The treatment of open femoral fractures with bone loss

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The results of the treatment of 31 open femoral fractures (29 patients) with significant bone loss in a single trauma unit were reviewed. A protocol of early soft-tissue and bony debridement was followed by skeletal stabilisation using a locked intramedullary nail or a dynamic condylar plate for diaphyseal and metaphyseal fractures respectively. Soft-tissue closure was obtained within 48 hours then followed, if required, by elective bone grafting with or without exchange nailing.

The mean time to union was 51 weeks (20 to 156). The time to union and functional outcome were largely dependent upon the location and extent of the bone loss. It was achieved more rapidly in fractures with wedge defects than in those with segmental bone loss. Fractures with metaphyseal defects healed more rapidly than those of comparable size in the diaphysis. Complications were more common in fractures with greater bone loss, and included stiffness of the knee, malunion and limb-length discrepancy.

Based on our findings, we have produced an algorithm for the treatment of these injuries. We conclude that satisfactory results can be achieved in most femoral fractures with bone loss using initial debridement and skeletal stabilisation to maintain length, with further procedures as required.

Open femoral fractures are uncommon and there are few reports which refer specifically to their management. Although they are usually the result of high-energy trauma and are often associated with considerable comminution, bone loss is infrequent. However, in a minority it can occur either at the time of the original injury or as part of subsequent debridement.

The surgical treatments available to manage this bone loss include exchange nailing, bone grafting, bone transport and femoral shortening, with or without subsequent lengthening. Standardisation of treatment is difficult because of the considerable variation in soft-tissue and bony injury, and there are currently no published guidelines regarding the role of the various options. The aim of this study was to analyse the results of treatment of open femoral fractures with bone defects in order to define a treatment protocol for their management.

Patients and Methods

Between January 1988 and September 2008, a consecutive series of 2071 femoral fractures (subtrochanteric, diaphyseal and distal metaphyseal) were treated in our unit. There were 153 (7.4%) open fractures. Details of all patients were recorded prospectively on a trauma database. For the purposes of this study, we reviewed all open fractures with significant bone defects, which we defined as a segmental or wedge defect > 2 cm either at the time of injury or following debridement. We excluded those with small, devitalised fragments removed at debridement. This left a series of 47 fractures (2.3% of all femoral fractures and 30.7% of open femoral fractures) with a significant bone defect.

A total of 16 fractures were excluded. Of these, six patients (seven fractures) died of multiple injuries within the first six hours of injury. Four multiple trauma patients (five fractures) died from other injuries within seven days of admission and three patients (four fractures) with severe Gustilo grade IIIC injuries were treated by primary above-knee amputation, bilateral in one patient.

This study comprised the remaining 31 fractures in 29 patients (23 male, six female) with a mean age of 35.5 years (14 to 71). Road-traffic accidents were the cause of the fracture in 24 patients and falls from a height in five. Multiple injuries (an Injury Severity Score ≥ 16) were present in 17 patients (19 fractures, 61%). There were additional orthopaedic injuries in
22 patients (75.9%) and in six of these (21%), there was an open or closed contralateral femoral fracture.

All wounds were graded at the time of debridement according to Gustilo and Anderson.8,9 There were 14 grade IIIA and 15 grade IIIB fractures. Two patients with grade IIIC fractures underwent successful vascular reconstruction.

The morphology of the fracture at presentation was assessed using the AO classification12 (Table I). All but one fracture presented with moderate to severe comminution (grade III or IV) according to the Winquist-Hansen grading system.13

The fractures were managed routinely with a thorough soft-tissue and bone debridement along with 9 l of saline lavage. All devitalised bone fragments were removed and a careful individual confirmation was made of the vascularity of all surrounding soft tissue and remaining bone. The protocol for treating the bone defects was based on restoration of femoral length and immediate, stable internal fixation. Diaphyseal fractures were stabilised using a reamed locked Grosse-Kempf intramedullary nail (Howmedica, Rutherford, New Jersey). The nailing was carried out on a fracture table, using an antegrade technique in 16 cases. A Gamma3 cephalomedullary nail (Stryker Osteosynthesis, Stryker Corporation, Geneva, Switzerland) was used in one patient with an ipsilateral fracture of the femoral neck. Another patient with a distal diaphyseal fracture and metaphyseal comminution underwent fixation with a dynamic condylar plate. In order to prevent damage to the exposed soft tissues, reaming was not undertaken when passing through areas of bone loss. Static locking was used to maintain femoral length. In one case with 3 cm sequential loss femoral shortening was performed at the time of initial intramedullary nailing.

