractures that did not require plastic surgery were mobilised, with appropriate aids, as soon as pain permitted. Patients with split skin grafts or skin flaps were mobilised as soon as the state of the soft tissues permitted. No postoperative plaster casts were required, but back shells were used to prevent equinus contractures of the ankle in those patients who were unconscious or on ventilators for a prolonged postoperative period. Passive and active movement of the knee, ankle and subtalar joints were encouraged as soon as possible after surgery.

Bone union was determined by the usual clinical and radiological criteria. The presence of an intramedullary nail means that the surgeon cannot adequately stress the fracture site and we have found that the loss of pain on walking is a better clinical indicator of union. Infection was defined as a purulent discharge from which organisms were grown. Malunion was defined as more than 1 cm of lengthening or shortening or more than 5° of rotational or angular deformity.

The patients were all followed up for a minimum of 18 months or until six months after union.

RESULTS

Type II fractures. The mean time to union for the 14 type II fractures was 23.5 weeks (range 12 to 90). One wound became infected with Staphylococcus aureus following primary closure. After several failed operative procedures, a vascularised fibular graft eventually achieved union of the fracture. There were no malunions and the remaining 13 patients all regained full movements in the knee, ankle and subtalar joints.

Type III fractures. The combined results of the type IIIa and type IIIb fractures are given for comparative purposes as few previous authors have subdivided these fractures. The mean time to union for 27 type III fractures was 38.2 weeks (range 21 to 94). There were two cases of infection and one malunion. Six patients required bone grafting.


Table 1. Methods of definitive wound management and the incidence of infection

<table>
<thead>
<tr>
<th>Wound management</th>
<th>Number</th>
<th>Fracture type</th>
<th>Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granulation</td>
<td>14</td>
<td>10 II, 4 IIIa</td>
<td>0</td>
</tr>
<tr>
<td>Primary suture</td>
<td>1</td>
<td>1 II</td>
<td>1</td>
</tr>
<tr>
<td>Secondary suture</td>
<td>4</td>
<td>2 II, 2 IIIa</td>
<td>0</td>
</tr>
<tr>
<td>Split skin graft</td>
<td>10</td>
<td>1 II, 4 IIIa, 5 IIIb</td>
<td>0</td>
</tr>
<tr>
<td>Flap</td>
<td>12</td>
<td>4 IIIa, 8 IIIb</td>
<td>3</td>
</tr>
</tbody>
</table>

Type IIIa fractures. The 14 type IIIa fractures united in an average time of 27.2 weeks (range 21 to 52). There were no infections, no malunions and no patient required bone grafting. However five patients had an exchange nailing procedure to stimulate union. Fewer patients (78.6%) than in the type II group regained full function of knee, ankle and subtalar joints.

Type IIIb fractures. The 13 type IIIb fractures united in an average time of 50.1 weeks (range 32 to 94). There were three infections, one caused by Staphylococcus aureus, one by Escherichia coli and one from a combination of Staphylococcus aureus, Escherichia coli and Hafnia alvei. There were two malunions, both iatrogenic: one fracture healed in 20° of valgus following incorrect insertion of the proximal cross-screw and the second was unintentionally lengthened by 1 cm because the surgeon failed to notice a proximal tibiofibular dissociation.

Further evaluation of the type IIIb cases suggests that they fell into two distinct subgroups. The first subgroup contained seven patients who had bone defects less than 2 cm in length and involving no more than 50% of the tibial circumference. Four of these patients healed without bone grafting (Fig. 1) and the other three united after exchange nailing. The mean time to union in this subgroup was 38 weeks.

The second subgroup contained six patients with bone loss of more than 2 cm and involving more than 50% of the tibial circumference (Fig. 2). All these fractures required bone grafts and five required two grafting procedures. The mean time to union in this group was 78 weeks.

Overall, 46% of the type IIIb fractures required open bone grafting. The severity of the soft-tissue damage in the type IIIb fractures is reflected in the fact that only two patients in this group regained full function in all three joints.

