The annual incidence of open fractures of long bones has been estimated to be 11.5 per 100 000 persons with 40% occurring in the lower limb, commonly at the tibial diaphysis. Open fractures in the leg tend to be more severe compared with those in the arm because of the degree of soft-tissue damage and the frequency of associated musculoskeletal injuries. Open fractures of the femur are usually the result of high-energy trauma and therefore tend to be seen in patients with multiple injuries.

Various classification systems have been proposed in an effort to grade the extent of the initial injury and to offer useful prognostic clues to help in deciding the optimal management. The most widely used is that of Gustilo and Anderson which describes three groups of increasing severity based on the size of the open wound, the degree of contamination and the extent of soft-tissue injury. The major disadvantage of the original classification was that the type-III category included a broad spectrum of open injuries of differing severity and, subsequently, of variable prognosis. Therefore in 1984 Gustilo et al reclassified the type-III injuries into three subgroups based on the extent of bone exposure, the requirements for adequate soft-tissue cover of the exposed bone and the need for vascular repair. The revised system has been used widely, but its reliability has been challenged in a survey conducted by Brumback and Jones which showed a moderate to poor interobserver agreement, even among experienced orthopaedic surgeons.

Initial evaluation and management
The initial evaluation of a patient with an open fracture of a limb should always follow the principles and guidelines of the Advanced Trauma Life Support System. Other concomitant serious and, possibly, life-threatening injuries should be sought. Any further assessment of the site of the open fracture, apart from control of active bleeding, should be deferred for the secondary survey.

After initial adequate resuscitation and stabilisation of the patient, the open fracture should be dealt with in the operating theatre as soon as possible, preferably within six hours of the injury. This is of paramount importance. Restoration of gross alignment of the limb should take priority in the initial management since obvious angulation and displacement or prominent bone fragments could exert undue pressure on soft tissues or neurovascular structures. Care should be taken to avoid the introduction of gross contamination into the intramedullary canal. The neurovascular status of the limb should be carefully evaluated. The distal arterial pulses, capillary refill and overall colour of the limb, and the presence of active bleeding from the wound must be recorded. Although a thorough neurological examination is impossible at this stage, motor and sensory function should be noted. In severe trauma to the leg, preservation of plantar sensation has been thought to be an important prognostic factor in deciding whether salvage of the limb is worthwhile. However, the Lower Extremity Assessment Project (LEAP) study noted that in a significant number of mangled limbs with initial loss of plantar sensation this ultimately resolved, presumably because of neuropraxia of the posterior tibial nerve.

A detailed history of the injury will help the assessment of soft-tissue damage and contamination since the velocity of the impact, the presence of any crush component and the location where the injury occurred will aid the appreciation of the damaged limb. The amount of energy absorbed by the limb creates a shock wave within the soft tissues which is responsible for the bony comminution and for a variable degree of disruption and stripping of soft tissues, as well as creating a momentary vacuum which tends to suck foreign material into the depths of the wound. Specific environmental exposure should be carefully documented. Injuries in a farmyard or when heavily contaminated by soil are associated with...
Clostridium perfringens, and wounds exposed to the environment of a lake or a river carry the risk of infection by Pseudomonas aeruginosa or Aeromonas hydrophila. A digital photograph should be taken.

After initial evaluation the open wound should be sealed with sterile dressings and the limb immobilised in a well-padded splint. Debridement and irrigation with sterile saline solution in the emergency room should be avoided in case of inoculation of the deeper tissues with nosocomial micro-organisms. Only easily accessible foreign bodies should be removed before the application of the sterile dressings. Nevertheless, irrigation of the open wound in the emergency room is advocated by some authors in the case of heavily contaminated wounds. The practical value of obtaining specimen cultures from the open wound in the emergency room has been questioned, since they usually isolate superficial contaminants or normal skin flora, while, at the same time, carry the risk of causing wound contamination.