Distal metaphyseal fractures which were not amenable to nailing, either because of their proximity to the knee joint or articular involvement, were stabilised using a dynamic condylar plate14 (Institut Straumann AG, Walden-berg, Switzerland). One of these patients had life-threatening injuries elsewhere and was provisionally stabilised with a transarticular external fixator, which was converted to a dynamic condylar plate within 48 hours of presentation.

### Table I. Outline of all fractures, treatment and time to union

<table>
<thead>
<tr>
<th>Fracture</th>
<th>AO classification12</th>
<th>Type</th>
<th>Site</th>
<th>Defect size (cm)</th>
<th>Fixation*</th>
<th>Secondary procedures†</th>
<th>Time to union (weeks)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>32b3.2</td>
<td>Wedge</td>
<td>Diaphyseal</td>
<td>5</td>
<td>GK nail</td>
<td>BG + XN 20, 32 weeks</td>
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<td>Wedge</td>
<td>Diaphyseal</td>
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<td>GK nail</td>
<td>BG 8 weeks</td>
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<td>32c2.1</td>
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<td>Diaphyseal</td>
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<td>GK nail</td>
<td>XN 20, BG 28 weeks</td>
<td>52</td>
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<tr>
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<td>Wedge</td>
<td>Diaphyseal</td>
<td>3</td>
<td>GK nail</td>
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<tr>
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<td></td>
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<td>Gamma nail</td>
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<td>DCS</td>
<td></td>
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<td>Metaphyseal</td>
<td>4</td>
<td>DCS</td>
<td></td>
<td>33</td>
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<td>DCS</td>
<td></td>
<td>33</td>
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<td>Ex-fix then DCS</td>
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<td>GK nail</td>
<td>XN 20, XN 45 weeks</td>
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<td>GK nail</td>
<td>XN + BG 14 weeks</td>
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<td>DCS</td>
<td>XN + BG 44, 52 weeks</td>
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<td>BG 10 weeks</td>
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<td>BG 6, 8, 20 weeks, shorten + transport</td>
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<td>Ex-fix then DCS</td>
<td>Ex-fix then DCS, BG 6 weeks, osteotomy</td>
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<td>5, 20 weeks</td>
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<td>Change DCS 5, 20 weeks + ISKD lengthening</td>
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</tbody>
</table>

* GK, Grosse-Kempf (Howmedica); DCS, dynamic condylar screw; Ex-fix, external fixator
† BG, autogenous open bone graft; XN, exchange nail; ISKD, intramedullary skeletal kinetic distractor (Orthofix)
once physiological stability was restored. Two patients underwent intramedullary nailing on a fracture table using a retrograde technique with an adjuvant condylar screw fixation. Another had definitive fixation using a unilateral external fixator with bone transport.

In all cases, the aim was to restore the pre-injury length and alignment. The contralateral femur was used to judge correct length and rotation. In patients with bilateral fractures, the less comminuted fracture was used as the control.

Broad-spectrum antibiotic prophylaxis was given for 48 hours. All wounds were left open primarily and re-inspected within 48 hours. If they were satisfactory, soft-tissue cover was completed with the method being determined by the site and severity of the wound. Wound cover was obtained by delayed closure in 25 cases, split-skin grafting in five and a local flap in one. If other injuries permitted, the patients were mobilised touch weight-bearing once the state of the soft tissues was satisfactory. Early active hip and knee joint movements were encouraged as soon as possible, depending on the severity of other injuries.

The amount of bone loss was measured radiologically and at the time of the initial operation. The defects were either wedge-shaped with a degree of residual cortical contact between the fracture ends, or circumferential, with no residual cortical contact. The greatest length of bone loss was recorded. A decision regarding the form and timing of surgery were prospectively recorded and the case was 98 weeks (52 to 262). Complications requiring further surgery were treated expectantly, as all showed early signs of filling in with new bone when assessed at six weeks. Only three required further surgery and all united.

The mean time to union for the five fractures with smaller defects was 33.6 weeks (16 to 58). Four fractures united at 28 weeks, achieving union at 52 weeks. Another with a wedge defect of 5 cm was treated by open bone grafting on two separate occasions, and also went on to union at 52 weeks.

Two patients with leg-length discrepancies of 2 cm and 2.5 cm at follow-up declined further surgery and were treated with a shoe insert. There were no other complications in this sub-group.

Six distal metaphyseal fractures (fractures 9 to 14 in Table I) had wedge defects measuring between 2 cm and 4 cm (Fig. 1). All united without further intervention at a mean of 30.8 weeks (24 to 39). One healed with a varus malunion of 12° and did not undergo treatment for this. There were no other complications in this sub-group.