Exchange nailing. Exchange nailing refers to the removal of the intramedullary nail, reaming of the medullary canal by at least a further millimetre and the insertion of a larger nail. The procedure is usually carried out for nonunion. In this series 13 exchange nailing were performed and eight were successful in stimulating bone union. Five of these were in type IIIa fractures and three in the subgroup of type IIIb without significant bone loss. Of the five unsuccessful procedures, one was carried out in an infected type II fracture and the other four in type IIIb fractures with significant bone loss.

Soft-tissue closure. The definitive management of all wounds is given in Table I and the results of flap cover in the more severe fractures are shown in Table II. No infection followed secondary wound suture, split skin grafting, or leaving the wound to heal by granulation.

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Fig. 2a

Fig. 2b

Fig. 2c

Figure 2a – Bone loss, more than 2 cm in length and involving more than 50% of the circumference. This fracture became infected after partial failure of a myocutaneous flap. Further bone resection and insertion of gentamicin beads controlled the infection; b) a bone graft, followed by exchange nailing failed to bring about union. A second graft and a fibular osteotomy eventually resulted in bone union, eight months after the injury; c) despite the distal location of the fracture and the prolonged treatment, the ankle regained good movements. We believe that locked nailing allows for better hind-foot function than other methods of management.
Twelve patients were treated by flap cover, two at the first operation and the rest two to 12 days after injury (average 3.8). Eight flaps were completely successful and two were partially successful, covering 80% to 90% of the wound but leaving exposed periosteum, and denuded bone. Two failed completely. In the two partial successes the residual defects were left to granulate and although this eventually occurred, both fractures became infected. The two complete flap failures were treated by immediate cover with further flaps and neither fracture became infected.

Fasciocutaneous flaps were used to close eight wounds. Six were carried out within four days of the injury and all these were successful. Of the two flaps which failed, one was performed 12 days after injury and one was carried out by an inexperienced surgeon.

**DISCUSSION**

External skeletal fixation has become the established treatment for severe open tibial fractures despite the problems of malunion and pin-track sepsis associated with its use (Edwards et al 1984; Blick et al 1989; Court-Brown et al 1990b). In earlier years intramedullary nailing using unreamed unlocked nails had produced good results in type III open tibial fractures but the method did not adequately stabilise comminuted or segmental fractures. This meant that these had to be excluded or plaster casts had to be worn to provide additional stability (Hasenhuttl 1981; Velazco, Whitesides and Fleming 1983). Several authorities have declared themselves firmly against the use of reamed intramedullary nails in the management of type II and III open tibial fractures. Chapman (1986) has stated that reamed nailing carries an unacceptably high rate of infection and Gustilo, Gruninger and Davis (1987) advised that if reamed nailing is to be undertaken it should be delayed for between three and six weeks and carried out as an elective procedure when the soft tissues have healed. Gustilo and his co-workers have however also pointed out some of the disadvantages of conversion from external fixation to intramedullary nailing (Maurer, Merkow and Gustilo 1989).

The belief that reamed nailing of severe open tibial fractures prejudices fracture union and increases the incidence of sepsis has not been tested in clinical practice. Rhinelander and Wilson (1982) and Brookes (1990) have both shown that reaming renders the endosteal surface of the cortex ischaemic for a time although Brookes demonstrated how medullary blood vessels proliferate after a relatively short period. In theory, disruption of the medullary blood supply in a bone already denuded of periosteum, as in a severe open tibial fracture, may render all, or part of the diaphysis ischaemic, increasing the risks of infection and nonunion.

The contrary view is that the tibial nutrient artery which supplies the endosteal surface of the cortex has probably already been damaged and that further medullary reaming can hardly worsen the situation. Since all bone fragments denuded of periosteum should be removed from the wound, all the bone that is left should have a good periosteal blood supply. Strachan et al (1990) have recently suggested that the periosteal reserve is so great that loss of the intramedullary blood supply in the presence of an intact periosteum is of little importance.

The locked tibial nail has been shown to provide excellent stability in all closed and in type I open tibial fractures (Court-Brown et al 1990a). Bone and Johnson (1986) used reamed intramedullary nails, mostly without locking screws, and reported a 25% infection rate in type II and III open tibial fractures. No analysis of the use of a reamed and locked nail in the management of type II and III open tibial fractures has previously been published.