Patzakis and Wilkins, in a prospective study of wounds in 1104 open fractures, found that although there was a positive initial culture in 64.1%, eventually only 7.0% became infected. Organisms isolated in the initial cultures were found in 66% of the infected cases. A positive post-debridement culture for Clostridium perfringens was found to increase the risk of developing a clostridial infection.

The high prevalence of microbial contamination of the open wounds predisposes to the development of infection which is related to the severity of the damage to the soft tissue. The role of prophylactic antibiotic therapy in the initial management of open fractures is well established. The risk of infection and the type of the offending microorganisms depend on the severity of soft tissue damage. As the role of both Gram positive and Gram negative microorganisms in causing deep infections in open fractures has been clearly established, it is apparent that most open fractures require combined antibiotic therapy. A second-generation cephalosporin for 48 to 72 hours seems to be adequate prophylaxis for type-I open fractures. For grade-II and grade-III open fractures a combination of a second-generation cephalosporin with an aminoglycoside offers the best protection against most Gram-positive cocci and Gram-negative bacteria. The addition of penicillin G as a third antimicrobial agent is highly recommended for open fractures which have been exposed to soil or a farm environment and in injuries with a considerable crush component or vascular compromise. Antibiotic treatment for three days is appropriate since longer periods of therapy have not been shown to offer better protection and carry the risk of creating resistant bacterial strains.

Definitive treatment

The treatment of open fractures requires the simultaneous management of both skeletal and soft-tissue injury. These will be analysed separately, based on the evidence of the current literature.

Skeletal injury

Early stabilisation is of paramount importance and, ideally, should be performed at the time of the initial debridement. It restores alignment of the limb, eliminates gross movement at the site of the fracture, limits further soft-tissue damage and decreases the risk of further bacterial spread. It also improves blood flow and venous return in the limb and reduces post-traumatic oedema, pain and stiffness.

The types of fixation currently available are external fixators, plates and screws, and reamed and unreamed locking nails. External fixators were considered to be the preferred method for obtaining bone stability. The introduction of reamed locking nails was met with caution in case of an increase in complications, mainly in the form of infection and nonunion due to compromise of the cortical blood supply as a result of reaming. The advent of unreamed locking nails sparked new interest in nailing open fractures.

The development of biological techniques in plate fixation and the design of implants which cause the least possible interference with the periosteal blood supply have enhanced the use of plates and screws for stabilisation of even open tibial fractures.

We have undertaken a systematic analysis of the most significant publications on the treatment of open fractures of the tibia and femur in the last two decades in the English literature, focusing specifically on the outcome and complications. The criteria for inclusion were as follows:

1) The target population consisted of patients suffering from an open fracture of the tibial diaphysis either as a solitary injury or in polytrauma.
2) Stabilisation was by external fixation, intramedullary nailing (with or without reaming) or plates and screws.
3) All articles contained complete data regarding union (the primary outcome), rates of deep infection and re-operation.
4) The study described more than eight cases.

Manuscripts reviewing open metaphyseal tibial fractures, open intra-articular fractures of either end of the tibia or combined ipsilateral injuries of the femur and tibia (floating-knee injuries) were excluded. In total 30 studies were analysed.

Statistical analysis was performed using commercially-available computer software (SPSS 12.0.1, Chicago, Illinois). Parametric and non-parametric methods were employed as appropriate. One-way analysis of variance (ANOVA) and a post-hoc Tukey test were used to assess for statistically significant differences in continuous variables. Statistical significance was set at p < 0.05.

