‘Modern’ distal femoral locking plates allow safe, early weight-bearing with a high rate of union and low rate of failure

FIVE-YEAR EXPERIENCE FROM A UNITED KINGDOM MAJOR TRAUMA CENTRE

Aims

Fractures of the distal femur can be challenging to manage and are on the increase in the elderly osteoporotic population. Management with casting or bracing can unacceptably limit a patient’s ability to bear weight, but historically, operative fixation has been associated with a high rate of re-operation. In this study, we describe the outcomes of fixation using modern implants within a strategy of early return to function.

Patients and Methods

All patients treated at our centre with lateral distal femoral locking plates (LDFLP) between 2009 and 2014 were identified. Fracture classification and operative information including weight-bearing status, rates of union, re-operation, failure of implants and mortality rate, were recorded.

Results

A total of 127 fractures were identified in 122 patients. The mean age was 72.8 years (16 to 101) and 92 of the patients (75%) were female. A consultant performed the operation in 85 of the cases, (67%) with the remainder performed under direct consultant supervision. In total 107 patients (84%) were allowed to bear full weight immediately. The rate of clinical and radiological union was 81/85 (95%) and only four fractures of 127 (3%) fractures required re-operation for failure of surgery. The 30-day, three- and 12-month mortality rates were 6 (5%), 17 (15%) and 25 (22%), respectively.

Conclusion

Our study suggests an exponential increase in the incidence of a fracture of the distal femur with age, analogous to the population suffering from a proximal femoral fracture. Allowing immediate unrestricted weight-bearing after LDFLP fixation in these elderly patients was not associated with failure of fixation. There was a high rate of union and low rate of re-operation.

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Non-operative treatment of fractures of the distal femur often results in inadequate reduction of the injury and loss of weight-bearing capacity and mobility, while surgical treatment has been associated with high rates of re-operation for failure of fixation and nonunion.1-3 Fractures of the distal femur (Arbeitsgemeinschaft für Osteosynthesefragen (AO) type-33)4 accounted for 0.4% of fractures occurring each year in a United Kingdom cohort study.5 A bimodal distribution has been reported,6 but increasingly this is as an osteoporotic fracture occurring most commonly in elderly women.7 Although distal femoral fractures are much less common than their proximal counterparts, accounting for just 3% to 6% of all femoral fractures,5,6 there are demographic parallels between the two. Both groups have high rates of intercurrent health problems, and it has been suggested that fractures of the distal femur should be treated to similar standards of care as proximal fractures.7,8 While these fractures are most commonly surgically treated by plate osteosynthesis or intramedullary nailing (IMN), other reconstructive options include complex primary arthroplasty and external fixation. Plating techniques have evolved from blade and dynamic condylar plates to pre-contoured locking plates, with designs refined over several generations.9 Such plates have been in use in our major trauma centre for more than five years, as part of a treatment strategy driven by early weight-bearing
and mobility. In this retrospective analysis, we describe the population and clinical and radiological outcomes of surgery.

**Patients and Methods**

The project was registered locally as a service evaluation and required no further institutional review. Our clinical database (Bluespier, Droitwich, United Kingdom), containing details of all patients referred to the on-call orthopaedic team, was examined to identify all patients undergoing fracture fixation with lateral distal femoral locking plates (LDFLP) between November 2009 and November 2014. Within this system, electronically recorded operation notes were reviewed and patient demographics and details of surgery recorded. Skeletally immature patients and those undergoing treatment for complications of primary surgery undertaken elsewhere were excluded.

Using a Picture Archiving and Communication System (Phillips IntelliSpace PACS, Guildford, United Kingdom), intra-operative fluoroscopy and pre- and post-operative radiographs were reviewed to determine fracture pattern and plate and screw configuration. Each radiograph was assessed by consensus including at least two senior trainees (WECP, DGGW, HCG, SFB, RF). Where disagreement occurred, a third opinion was sought from a senior author (EG, SGN). The final outcome was determined to be one of fracture healing problems had occurred, had required any re-operations for any reason, and whether they could bear weight on the limb without discomfort or deformity.