**Table II. Types of flaps and their success rates**

<table>
<thead>
<tr>
<th>Flap</th>
<th>Number</th>
<th>Fracture type</th>
<th>Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local fasciocutaneous</td>
<td>8</td>
<td>3 IIIa, 5 IIIb</td>
<td>6</td>
</tr>
<tr>
<td>Local muscle/myocutaneous</td>
<td>2</td>
<td>1 IIIa, 1 IIIb</td>
<td>1</td>
</tr>
<tr>
<td>Free muscle (latissimus dorsi)</td>
<td>2</td>
<td>2 IIIb</td>
<td>1</td>
</tr>
</tbody>
</table>

We had good results in type II fractures, except for the one patient whose wound was closed primarily. Even when this case is included the average time to union, the malunion rate and the recovery of joint movement all compared well with the results for closed and type I open fractures (Court-Brown et al 1990a).

The treatment of type III open fractures with a reamed locking nail is more contentious. However, Table III shows that the overall results compare favourably with recently published results for external skeletal fixation. The average overall union time of 38.2 weeks is very similar to our own series for external fixation of type III fractures (Court-Brown et al 1990b) and to that of Edwards et al (1985). The average union time of Blick et al (1989) may have been prolonged by the relatively large number of IIIb fractures in their series.

The different prognosis for type IIIa and IIIb fractures means that it is important to separate them when comparing results. Table IV shows separately our IIIa and IIIb results compared with other recent series treated by external fixation. The uniformity of results suggests that whatever the theoretical advantages or disadvantages of reamed nailing the time to union and the rate of infection are the same as for external fixation.

However, we believe that intramedullary nailing is superior in several ways. Fewer cases required bone grafting, there was a lower incidence of malunion and less residual joint stiffness. The method gives better
Table III. Some recent reports of the management of type III open tibial fractures

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment</th>
<th>Union time (weeks)</th>
<th>Infection (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Court-Brown et al (1990)</td>
<td>External fixation</td>
<td>36.7</td>
<td>17.6</td>
</tr>
<tr>
<td>Court-Brown (1991)</td>
<td>Intramedullary nailing</td>
<td>38.2</td>
<td>11.1</td>
</tr>
</tbody>
</table>

Table IV. Time to union for Gustilo type IIIa and IIIb fractures in recent series

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment</th>
<th>Union time (wk) IIIa</th>
<th>IIIb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blick et al (1989)</td>
<td>External fixation</td>
<td>38.6</td>
<td>47</td>
</tr>
<tr>
<td>Court-Brown et al (1990)</td>
<td>External fixation</td>
<td>26.5</td>
<td>47.4</td>
</tr>
<tr>
<td>Court-Brown (1991)</td>
<td>Intramedullary nailing</td>
<td>27.2</td>
<td>50.1</td>
</tr>
</tbody>
</table>

Table V. A protocol for the treatment of nonunion following the use of a reamed interlocking nail. Exchange nailing of fracture types I and II is rarely required as the incidence of nonunion is low. In type IIIb fractures with significant bone loss, bone grafting should be undertaken as soon as the soft-tissue envelope has healed.

<table>
<thead>
<tr>
<th>Fracture type</th>
<th>Average union time (weeks)</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>14.7</td>
<td>Exchange nailing 10 to 12 weeks</td>
</tr>
<tr>
<td>II</td>
<td>23.5</td>
<td>Exchange nailing 12 to 16 weeks</td>
</tr>
<tr>
<td>IIIa</td>
<td>27.2</td>
<td>Exchange nailing 16 to 18 weeks</td>
</tr>
<tr>
<td>IIIb (no bone loss)</td>
<td>38</td>
<td>Exchange nailing 20 to 24 weeks</td>
</tr>
<tr>
<td>IIIb (bone loss)</td>
<td>74</td>
<td>Open bone grafted 6 to 8 weeks</td>
</tr>
</tbody>
</table>

access to the soft tissues for flap cover and is more acceptable to patients. In our earlier series of type III fractures treated by external fixation (Court-Brown et al 1990b) 50% of the IIIa and 78% of the IIIb fractures required bone grafting. Using reamed intramedullary nailing combined with later exchange nailing the requirement for open bone grafting fell to zero in the IIIa fractures and to 46% in the IIIb group. The malunion rate fell from 35% to zero in the IIIa group and from 71% to 15% in the IIIb fractures. We also found a 40% incidence of stiffness in knee, ankle or subtalar joints in the externally fixed IIIa group compared with 21% for the nailed IIIa fractures. We had a high incidence of joint stiffness in both externally fixed and nailed IIIb fractures reflecting the severity of these injuries.