External fixation. A total of 13 papers dealt with the use of external fixation for the treatment of open tibial fractures. Among them there were four randomised, prospective studies comparing external fixation with unreamed locking nailing, one randomised, prospective study comparing external fixation with plates, one prospective cohort study and three retrospective case-control studies comparing external fixation with unreamed
A REVIEW OF THE MANAGEMENT OF OPEN FRACTURES OF THE TIBIA AND FEMUR

35,49,50 and four retrospective cohort studies.33,41-43 A total of 536 open tibial fractures were treated by external fixation of which 82% were grade-III open injuries. The timing of soft-tissue cover for the grade-III open fractures was recorded in nine papers, with a total of 405 fractures treated by external fixation.33,34,40-43,46-48

In all of these fractures soft-tissue cover was delayed for more than 72 hours. Union had occurred in 94% at a mean time of 37 weeks. Severe open tibial fractures often require repeated procedures in the form of soft-tissue cover, bone grafting, exchange nailing etc, in order to achieve union. Therefore, the time frames for union derived from the treatment of closed fractures are not applicable. The overall incidence of delayed union, namely after six months, was 24% as judged from eight papers with a total of 392 open tibial fractures with complete follow-up.34,40,41,44-46,48,49

The rate of failure of the implants was judged from four papers describing 149 open tibial fractures. Only four (2.7%) failures occurred.45-49 However, 68.5% of the above 536 fractures required at least one further operation before union was achieved. The rate of malunion with the use of external fixation was up to 20% in 458 fractures.22% of grade-III open tibial fractures treated by external fixation resulted in union in 95%, the rate of deep infection was 7% and 33% required further surgery. Bone grafting was necessary in 14.4%. Chronic osteomyelitis ensued in 0.7%.38,40,47,49,51-58 The rate of delayed union was 22%38,40,44-46,49,51,53-56,58 and of malunion 10%.38,40,44-47,51-53,55-59 The use of small, unreamed nails was associated with a significant incidence (12.4%) of fracture of the implant.38,45-47,49,51-53,55-59

Unreamed-intramedullary nails. We analysed 17 papers describing the use of unreamed nails in the treatment of open tibial fractures.38,40,44-47,49-59 There was a total of 666 fractures, 53% of which were grade III. There were four retrospective cohort studies,51,52,54,57 two retrospective case-control studies comparing external fixation with unreamed intramedullary nailing,49,50 five randomised prospective studies, four of which compared external fixation with unreamed nailing,40,44,46,47 one reamed versus unreamed nailing51 and six prospective cohort studies.38,45,53,56,58,59 The timing of soft-tissue cover for grade-III fractures, was documented in ten studies.30,45-47,51,54-58 Most grade-III open fractures (89%) were managed by delayed soft-tissue cover after the first 72 hours. The use of unreamed nails resulted in union in 95%, the rate of deep infection was 7% and 33% required further surgery. Bone grafting was necessary in 14.4%. Chronic osteomyelitis ensued in 0.7%.38,40,47,49,51-58 The rate of delayed union was 22%38,40,44-46,49,51,53-56,58 and of malunion 10%.38,40,44-47,51-53,55-59 The use of small, unreamed nails was associated with a significant incidence (12.4%) of fracture of the implant.38,45-47,49,51-53,55-59

External fixation versus unreamed nails. In order to delineate further the role of external fixation and unreamed locking nailing in the management of open tibial fractures, we performed a meta-analysis of randomised, prospective studies comparing directly these two methods of stabilisation. There were four studies, comprising 296 fractures, in the English literature.40,44,46,47 Three were randomised prospective trials comparing external fixation with modern unreamed intramedullary nailing40,46,47 and the other of external fixation with the use of Enders nails.44 There was no statistically significant difference between these two methods of stabilisation with respect to union, delayed union, deep infection and chronic osteomyelitis. The use of external fixation was associated with a statistically significant increased rate of malunion and further surgery whereas unreamed nailing showed a statistically significant increase in the rate of failure of the implant. The use of autologous bone graft was deemed to be necessary in 18.7% of the open fractures treated by unreamed nailing and in 34.6% of those treated by external fixation. This difference was statistically significant (p = 0.002). These results did not show any notable superiority of external fixation over unreamed nailing which would justify its use as a definitive treatment of these injuries. Even in grade-IIIB open tibial fractures unreamed nailing did not seem to alter the relative risk of nonunion or deep infection in comparison with external fixation.66

