ORIGINAL ARTICLE

Minimally invasive fixation of type B and C interprosthetic femoral fractures

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KEYWORDS
Femoral fracture; Interprosthetic fracture; Periprosthetic fracture; Internal fixation; Locked-plate; Minimally invasive

Summary

Introduction: Interprosthetic femoral fractures are rare and raise unresolved treatment issues such as the length of the fixation material that best prevents secondary fractures. Awareness of the advantages of locked-plate fixation via a minimally invasive approach remains limited, despite the potential of this method for improving success rates.

Hypothesis: Femur-spanning (from the trochanters to the condyles) locked-plate fixation via a minimally invasive approach provides high healing rates with no secondary fractures.

Materials and methods: From January 2004 to May 2011, all eight patients seen for interprosthetic fractures were treated with minimally invasive locked-plate fixation. Mean time since hip arthroplasty was 47.5 months and mean time since knee arthroplasty was 72.6 months. There were 12 standard primary prostheses and four revision prostheses; 11 prostheses were cemented and a single prosthesis showed femoral loosening. Classification about the hip prostheses was Vancouver B in one patient and Vancouver C in seven patients; about the knee prosthesis, the fracture was SoFCOT B in three patients and SOFCOT C in five patients, and a single fracture was SoFCOT D. Minimally invasive locking-plate fixation was performed in all eight patients, with installation on a traction table in seven patients.

Results: Healing was obtained in all eight patients, after a mean of 14 weeks (range, 12–16 weeks). One patient had malalignment with more than 5° of varus. There were no general or infectious complications. One patient died, 32 months after surgery. The mean Parker-Palmer mobility score decreased from 6.2 pre-operatively to 2.5 at last follow-up. Early construct failure after 3 weeks in one patient required surgical revision. There was no change in implant fixation at last follow-up. No secondary fractures were recorded.
Discussion: In patients with type B or C interprosthetic fractures, femur-spanning fixation not only avoids complications related to altered bone stock and presence of prosthetic material, but also decreases the risk of secondary fractures by eliminating stress riser zones. The minimally invasive option enhances healing by preserving the fracture haematoma. Thus, healing was obtained consistently in our patients, with no secondary fractures, although the construct failed in one patient.

Level of evidence: Level IV.

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Introduction

Interprosthetic fractures account for only about 1.25% of all femoral fractures [1] but are becoming increasingly common as both the life expectancy of the population and the number of joint replacements increase [1,2]. Interprosthetic fractures constitute a distinctive entity associated with specific therapeutic challenges related to the unfavourable local mechanical conditions. The advanced age and history of arthroplasty in these patients are associated with both quantitative and qualitative alterations in bone stock.

A variety of surgical techniques are available including standard plate fixation, locking-plate fixation, retrograde intramedullary nailing, revision implant spanning the weak zone, and total femur replacement [3]. Treatment decisions are based on the remaining bone stock and quality of implant fixation. If the implants are securely fixed, the treatment must provide stability and strength to avoid secondary mechanical complications. Regardless of the treatment option chosen, interprosthetic fractures carry a poor prognosis with high rates of mortality and re-operation [4,5].

Minimally invasive surgery to preserve the haematoma and periosteum, combined with a locking screw fixation device to improve holding power in the fragile bone tissue [6–11], seems particularly well suited to the treatment of interprosthetic fractures. Since 2004, all patients with interprosthetic fractures seen at our centre, including those with implant loosening, have been managed with minimally invasive approaches and locking-plate fixation. Our working hypothesis was that minimally invasive locking-plate fixation spanning the femur from the condylar region to the proximal femur at the level of the hip implant stem provided high healing rates while minimising the risk of construct failure and secondary fracture.

Material and method

Patients

We retrospectively studied the eight consecutive patients with interprosthetic fractures managed at our centre from 2004 to 2011. During this period, all interprosthetic femoral fractures were treated with minimally invasive locked-plate fixation, even in patients with loosened implants. No patients required conversion from minimally invasive to extensive surgery for interprosthetic fractures during the study period.