We identified 105 AO type-33 fractures recorded on our system, and a further 22 type-32 distal diaphyseal femoral fractures treated by the same strategy. All fractures were fixed with either the 4.5 mm Variable angle locking compression plate (VA-LCP) Curved Condylar Plating System (Synthes, West Chester, Pennsylvania) or the 4.5 mm Peri-Loc Distal Femur Locking Plate System (Smith & Nephew, Andover, Massachusetts). In all, ten patients managed by retrograde intramedullary nailing (RIMN) were excluded. As all patients admitted with these fractures are discussed at our trauma review, no patients would have been omitted from the database or treated non-operatively.

The mean age of our patients was 72.8 years (16 to 101), with just 14 fractures (11%) occurring in patients under the age of 50 years. The latter group appeared to represent a separate fracture population with approximately ten times the rate of open fracture and four times the rate of intra-articular fracture compared with patients aged 50 years and over (Table I).

A total of 97 fractures (75%) occurred in female patients. Most patients had significant medical comorbidity, with 74 (61%) recorded as American Society of Anaesthesiologists (ASA) grade III or above (ASA I, 11 (9%); ASA II, 37 (30%); ASA III, 66 (54%); ASA IV, 8 (7%)).

**Statistical analysis.** Age-adjusted relative incidence was estimated using local population demographics.

**Results**

The age distribution of our patients appeared to be bimodal with a smaller distinct group of young patients contrasting with a much larger older group. Only 14 fractures occurred in patients under 50 years old. However, among the younger group the incidence of intra-articular fractures was four times higher and the incidence of open fracture was ten times as frequent. The age-related relative risk for this fracture is shown in Figure 1.

Of the 127 fractures, 11 were open with primary closure possible in nine, and two required delayed closure with a

<table>
<thead>
<tr>
<th>Fracture characteristics by patient age</th>
<th>Age group yrs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under 50</td>
<td>Over 50</td>
</tr>
<tr>
<td>Number of fractures (%)</td>
<td>14 (11)</td>
<td>113 (89)</td>
</tr>
<tr>
<td>Open fractures (%)</td>
<td>6 (42)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Intra-articular (%)</td>
<td>7 (60)</td>
<td>13 (12)</td>
</tr>
<tr>
<td>Periprosthetic (%)</td>
<td>0 (0)</td>
<td>71 (63)</td>
</tr>
<tr>
<td>American Society of Anaesthesiologists grade III or IV (%)</td>
<td>2 (14)</td>
<td>72 (64)</td>
</tr>
</tbody>
</table>
local flap. Three open fractures were temporarily stabilised with external fixators and definitively fixed with LDFLP. Table II\textsuperscript{12} further demonstrates the fracture characteristics.

A consultant performed the operation in 85 of 127 of the cases (67%). The remainder were supervised by a consultant or performed by a senior trauma fellow.

The most commonly used plate length was 14 holes, with a median of six locking screws distal to the fracture (4 to 9). The average working length (the distance between closest screw above and below the fracture) was five screw holes. In seven fractures (6%), the proximal fixation was supplemented with either cerclage cables, a periprosthetic locking attachment plate or both.

In 107 of 127 fractures (84%), patients were permitted to bear full weight as tolerated immediately. No patients had primary bone grafting or cement augmentation or underwent dual plating in their primary fixation. Outcomes. Four fractures (3%) required re-operation for loss of fixation prior to union.

Two further fractures (2%) underwent re-operation for infection but revision fixation was not required. The metalwork was retained until union in both cases but

\*Gustilo open fracture classification\textsuperscript{12}

AO, Arbeitsgemeinschaft für Osteosynthesefragen; THA, total hip arthroplasty; DHS, dynamic hip screw; TKA, total knee arthroplasty; IMN, intramedullary nailing