Patient acceptability is clearly subjective and influenced, not least, by the surgeon's preference. However our patients have been consistent in their dislike of prolonged external fixation and where a choice is possible they select nailing. The absence of transfixing pins helps the plastic surgeon in the planning and execution of skin grafting procedures.

The importance of defining the extent of bone loss in type IIIb fractures was noted by Blick et al (1989). In their series of externally fixed fractures they defined bone loss as more than 50% of the cortical diameter and showed that fractures with bone loss united in an average of 57 weeks compared to 44 weeks for the group without bone loss. Our type IIIb fractures were readily divided into two subtypes based on the amount of bone lost and our results indicate that if a reamed nail is used to stabilise bone defects of more than 2 cm and 50% of the cortical diameter, bone grafting will always be required. We agree with Behrens et al (1983) and Blick et al (1989) that bone grafting should be undertaken at an early stage. Defects of 2 cm or less treated with a reamed intramedullary nail (see Fig. 1) may well unite without bone grafting or may only require an exchange nailing procedure.

Exchange nailing was successful in promoting union in IIIa fractures and in type IIIb fractures without significant bone loss. We suggest that exchange nailing should be used in all such patients where nonunion is suspected. The times to union for the several Gustilo types of open fracture have been given here and in our previous paper which dealt with the less severe open fractures (Court-Brown et al 1990a). From this experience we have devised a treatment protocol for suspected or actual nonunion based on the type of fracture and the expected time to union (Table V). Careful assessment of exchange nailing over the last five years has shown it to be inappropriate in the treatment of infected fractures or those with significant bone loss. Attempts at reaming a segment of healed autogenous corticocancellous bone graft in an effort to promote union at the other end of the segment have also failed and we would not recommend this procedure. The number of times that a medullary canal can usefully be reamed to promote union is unknown although one of us has documented a case where a second exchange nailing was performed to secure union (Court-Brown 1991).

Several authors (Byrd, Cierny and Tebbets 1981;
Godina 1986; Gustilo et al 1987; Blick et al 1989) have drawn attention to the importance of early soft-tissue cover although the exact timing of wound closure is still debated. Primary closure should never be undertaken and although we had no infections following secondary suture we believe this, too, may be hazardous because of the tendency to close such wounds under tension. Small wounds will granulate and larger wounds should be covered by either split thickness skin grafts or, if there is exposed bone, a flap. We had a high rate of flap failure (33%), but three of the four flaps that failed were carried out by plastic surgeons inexperienced in post-traumatic soft-tissue reconstruction. When a flap fails it is essential that it be excised and further immediate flap cover undertaken, or osteomyelitis will ensue.

Byrd et al (1981) warned against the use of local pedicle flaps in type III fractures because of the wide extent of the soft-tissue damage. However we found fasciocutaneous flaps useful if performed within four days and by an experienced plastic surgeon. We agree with Louton, Harley and Hagerty (1989) that this procedure is very useful in the management of small defects. For larger defects we favour a free latissimus dorsi or rectus abdominis flap.

In all four cases which developed osteomyelitis there was evidence of surgical error. Three followed inappropriate management of the soft tissues, including one primary closure, one poor quality myocutaneous flap and one fasciocutaneous flap performed too late, at 12 days. The remaining case was due to inadequate wound toilet, avascular bone being left in the wound.

Recently there has been a tendency towards preoccupation with the mechanics of fracture management and fixation techniques. We believe that improved results also depend on the surgeon’s awareness of the biology of fracture treatment. Adequate wound toilet and early reconstruction of the soft-tissue envelope, followed by early bone grafting, are the keys to union and a low infection rate. The time to union and the rate of infection are similar whether nailing or external fixation are used, suggesting that the results are independent of the type of fixation. However, our results do suggest thatreamed nailing reduces the need for bone grafting and results in a lower incidence of malunion and joint stiffness.

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REFERENCES


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