There were seven women and one man with a mean age of 78 years (range, 54–89 years; median, 78.5 years). Mean body mass index (BMI) was 26.4 kg/m² (range, 18–31 kg/m²; median, 27 kg/m²). The mean pre-operative Parker-Palmer score [12], used to assess self-sufficiency, was 6.25 (range, 2–9; median 7.5). Of the eight patients, two lived at home and six in retirement homes. The mean ASA score was 3. None of the patients had chronic inflammatory joint disease and none was taking corticosteroids. All fractures were caused by a fall at home. In one patient (#1), 2 months after an interprosthetic fracture managed with minimally invasive locking-plate fixation, another fall caused a second fracture starting at the most proximal screw of the construct, which did not fully span the interprosthetic interval (Fig. 1). Only the second fracture was included in the study. The first fracture was fully healed at the time of the second fracture, with 10° of flexion deformity. Minimally invasive revision surgery was performed on a traction table. Fixation was achieved using a long distal plate, proximal cerclage, and periprosthetic screws spanning the entire interprosthetic interval (Fig. 1).

The reason for hip arthroplasty was osteoarthritis in three patients, avascular necrosis in two, a femoral neck fracture (intermediate prosthesis) in one, and unknown in two. In five patients, the prostheses were cemented. Three patients had long femoral stems, including two with revision implants (one locked stem and one cemented stem). In the seven patients for whom the date of hip arthroplasty was known, mean time from hip arthroplasty to the interprosthetic fracture was 47.6 months (range, 2–148 months; median, 25 months). One patient had loosening of the femoral component but reported no symptoms prior to the fracture.

Osteoarthritis was the reason for knee arthroplasty in all eight patients. The knee prostheses were cemented in six patients, and one patient had a femoral extension stem implanted during revision surgery. In the five patients for whom the date of knee arthroplasty was known, mean time from knee arthroplasty to the interprosthetic fracture was 72.6 months (range, 6–208 months; median, 64 months). None of the patients had loosening of the knee prosthesis.

In the Vancouver classification system [13], the fractures about the hip prostheses were type B in one patient and type C in seven patients. In the SoFCOT classification system [14], the fractures about the knee prostheses were type B in three patients and type C in five patients; a single patient (#2) was classified as having a type D fracture [3]. The middle third of the femur was involved in two patients and the distal third in six patients. The fracture line was oblique in
Figure 1  Interprosthetic fracture, SoFCOT type B for the knee prosthesis and Vancouver type C for the hip prosthesis. Repeat fracture illustrating the need to span the entire femur. a: first fracture (antero-posterior and lateral views); b: postoperative radiograph taken after fixation of the first fracture. Note the weak zone between the plate and the hip prosthesis. Eight weeks later, after complete healing of the first fracture, new fracture between the locked-plate and hip prosthesis (antero-posterior and lateral views); c: second fixation procedure, with a longer plate. Radiograph showing the healed fracture.

three patients, spiral in three patients, and transverse in two patients (Table 1).

Operative technique

The operative technique was based on previously described principles [11,15,16]. The objective was to eliminate stress riser zones by spanning the entire femur from the condylar region to the proximal femur. Fixation was with a titanium large-fragment locking compression plate (LCP, Synthes, Etupes, France). Either an anatomically contoured diaphy-seal plate or an anatomically contoured distal femoral plate was used. The distal plate was preferred, as the less invasive stabilisation system (LISS) facilitated its implantation and the distal part of the plate allowed the insertion of multiple condylar locking screws. The patient was installed on a traction table or standard table according to surgeon preference and independently from the characteristics of the fracture. To minimise intra-operative radiation exposure, the cutaneous landmarks (fracture, prosthesis, joint, incision line, and femoral axis) were marked on antero-posterior and lateral views. The minimally invasive lateral paracondylar approach was chosen. Indirect reduction via external manoeuvres under fluoroscopic guidance was consistently attempted. Traction along the axis of the femur with a support pad was used when the procedure was performed on a standard table. Otherwise, the traction table was used with a counter-support secured to the table under the distal femur. Intra-operative stratagems used when reduction was less than ideal [15] included selection of anatomically contoured plates, intra-focal pinning, and lag screw fixation of the bone to the plate. The constructs complied with stringent mechanical requirements to allow weight-bearing as tolerated during the postoperative period [11,15,16]:

- bicortical locking screws were consistently used in femoral regions free of implant components, and bicortical screws were used whenever possible if the prosthetic material did not block the planned screw trajectory;
- flat-tipped screws were selected in regions containing prosthetic stems, to ensure maximum holding power;
- when screw fixation seemed insufficiently secure about the prostheses, cerclage wires were added to counter-act pulling forces, via a minimally invasive approach and under fluoroscopic guidance to ensure preservation of the fracture haematoma (Fig. 2);
- full weight bearing was allowed only in patients with Parker-Palmer scores of at least 3 or 4, indicating a good degree of self-sufficiency and provided the above-described principles of internal fixation are followed [12].

Evaluation of outcomes

Outcomes were evaluated by an independent observer (JC). A clinical evaluation was performed and the Parker-Palmer score was determined [12]. In our elderly patients, we considered that the prognosis and functional outcome were related to the degree of self-sufficiency and not to the prostheses. Fracture healing was defined radiographically as at least two solid cortices [11]. The axes were evaluated on radiographs obtained in the immediate postoperative period and at re-evaluation. Deviations of more than 5° were taken to indicate malalignment [11]. Patients were evaluated clinically for evidence of rotational malalignment.

Statistical analysis

Quantitative variables were evaluated using the Wilcoxon signed-rank test for paired data. Values of $P$ lower than 0.05 were considered significant.

Results

All eight patients were followed up until radiological healing was achieved. One patient died, after 32 months, but was nevertheless included in the study as his fracture was healed at last follow-up. Mean follow-up was 39 months (range, 12–99 months; median, 30.4 months). At last evaluation, the mean Parker-Palmer score [12] was 2.5 (range,
Table 1  Case series of eight patients with interprosthetic fractures.

<table>
<thead>
<tr>
<th>Case #</th>
<th>Sex</th>
<th>Age (y)</th>
<th>Preop. Parker-Palmer score</th>
<th>BMI</th>
<th>Hip prosthesis type</th>
<th>Time since hip replacement (months)</th>
<th>Knee prosthesis type</th>
<th>Time since knee replacement (months)</th>
<th>Fracture type</th>
<th>Vancouver for the hip [13]</th>
<th>SoFCOT for the knee [14]</th>
<th>Time to healing (weeks)</th>
<th>FU (months)</th>
<th>Parker-Palmer score at last FU [12]</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>54</td>
<td>9</td>
<td>18</td>
<td>Cementless</td>
<td>2</td>
<td>Cemented</td>
<td>17</td>
<td>Vancouver</td>
<td>C SoFCOT C (previous interprosthetic fracture 8 weeks earlier)</td>
<td></td>
<td>15</td>
<td>21</td>
<td>4</td>
<td>10° flexion deformity after he first fracture (distal site)</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>89</td>
<td>6</td>
<td>25</td>
<td>Cementless</td>
<td>13</td>
<td>Long cemented stem</td>
<td>UK</td>
<td>Vancouver</td>
<td>B1 SoFCOT B1 Type D</td>
<td></td>
<td>16</td>
<td>65</td>
<td>2</td>
<td>Construct failure after 3 weeks</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>82</td>
<td>9</td>
<td>27</td>
<td>Long cemented stem</td>
<td>86</td>
<td>Cemented</td>
<td>6</td>
<td>Vancouver</td>
<td>C SoFCOT B1</td>
<td></td>
<td>14</td>
<td>99</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>4 died</td>
<td>F</td>
<td>78</td>
<td>2</td>
<td>31</td>
<td>Cemented</td>
<td>25</td>
<td>Cemented</td>
<td>68</td>
<td>Vancouver</td>
<td>C SoFCOT C</td>
<td></td>
<td>12</td>
<td>32 (died)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>79</td>
<td>3</td>
<td>33</td>
<td>Long cemented stem</td>
<td>148</td>
<td>Cementless</td>
<td>208</td>
<td>Vancouver</td>
<td>C2 SoFCOT C</td>
<td></td>
<td>15</td>
<td>33</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>76</td>
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<td>47</td>
<td>Cementless</td>
<td>64</td>
<td>Vancouver</td>
<td>C SoFCO TB1</td>
<td></td>
<td>15</td>
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<tr>
<td>7</td>
<td>F</td>
<td>86</td>
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<td>23</td>
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<td>UK</td>
<td>Cemented</td>
<td>UK</td>
<td>Vancouver</td>
<td>C SoFCOT C</td>
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<tr>
<td>8</td>
<td>M</td>
<td>78</td>
<td>3</td>
<td>27</td>
<td>Long cemented stem</td>
<td>12</td>
<td>Cemented</td>
<td>UK</td>
<td>Vancouver</td>
<td>C SoFCOT C</td>
<td></td>
<td>14</td>
<td>27</td>
<td>1</td>
<td>10° varus</td>
</tr>
</tbody>
</table>