Reamed intramedullary nails. We identified four studies of the use of reamed intramedullary nails in the management of open tibial fractures.37,55,60,61 Two were retrospective cohort studies,60,61 one was a prospective study57 and the other was a randomised, prospective clinical trial.55 They described 187 fractures of which 43% were grade-III open injuries (IIIA, 16%; IIIB, 27%). Details regarding the handling of the soft-tissue envelope were available in three studies comprising a total of 80 fractures.37,55,60 Soft-tissue cover had been undertaken within the first 24 hours in 2.5% of the cases, at between 24 and 72 hours in 37.5% and in the remainder later than this. The overall rate of union was 97%, while in 15.5% of the cases bone-grafting procedures were required. The site of deep infection was estimated to be 6.4%, with only 0.75% of the open fractures eventually developing chronic osteomyelitis. Malunion was noted in 6%. In 31.6% at least one further procedure was required in order to achieve consolidation or to treat complications. The rate of failure of the implant was very low (3%), particularly in comparison with unreamed nailing.

Reamed versus unreamed nails. Only one prospective, randomised trial compared the effect of reamed versus unreamed nailing on the various outcomes of open tibial fracture.55 Another prospective, randomised study compared the effect of reamed versus unreamed intramedullary nailing on both closed and open tibial fractures but had excluded the more severe grades of open fracture,67 thereby limiting the value of their conclusions.

Keating et al.55 compared a group of 50 open tibial fractures treated by reamed nailing, including seven grade-IIIB fractures, with another group of 44 open tibial fractures including four grade-IIIB fractures treated by unreamed nailing. There was no statistically significant difference between the two groups with regard to the time to union, the rate of union, infection and the frequency of breakage of the nail. In the group treated without reaming, there
were significantly more broken screws (29%) than in the reamed group (9%). The functional outcome, in terms of knee pain, range of movement, return to work and recreational activity, did not differ significantly between the two groups.

**Reamed nails versus external fixation.** We could find no article comparing reamed intramedullary nailing with the use of external fixators. Bhandari et al\(^6\) carried out an indirect comparison between reamed intramedullary nails and external fixators from a number of prospective, randomised studies comparing external fixation with unreamed nailing and unreamed with reamed nailing. They concluded that the use of reamed nails significantly reduced the risk of re-operation when compared with external fixators but not that of deep infection or nonunion.

**External fixation and delayed reamed intramedullary nailing.** Some authors have proposed sequential management with initial external fixation followed by delayed reamed nailing, particularly for the treatment of type-III fractures, in the belief that immediate intramedullary nailing poses an increased risk of septic complications.\(^6,69\) Also, reamed intramedullary nailing, especially in polytrauma, has the risk of compromise of pulmonary function.\(^70\)

We identified four relevant publications.\(^67-70\) One of these was a prospective, randomised trial comparing external fixation followed by plaster with external fixation followed by reamed intramedullary nailing.\(^62\) The other three were retrospective cohort studies.\(^63-65\) Overall, there were 96 open tibial fractures, including 51 grade III, treated by external fixation followed by reamed intramedullary nailing.

All grade-III open fractures were managed by delayed soft-tissue cover. Autologous iliac bone graft was used in 17%. Union was achieved in 92% at a mean time of 38.5 weeks. In 23% at least one further procedure was required in order to obtain union or to treat serious complications. The mean duration of external fixation was 39 days. Pin-track infection occurred in 15.3% of cases. The mean time of conversion from external fixation to intramedullary nailing with reaming was 26 days, always after complete healing of the pin track and with a normal ESR. Despite this policy, the overall rate of deep infection was 17%, with 2.5% of cases developing chronic osteomyelitis. Three studies provided information regarding delayed union,\(^63-65\) which occurred in 14% and of malunion, which occurred in 11%.\(^62-64\)