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<table>
<thead>
<tr>
<th>Fracture characteristics</th>
<th>n (%)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphyseal (AO type-32)</td>
<td>22 (17)</td>
<td>18 (14)</td>
</tr>
<tr>
<td>Periprosthetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No prosthesis</td>
<td>4 (3)</td>
<td></td>
</tr>
<tr>
<td>Extra-articular distal metaphyseal</td>
<td>85 (67)</td>
<td>52 (41)</td>
</tr>
<tr>
<td>Periprosthetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No prosthesis</td>
<td>33 (26)</td>
<td></td>
</tr>
<tr>
<td>Intra-articular distal metaphyseal</td>
<td>20 (16)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>AO type-33B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AO type-33C</td>
<td>16 (12)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>127 (100)</td>
<td></td>
</tr>
<tr>
<td>Periprosthetic fractures</td>
<td>71 (86)</td>
<td>15 (12)</td>
</tr>
<tr>
<td>Below THA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below short IMN</td>
<td>3 (2)</td>
<td></td>
</tr>
<tr>
<td>Below DHS</td>
<td>2 (1)</td>
<td></td>
</tr>
<tr>
<td>Above TKA</td>
<td>36 (28)</td>
<td></td>
</tr>
<tr>
<td>Interprosthetic</td>
<td>15 (12)</td>
<td></td>
</tr>
<tr>
<td>Open fractures – Gustilo Grade</td>
<td>11 (9)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Grade I\textsuperscript{*}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade II</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Grade IIIa</td>
<td>5 (4)</td>
<td></td>
</tr>
<tr>
<td>Grade IIIb</td>
<td>1 (1)</td>
<td></td>
</tr>
<tr>
<td>Grade IIIc</td>
<td>1 (1)</td>
<td></td>
</tr>
</tbody>
</table>

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\*Gustilo open fracture classification\textsuperscript{12}

Graph showing relative incidence of fractures of the distal femur, adjusted for age demographics of the local population.
subsequently removed in one. Table III provides further information for the cases of failure.

Excluding patients who died (n = 34) during the study period prior to union or who were lost to follow-up (n = 6), our rate of clinical and radiographic union was 95% (81 of 85 fractures). Two of the four fractures which failed to unite after the initial surgery achieved union after revision fixation at between seven and 12 months. One patient died during follow-up, the other underwent complex knee arthroplasty with a linked prosthesis.

A total of 59 fractures (46%) with complete radiographs available had radiological union at a mean of seven months (3 to 14) after primary fixation without re-operation. Further outpatient review was not possible for 22 patients (17%) with fractures. Telephone follow-up at a mean of 31 months (9 to 45) confirmed satisfactory clinical outcomes. These fractures were deemed to have united.

In all, 34 fractures (27%) occurred in 34 patients who subsequently died without radiographic evidence of union. None of these patients had required re-operation. Satisfactory reduction and stable fixation was noted on the last radiographs prior to death.

Six patients (5%) each with unilateral fractures were lost to follow-up prior to union but have not re-presented to our unit with complications, and had satisfactory fixation and reduction on last available radiographs. Five of these patients are known to live abroad, and were repatriated to follow-up prior to union but have not re-presented to our unit with complications, and had satisfactory fixation and reduction on last available radiographs. Five of these patients are known to live abroad, and were repatriated.

After successful union, six patients (5%) had symptomatic metalwork removed. A further three patients (2%) underwent re-operation for a fracture above the femoral plate, all after successful union of the primary fracture.

Excluding the six patients lost to follow-up, 42 (of 116 patients, 36%) died within the follow-up period. The cumulative 30-day, three-month and 12-month rates of mortality were 6 (5%), 17 (15%) and 25 (22%), respectively.

Discussion
Demographics. Our study data suggest an exponential increase in the incidence of distal femoral fractures in the elderly, echoing recent literature. In the 11% of fractures occurring in patients under the age of 50 years, there were much higher rates of open and intra-articular fracture. This implies a higher energy transfer, and hence different pattern of injury to that seen in the older patients who are more likely to suffer from osteoporosis. Although fixation was equally successful in both younger and older subgroups, the small number of patients in the younger group means that the low rates of failure must be interpreted with some caution.

This estimate of relative incidence assumes that no non-operatively treated fractures were missed and equates our catchment population to our local population. In fact, our catchment population for high-energy fractures in young patients extends beyond our local population of this age group, as we receive direct transfer in our capacity as a major trauma centre. In contrast, older patients with isolated low-energy fractures of the distal femur will tend to be treated at their local district general hospital. Despite our larger catchment population for young high-energy injuries, we observed an apparent exponential increase in relative incidence with age.