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Results

There were 18 diaphyseal fractures and 13 distal femoral metaphyseal fractures with significant bone loss comprising 14 wedge and 17 segmental defects. The mean length of the wedge defects was 3.4 cm (2 to 6) and of the segmental defects it was 5.8 cm (3 to 11). All fractures united eventually at a mean of 51 weeks (16 to 156). The mean time to union was skewed by a small number of fractures requiring prolonged and complex treatment. The median time to union was less, at 34 weeks (Table I).

Wedge defects. The 14 fractures with wedge defects were treated expectantly, as all showed early signs of filling in with new bone when assessed at six weeks. Only three required further surgery and all united.

All eight of the fractures with diaphyseal wedge defects (fractures 1 to 8 in Table I) eventually united with a mean time to union of 40.5 weeks (26 to 64). The five fractures which healed without intervention achieved union at a mean of 38.8 weeks (31 to 64). One fracture with a wedge defect of 3 cm and no evidence of union by 18 weeks was treated by exchange nailing at 20 weeks and open bone grafting at 28 weeks, achieving union at 52 weeks. Another with a wedge defect of 5 cm was treated by open bone grafting on two separate occasions, and also went on to union at 52 weeks.

Two patients with leg-length discrepancies of 2 cm and 2.5 cm at follow-up declined further surgery and were treated with a shoe insert. There were no other complications in this sub-group.

Segmental defects. Ten diaphyseal fractures (fractures 15 to 24 in Table I) had segmental defects. Due to the wide range in size of the defect they were subdivided into those with smaller defects < 6 cm (3 to 4), and larger defects > 6 cm (6 to 8).

The mean time to union for the five fractures with smaller defects was 33.6 weeks (16 to 58). Four fractures united without further intervention after the initial fixation, and one underwent elective bone grafting at three weeks.

The five patients with larger segmental defects united at a mean of 93.6 weeks (20 to 156). One with a concomitant head injury produced marked callus and had solid bony union across a 6 cm defect by 20 weeks, without needing a secondary procedure. He also had an associated open patellar fracture with bone loss, which required patellectomy, and severe residual stiffness of the knee with
a range of movement from 15° to 80°. The remaining four patients with large diaphyseal segmental defects showed no evidence of spontaneous union and underwent planned secondary exchange nailing with open bone grafting. One of these fractures with a 6 cm defect united at 36 weeks (Fig. 2). One fracture with an 8 cm defect required two exchange nailing and bone grafting operations and another with a similar defect required three procedures to achieve union. Both fractures healed at 156 and 120 weeks respectively. The final patient with a 7 cm defect had bone grafting, then exchange nailing with secondary shortening following a minimal response to the initial bone grafting operation. Once union was achieved at 136 weeks, the bone was lengthened using a unilateral external fixator over an intramedullary nail.

Two patients in this group ultimately had a significant leg-length discrepancy of 2 cm and 3 cm, and two patients had persistent stiffness of the knee, with flexion deformities of 5° and 15° and flexion to 130° and 100° respectively. There were no other complications in this sub-group.

There were seven distal femoral metaphyseal segmental defects (fractures 25 to 31 in Table I), with a mean bone loss of 6.6 cm (3 to 11). Six fractures underwent autogenous bone grafting between six and 12 weeks post-injury. Four of these fractures united at a mean of 51 weeks (20 to 99). One with the largest metaphyseal defect, measuring 11 cm, failed to unite following the initial bone grafting procedure and required shortening and bone transport, using a unilateral external fixator. The fracture eventually united at 88 weeks. The other patient, with a 5 cm defect and treated initially with a dynamic condylar plate, underwent debridement on two occasions with shortening of the femur and exchange of the plate at five and 20 weeks for infected nonunion. Proximal osteotomy and bone transport was later performed over an Intramedullary Skeletal Kinetic Distractor nail (Orthofix Inc., McKinney, Texas), with union of both the fracture and lengthening at 106 weeks.

Two patients had a residual leg-length discrepancy of 1 cm and 2.5 cm, respectively. One healed with varus malunion of 25° which was corrected by a valgus osteotomy. Three patients had stiff knees with a flexion deformity of between 5° and 10° and flexion to between 120° and 130°. Two of these have undergone successful quadricepsplasty.

Discussion

Our results indicate that wedge defects in the distal femoral metaphysis had a relatively good prognosis, with the shortest mean time to union and no requirement for further surgery. Conversely, large diaphyseal segmental defects of > 6 cm were much more difficult to treat and were associated with prolonged times to union. These defects had a greater requirement for further operations, with exchange nailing and bone grafting needed on at least one occasion for each fracture. Segmental defects in the metaphysis tended to be more extensive than in the diaphysis. Despite this, they healed more rapidly than diaphyseal defects of a similar size. This is probably related to a better blood supply and greater osteogenic potential in this area.