The major concern is the spread of infection throughout the medullary canal. McGraw and Lim,\(^64\) in a series of 16 patients treated with this sequential protocol, found a high rate of complications including deep infection in seven (44%) and nonunion in five (31%). They suggested that this protocol should be abandoned. Maurer et al\(^65\) found a very strong association between previous pin-track infection and the development of deep infection after nailing. It is difficult to define an appropriate time interval between the removal of the pins and nailing which will allow for the host’s defence mechanisms to eradicate any residual bacteria from the pin sites. Some experimental data suggest that this should be for at least four weeks.\(^71\) In the series of McGraw and Lim\(^64\) the extended period of external fixation and the high incidence of pin-track infection would have contributed to the poor results. However, Antich-Adrover et al\(^62\) and Blachut et al\(^63\) were able to improve the results of this sequential protocol dramatically by limiting the duration of external fixation and the associated prevalence of pin-track infection.

### Table I. Summary of the outcomes of the various types of bone fixation in open fractures of the tibia

<table>
<thead>
<tr>
<th>Method</th>
<th>Union rate (%</th>
<th>Delayed union rate (%)</th>
<th>Malunion rate (%)</th>
<th>Infection rate (%)</th>
<th>Re-operation rate (%)</th>
<th>Bone graft rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External fixation</td>
<td>99</td>
<td>29,30,36-45</td>
<td>24</td>
<td>29,30,37,39,44</td>
<td>92</td>
<td>68</td>
</tr>
<tr>
<td>UTN(^*)</td>
<td>96</td>
<td>34,36,40-43,45-55</td>
<td>24</td>
<td>34,36,40-42,45,47,47,51,54</td>
<td>92</td>
<td>34,36,40-43,45-55</td>
</tr>
<tr>
<td>RTN(^†)</td>
<td>97</td>
<td>33,51,57,58</td>
<td>Not documented</td>
<td>33,51,57,58</td>
<td>64</td>
<td>33,51,57,58</td>
</tr>
<tr>
<td>External fixation and delayed</td>
<td>92-70</td>
<td>67-70</td>
<td>14</td>
<td>67-70</td>
<td>11</td>
<td>67-70</td>
</tr>
<tr>
<td>RTN(^†)</td>
<td>100</td>
<td>44</td>
<td>39</td>
<td>44</td>
<td>35</td>
<td>44</td>
</tr>
</tbody>
</table>

\(^*\) UTN, unreamed tibial nailings  
\(^†\) RTN, reamed tibial nailings
Table I summarises the most significant outcomes of open tibial fractures in regard to the type of fixation.

**Management of associated soft-tissue injury**

The management of the soft-tissue defect is of paramount importance. Thorough debridement and skeletal stabilisation are the mainstays of the initial treatment, with appropriate antibiotics and tetanus prophylaxis. Traditional teaching advocates delayed closure of the wound in open fractures in case of septic complications. Primary wound closure in open tibial fractures, particularly grade III, is hazardous but the optimal timing of soft-tissue cover is debatable. Cierny et al compared retrospectively a series of 24 grade-III open tibial fractures managed by early wound cover within seven days by either a muscle or myocutaneous flap, with another series of 12, grade-III open tibial fractures which had later cover at 8 to 30 days. Complications with the wound occurred in 20.8% of the early cover group and in 83.3% of those with late cover. Both infection and malunion were significantly lower in the early cover group (4% and 4%, respectively) in comparison with the late group (50% and 17%, respectively).