Technical considerations. In patients with a small distal articular block of bone, pre-operative CT scans were undertaken. Plate fixation was achievable in all cases, with the design of the plate allowing at least four screws distally in all fracture patterns. It was not necessary to refer any patient for primary arthroplasty and cut-out of screws from the distal articular fragment was not witnessed. In periprosthetic fractures, the intact cement mantle of the knee or hip arthroplasty was noted to provide excellent purchase for screws (Fig. 2).

Fixation constructs with a short working length can result in excessive stiffness with inadequate strain to allow secondary bone healing, and also results in a concentration of strain that can result in breakage of the plate. Three of our four surgical failures were seen when a plate with 12 or fewer holes was used to fix a fracture with a working length of three or four holes. In contrast, there was only one failure in the 95 fractures where a plate with 13 holes or more was used. This failure was in a 16-hole VA-Condylar plate (Synthes, West Chester, Pennslyvania) which was inserted with an unusually long working length of eight holes. Overall, the small number of failures means that definite conclusions cannot be drawn from these findings. Long plates also reduce the risk of a secondary fracture above them, a complication that occurred in three of our patients after successful union of the primary fracture.
Learning from this, we adapted our technique to the use of a plate extending as far proximally as the greater trochanter. The proximal end of the plate can be bent laterally to accommodate the greater trochanteric flare, allowing locking screws to be directed into the femoral neck and thereby affording whole-bone fixation analogous to a cephalomedullary nail.

Most patients were allowed to bear weight as tolerated in the immediate post-operative period, increasingly so that our confidence in the technique grew, so that none of the last 49 fractures in the series were made non-weight bearing. Not all patients in this population will achieve this, but it does provide an easier route for rehabilitation.

No patient was immobilised in a cast. Some surgeons employed removable hinge-knee braces, but it was observed that these were often a hindrance to walking in elderly frail patients, in which case such patients were allowed to weight-bear without the brace.

**Alternative methods of fixation.** RIMN has biomechanical data suggesting that a multi-planar locked retrograde nail has the greatest stability (compared with locking compression plate and DCS) for type-A fractures of the distal femoral shaft with statistically higher stiffness and significantly lower micro-motion across the fracture gap with axial compression. However, the same study revealed RIMN had the lowest resistance to fatigue failure in intra-articular type-C fracture where distal locking screws failed after less than 10,000 cycles. Although the AO group advocate avoiding IMN in fractures within 6 cm of the joint surface, experts can manage these distal fractures with IM devices using additional techniques such as inter-fragmentary screws to reconstruct the articular block and blocking screws to ensure idea nail placement. In some peri-prosthetic fractures retrograde nailing is not possible due to the geometry of the existing arthroplasty. Compatibility guides are available. A recent review of 448 periprosthetic fractures of the distal femur after total knee arthroplasty (TKA) concluded slightly superior results in lateral locked plates to IMN (union rates of 87% and 84%, respectively) with lower complication rates associated with use of plates. Further data have recently favoured IMN fixation compared with LDFLP for short term EuroQol-5D scores and reduction in angular deformity. However, the matching of the groups is unclear, with A1 to C1 fractures included but with intra-articular fractures predominantly fixed with LDFLP.

TKA may be appropriate in multi-fragmentary intra-articular fractures in elderly patients, in fractures above loose implants and in the presence of significant pre-existing arthritis, particularly if there is associated deformity or instability of the knee. Currently, reports on this approach remain limited to small series.

External fixation is often applied when temporisation is required to manage multiple injuries, when a staged approach to treatment may be preferable. A quadrilateral frame construct has been proposed where external fixation is required.

Dynamic condylar screw and blade plates are generally regarded to be unforgiving implants. Insertion may disrupt the fracture further, requiring removal of bone stock which can complicate revision options. Biomechanically they are less suitable for osteoporotic bone and type-C fractures than locking plates, due to the relatively poor sagittal plane stability they provide. These implants have been larger superseded by the Less Invasive Stabilisation System (LISS) plate (Synthes). This allows for locking plate

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**Table III. Failure of surgical cases**