Diaphyseal segmental defects ≤ 6 cm also have a relatively good prognosis and the majority united after primary intramedullary nailing. Diaphyseal wedge defects and metaphyseal segmental defects had a less consistent prognosis, and the varied requirement for further bony procedures made it difficult to draw firm conclusions regarding their management.

Our results indicate that most open femoral fractures with bone loss can be managed successfully with adequate initial debridement and preservation of the pre-injury length with conventional internal fixation. Autogenous bone grafting, with adjuvant exchange nailing for diaphyseal fractures can
be performed to secure union if radiographs do not show callus formation at 12 weeks, without resorting to more complex techniques. Based on our results we have developed an algorithm for the management of these injuries (Fig. 3).

Our large consecutive series of prospectively collected and documented patients is a major strength of this study. Although the patients were not all treated by the same surgeon, the management protocol for these injuries was...
unchanged throughout. The low incidence of open femoral fractures with bone loss imposes some limitations on the study design. Our series was accumulated over a 20-year period and the treatment options during the earlier years would have been limited, as modern techniques of bone lengthening and transport were not available then. In particular, circular frames and intramedullary lengthening nails were not in routine use during the early years of the study.

Over three times the number of open femoral fractures were seen in the ten-year period from 1988 to 1997 (24 fractures), compared with 1998 to 2008 (seven). As motor vehicle accidents were the cause in over 80% of fractures (26 of 31), we can assume this decrease is due to the heightened awareness of road safety and improved safety features in motor vehicles, not least the introduction of seat belt regulations in 1993.

All the open fractures with bone loss in our series were a consequence of blunt trauma with bone loss occurring at injury or debridement. There were no gunshot injuries. We believe the prognosis would be significantly different for bone loss incurred in this way,15,16 therefore our findings should not be extrapolated to predict the outcome in gunshot injuries.

The largest studies of open femoral fractures involved the use of reamed locked intramedullary nails, with low complication rates,1-7 but the management of bone loss has received little attention. In two studies,1,2 seven patients had bone grafts for segmental defects, with union being achieved successfully. Lhowe and Hansen1 reported three patients out of 67 (4.5%) with open femoral fractures who required autogenous bone grafting and nailing and Brumback et al2 described four similar patients treated with the same techniques. All of their cases went on to union.

Two later studies3,4 described six cases of nonunion, which were all successfully managed with bone grafting, with or without exchange nailing, although this was not specifically for bone loss. The main focus of all these studies has been on the risk of infection and incidence of union in open femoral fractures and none specifically address the issue of bone loss.1-7

Alternative strategies for fixation can be used. Studies of external fixation17-20 and plating of open femoral diaphyseal fractures21,22 are characterised by small numbers and insufficient detail to determine the prognosis for patients with bone loss. Although the Ilizarov technique has been described for defects of the tibia,23 its role in the treatment of femoral defects is not as well defined.24,25 The use of circular frames to treat skeletal defects in the femoral diaphysis is difficult due to the bulk of the thigh, the cumbersome nature of the frame and poor patient acceptance. They may be more applicable to defects in the distal femoral metaphysis. Prolonged treatment can be expected and we feel that the use of internal fixation with intramedullary nailing for diaphyseal defects, and the dynamic condylar plate for distal metaphyseal defects, offers considerable practical advantages over conventional unilateral or fine-wire external fixation. These include ease of access for secondary soft-tissue and bony procedures, reduced rates of malunion, sepsis and late re-fracture, with better patient tolerance.

Newer techniques of lengthening with an intramedullary device are available and more suited to the management of femoral bone loss, as well as being ideal for lengthening the post-traumatic shortened femur. An alternative approach to that of our study is to shorten the femur initially to facilitate union and opt for later lengthening with one of these implants, such as the Intramedullary Skeletal Kinetic Distactor (Orthofix). This has been shown to give good outcomes in femoral lengthening for post-traumatic and congenital shortening.26 Although its use in one of our patients was successful, there is very limited data recommending its use in the acute management of open femoral fractures with bone loss.

We feel that satisfactory results can be achieved in most of these injuries using the principles of thorough initial debridement, stable internal fixation with restoration of leg-length and early soft-tissue cover. This is followed later, if required, by planned secondary bone grafting with or without exchange nailing, according to the size and location of the skeletal defect. The management of complex segmental diaphyseal defects of ≥ 6 cm is likely to be difficult and there may be a role for elective acute shortening with a subsequent lengthening procedure.

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