Caudle and Stern, focusing specifically on grade-IIIB open fractures, compared the rates of complications between two groups. In the first, 24 fractures, the exposed bone had been successfully covered by a local or distant muscle flap within the first week of injury, while in the second, 17 fractures, the open wound had not been successfully covered until more than one week after injury or had been allowed to heal by secondary intention. The first group had a rate of nonunion of 23% and of infection of 8%, while in those with late soft-tissue cover the figures were 77% and 59% respectively. Similar observations were recorded by Fischer et al. Patzakis and Wilkins reported that in 44% of infected open tibial fractures, the offending micro-organisms are acquired in hospital. The increasing incidence of resistant nosocomial infections and the financial burden of a policy of delayed soft-tissue cover have promoted a re-evaluation of the care of open fractures.

The advent of early microsurgical free-flap transfer for complex trauma of the limbs has been a valuable advance, helped by the shift from external to internal fixation which has facilitated microsurgical soft-tissue reconstruction. A radical ‘immediate’ or ‘very early fix and flap’ protocol has developed, based on a close collaboration between orthopaedic and microsurgical teams. A recent report on such management showed a rate of union of 100% although with delayed union in 62%, and of infection of 9.5%. The functional outcome of severe open grade-IIIB and grade-IIIC fractures treated by this aggressive approach has recently been published. The main drawback is the need for a joint orthopaedic and plastic surgery service, which is not feasible in many units, and the fact that major microsurgical procedures are contraindicated in patients with multiple injuries and hypovolaemic shock. Cole et al have proposed the use of local fasciocutaneous flaps for immediate cover of open fracture wounds. They described 50 open fractures, including 22 grade-IIIB, treated by thorough debridement and immediate local fasciocutaneous flap, followed by delayed, definitive stabilisation with unreamed interlocking nails. All fractures united at a mean of 26 weeks and only one required a bone graft. There was one deep infection (2%). The rate of re-operation was 40%, mostly for nail dynamisation. The authors attributed these favourable results to the immediate re-establishment of a physiological wound barrier, which played an instrumental role in preventing septic complications.

There is sufficient evidence to support a more aggressive approach to the open wound. While in less severe grades (I to IIIA) a secondary wound closure seems to yield the best results, in grade-IIIB and grade-IIIC fractures delayed wound care with repeated debridement and extended exposure of the deep structures results in additional tissue loss through desiccation and infection. In such cases, immediate or very early wound cover through microvascular free-flap transfer minimises the complications and improves the final outcome provided that appropriate facilities and expertise are available.

**Open tibial fractures and compartment syndromes**

A high index of suspicion should be maintained when treating open tibial fractures, since the presence of an open injury does not preclude the possibility of the development of a compartment syndrome. Bick et al, in a retrospective review of 198 open tibial fractures, found an incidence of accompanying compartment syndrome of 9.1%. There was a close association between the development of this complication and both the grades of the fracture and the degree of comminution; 83% of the fractures which developed a compartment syndrome were grade III, and 94% of them were moderately to highly comminuted (B2, B3, C2 and C3 by the AO classification). In patients with polytrauma early diagnosis of an impending compartment syndrome may be missed, since a closed-head injury, the need for intubation and prolonged anaesthesia can mask its clinical manifestation. Therefore, monitoring of the intercompartmental pressures in all unconscious and unco-operative patients suffering from a high-energy tibial fracture with a concomitant tense and swollen calf is mandatory for the prompt recognition and optimal management of the condition.

**Open fractures of the femoral shaft**

Open fractures of the femur are always the result of high-velocity injury and almost invariably associated, except for isolated gunshot injuries, with multiple trauma. Hence, the management of these serious injuries should follow the guidelines of the Advanced Trauma Life Support System and the principles of ‘damage control orthopaedics’. Although intramedullary nailing is currently considered to be the optimum method of treating closed femoral fractures, less consensus has been reached as to the best means of stabilisation of open fractures. Various methods of fixation have been used in the treatment of open femoral fractures. In order to assess the role of intramedullary...
nailing in the treatment of these fractures, we identified and analysed ten relevant reports in the English literature. All but one were retrospective studies. There was only one randomised, prospective trial, which compared immediate with delayed reamed nailing of open fractures of the femoral shaft. Overall, there were 525 open fractures and 521 had complete follow-up. The grade of open injury was documented in nine; grade I in 43%, grade II in 31% and grade III in 26%. The timing of stabilisation was recorded in nine papers describing 439 fractures; 79% were nailed primarily at the time of initial debridement and 21% later. The incidence of infection was 3% in the immediate nailing group and 5% in the delayed group (Fisher’s exact test, p = 0.54). The overall incidence of infection, derived from all ten papers, was 3.3% while the rate of union was 98%, at a mean time of 20 weeks. In 3% of the cases, iliac bone grafts were used to enhance healing.