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>AO classification</th>
<th>Fracture and fixation characteristics</th>
<th>Time to failure (mths)</th>
<th>Revision procedure</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>M</td>
<td>33 type-A3</td>
<td>High energy open fracture&lt;br&gt;12-hole VA-Condylar plate (Synthes, West Chester, Pennsylvania) with short working length (3 holes)&lt;br&gt;Plate broke</td>
<td>3</td>
<td>First revision to longer plate, broke again at five months&lt;br&gt;Second revision to orthogonal plating + limb shortening</td>
<td>Fracture united</td>
</tr>
<tr>
<td>61</td>
<td>M</td>
<td>33 type-A3</td>
<td>High energy fracture with medial 1 comminution&lt;br&gt;16-hole VA-Condylar plate with long working length (8 holes)&lt;br&gt;Plate broke</td>
<td>Revised to longer plate with shorter working length (5 holes)</td>
<td>Patient died during follow-up period</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>F</td>
<td>33 type-A3</td>
<td>Fracture in elderly patient with medial comminution&lt;br&gt;10-hole VA-Condylar plate with 4-hole working length&lt;br&gt;Plate broke</td>
<td>5</td>
<td>Revised to hinged TKA</td>
<td>Successful arthroplasty</td>
</tr>
<tr>
<td>95</td>
<td>M</td>
<td>33 type-A3</td>
<td>Fracture in elderly patient with medial comminution</td>
<td>2</td>
<td>Revised to 16-hole Peri-Loc plate (Smith &amp; Nephew, Andover, Massachusetts) with six screws distal to fracture and 5-hole working length</td>
<td>Fracture united</td>
</tr>
</tbody>
</table>

AO, Arbeitsgemeinschaft für Osteosynthesefragen; TKA, total knee arthroplasty
technology to be used with a minimally invasive plate osteosynthesis technique, in order to produce a fixed construct that is essentially an internally positioned external fixator. However, a meta-analysis of the LISS plate in nearly 700 femoral fractures across 21 studies showed up to 19% loss of reduction, 6% delayed union/nonunion, and 5% implant failure. Subsequently plating systems offer stainless steel pre-contoured design for implantation using a soft-tissue sparing technique. The locking screws may be fixed angle (as in the Peri-Loc plate) or variable angle (as in the VA-Condylar plate). The rationale for variable angle screws is increased versatility, allowing the surgeon a degree of choice in screw placement (usually a 30° arc), which can be useful in engaging in bone and avoiding an implant. This theoretical benefit has yet to be reflected in the literature in improved outcomes. Indeed, a recent study of 67 patients found increased failure rates in the VA-Condylar plate compared with the LISS plate (22% versus 14%). The more complex fracture patterns were fixed with the VA device in this series. In our study, all four failures of surgery were with the VA-Condylar plate, giving a failure rate of 5%. None of the 53 Peri-Loc fixations failed. The very small number of failures makes it difficult to draw robust conclusions on the causes of those failures.

Limitations. Only 46% of patients were followed up until radiographic union and we acknowledge it can be difficult to assess on plain radiographs, particularly in the low periprosthetic fractures. Neither multi-observer analysis of radiographs nor CT were employed, as our primary outcome was failure of fixation. For the same reason, as well as the difficulty in using complex outcome scoring systems in often frail, elderly patients, the telephone assessment was limited to re-operation, pain or limitation in weight-bearing status that might suggest nonunion, or imminent failure of fixation. We hypothesised that a significant proportion of these fractures may never fully unite, but in such cases the robust fixation would achieve its goal of pain relief, stability and mobility whilst ultimately outlasting the patient. The absence of any late failures of fixation, with all presenting within five months of the primary procedure, lends some weight to this assumption. While reporting a rate of failure of just 5%, we accept that the rate of nonunion, undetected through either failing to be reported during telephone assessment or death of the patient, may be much higher.

In conclusion, our study has found similarities inherent in the population suffering from both proximal and distal femoral fractures and, while the latter population may be smaller, we believe that these patients should benefit from the same targeted care as that afforded to the former group.

Although multiple treatment options exist for these fractures, we have found the use of LDFLPs to be a reliable strategy in all fracture configurations and patient groups, with lower rates of failure than those reported in the orthopaedic trauma literature to date. We advocate the use of LDFLPs to undertake soft-tissue sparing surgery, with sound biomechanical principles to permit unrestricted weight-bearing.

Take home message: - Surgeons treating distal femoral fractures with modern generation distal femoral locking plates should be aware of the biomechanical principles of using longer plates with the correct working length. - Using these can allow early unrestricted weight-bearing with low reported rate of failure.

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The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article.

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