Delayed union, defined as bone consolidation later than nine months, was observed in 2%, mainly in closed fractures treated by intramedullary nailing. Malunion, defined as a leg-length discrepancy of more than 2 cm, angular deformity in either the coronal or sagittal planes of more than 10˚ or rotational deformity in the transverse plane of more than 10˚, was seen in 6.5%. Secondary procedures such as bone grafting, exchange nailing or dynamisation were performed in 13.5% of the cases. Failure of the implant was seen in 1%, mainly in closed femoral fractures treated by intramedullary nailing. These papers suggest that early nailing of even grade-III open femoral fractures can be undertaken without additional risk of major complications in selected patients, based on the degree of soft-tissue disruption and contamination and the patients’ associated injuries.

Few papers describe the use of external fixators as definitive treatment of open fractures of the femur (Table II). Mohr et al treated 18 open fractures of the femur by external fixation. In 12 of these supplementary internal fixation was used in the form of interfragmentary screws, cerclage wires or short plates. The devices were retained until complete union at a mean of 5.5 months. No other means of supplementary fixation was used after removal of the fixators. However, Dabezies et al described 20 femoral fractures, 13 open, treated by the Wagner monolateral fixator for a mean of 3.5 months. After its removal, some form of protective immobilisation was used. The overall rate of union reached 100% with a rate of use of bone grafts of 13%. The rate of deep infection was 13.3% and of pin-track infection 15%. Malunion was seen in 23.3% of the cases. In five of 30 patients at least one secondary procedure was deemed to be necessary to obtain union or to treat complications, accounting for a rate of re-operation of 17%.

The use of external fixation resulted in loss of more than 10˚ of knee flexion in 26.7%. These results do not compare favourably with those for intramedullary nailing but external fixation is useful for interim fixation of severe open femoral fractures, particularly in polytrauma, with staged conversion to definitive intramedullary nailing at a more suitable time. External fixation can also provide reliable and expeditious stabilisation in group-IIIC injuries, allowing for a timely vascular repair, or in patients with associated unstable pelvic or spinal injuries, in which the use of standard fracture table for an ordinary nailing procedure is precluded.

The role for the plating of open femoral shaft fractures is also limited. Plates can be used as an alternative to external fixation in grade-IIIC open fractures and unstable pelvic or spinal injuries, which preclude the use of a fracture table.

The excellent results with reamed intramedullary nailing have been shadowed by concerns about the biological consequences of reaming and the increased risk of pulmonary complications or infection. This prompted the development of thin, solid nails which could be introduced without reaming. Several authors have described promising results with this type of nail.

We could not identify direct comparisons between reamed and unreamed nailing in open femoral fractures. However, there are a few randomised, prospective trials as well as retrospective comparisons of these two techniques, mainly in closed fractures. The results of these studies are summarised in Table III. Despite the apparent superiority of the reamed over the unreamed nails with regard to the healing time, there were no other statistically significant differences between these two techniques.

### Mangled lower limbs

Advances in microvascular techniques have allowed reliable repair of vascular and nerve injuries, which usually accompany severe open fractures of the lower limbs. In the early 1970s the introduction of free-flap transfer with microvascular techniques constituted a major advance in the treatment of open fractures with severe soft-tissue defects and limb ischaemia. Nevertheless, concerns have been raised as to whether a salvaged limb can always function better than a prosthesis. Hence, various scoring systems have been developed in an effort to determine reliably which limbs are salvageable.

| Table II. Outcomes of reamed femoral nails and external fixation in the treatment of open fractures of the femur |
|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Reamed femoral nails                              | External fixation                                | Union rate (%)                                    | Delayed union rate (%)                          | Malunion rate (%)          | Infection rate (%)          | Re-operation rate (%)          | Bone graft rate (%)    |
| 98.78-86                                         | 100.87,88                                       | 98.78-86                                         | Not reported                                   | 6.78-82,84,86                    | 3.87,88                      | 13.87,88                      | 48.78-82,84,86 |

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This is based on the recording of four variables in the patient admitted with severe injury to the lower limb: skeletal and soft-tissue injury, surgical shock, limb ischaemia, and the age of the patient. Each variable is graded on a numerical scale, ranging from 1 to 4 for the skeletal and soft-tissue injury group, 0 to 2 for surgical shock and age groups, and 0 to 3 for the limb ischaemia group. In a study by Helfet et al, a MESS score of 7 or higher had a predictive value of 100% for amputation. The predictive value of MESS has been challenged in another study since it was found to lack sensitivity. Even with the use of the available scoring systems, the decision as to whether to perform a limb-salvage operation rather than amputation in severe open fractures, is not an easy one. Such a decision should involve at least two senior surgeons experienced in modern techniques of limb-salvage.

The LEAP study, a multicentre, prospective, observational study, found that reconstruction and limb salvage typically result in two-year outcomes equivalent to those of amputation for high-energy injuries (Gustilo grade-IIB and grade-IIIIC fractures) below the distal femur. Interestingly, there was no significant difference in the scores on the sickness impact profile between the patients who had an above-knee and those with a below-knee amputation. Patients treated by a through-knee amputation had worse regression-adjusted sickness impact profile scores and slower self-selected walking speeds than those with a below-knee or above-knee amputation. At a follow-up at seven-years, MacKenzie and Bosse found that patients who reported low self-efficacy, weak social support, and high levels of depression, anxiety, and pain were significantly more likely to have poor outcomes.

McCarthy et al reported severe psychological distress after severe injury to the lower limb. Of their patients, 42% screened positive for a likely psychological disorder at 24 months after injury. Factors associated with a psychological disorder were poorer physical function, younger age, non-white race, poverty, a probable drinking problem, neuroticism, a poor sense of self-efficacy, and limited social support.

Table III. Outcomes of reamed versus unreamed nails in fractures of the femur

<table>
<thead>
<tr>
<th></th>
<th>Clatworthy et al103</th>
<th>The Canadian Orthopaedic Trauma Society104</th>
<th>Giannoudis et al105</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Reamed</td>
<td>Unreamed</td>
<td>Reamed</td>
</tr>
<tr>
<td>Fractures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open fractures</td>
<td>22</td>
<td>23</td>
<td>121</td>
</tr>
<tr>
<td>Union rate</td>
<td>100</td>
<td>100</td>
<td>98.3</td>
</tr>
<tr>
<td>Mean time to union</td>
<td>28.5 wks</td>
<td>39.4 wks</td>
<td>Not reported</td>
</tr>
<tr>
<td>p</td>
<td>0.007</td>
<td></td>
<td>0.049</td>
</tr>
<tr>
<td>Delayed union rate</td>
<td>57</td>
<td>18</td>
<td>Not reported</td>
</tr>
<tr>
<td>Implant failure rate</td>
<td>13.6 (3 fr: 1 open, 2 closed)</td>
<td>13 (3 fr: 2 open, 1 closed)</td>
<td>Not reported</td>
</tr>
<tr>
<td>Re-op rate</td>
<td>13.6</td>
<td>43.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Infection rate</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not stated in each group (1 out of 228 fr)</td>
</tr>
</tbody>
</table>

References


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