F: female; M: male; Preop.: preoperative; BMI: body mass index; UK: unknown; FU: follow-up.
1–6; median, 2) compared to 6.25 (range, 2–9; median, 7.5) before surgery (P < 0.03); two patients were living at home and six in retirement homes.

Postoperative rehabilitation involved full weight bearing as tolerated in five patients, partial weight bearing up to 20 kg for 6 weeks in one patient (early in our experience), and ambulation without weight bearing on the operated side in two patients, one with a pre-operative Parker-Palmer self-sufficiency score lower than 3 [12] and the other with early construct failure requiring revision surgery.

Fracture healing was obtained in all eight patients. Mean time to healing was 14 weeks (range, 12–16 weeks; median, 14.5 weeks) (Fig. 3). Malalignment with 10° of varus was noted in one patient. Comparison of the immediate postoperative radiographs to the radiographs at fracture healing showed no axis changes despite the early weight bearing. None of the patients had clinical evidence of rotational malalignment. At last follow-up, no changes in pre-operative cementing were detected.

All procedures were performed by senior surgeons, under general anaesthesia, via a minimally invasive approach. Mean operative time was 90 minutes (range, 40–135 minutes; median, 95 minutes). A traction table was used in seven patients and a standard table in one patient. Fixation was with an anatomically contoured distal femoral plate in seven patients (number of holes, nine [n = 2], 11 [n = 1], 13 [n = 3], or 15 [n = 1] and an 18-hole anatomically contoured femoral diaphyseal plate in one patient. The constructs were built almost entirely using locking screws, with a mean of 5 screws above and 5 below the fracture line. Additional cerclage was performed in five patients to counteract pulling forces (proximally in three patients and distally in one patient).

No infectious or general complications were recorded. There was a single mechanical complication, consisting in early construct failure after 3 weeks. This complication was ascribable to technical weaknesses with an insufficiently secure construct and required revision surgery via a conventional approach on a traction table. Fixation was with a long femoral diaphyseal plate and multiple cerclage wires and periprosthetic screws. The outcome was favourable, with primary fracture healing.

Discussion

Interprosthetic femoral fractures are rare, with fewer than two cases annually in most case series [17–20]. They occur in fragile elderly patients who have bone stock alterations that limit the holding power of the fixation material and increase the risk of mechanical complications. There is no consensus regarding the best treatment strategy [17–24]. We elected to preserve the fracture haematoma as a means of promoting healing and to use femur-spanning fixation material to prevent secondary fractures. Our working hypothesis was that minimally invasive locked-compression-plate fixation extending from the trochanteric to the condylar region would produce a high healing rate while avoiding secondary fractures. Our data validate this hypothesis, although early construct failure occurred in one patient. The occurrence of a second fracture in patient #1 (without adequate fixation) supports the usefulness of spanning the entire femur in order to avoid creating stress riser zones.

Our study has several limitations. The small number of patients and large number of surgeons reflect the low incidence of interprosthetic fractures and the 7-year recruitment period. However, all surgeons adhered strictly to the same technique. The retrospective study design and absence of a control group are also ascribable to the low incidence of these fractures. Conclusions can be drawn only for type B and C fractures, which contributed all cases but one; data from the single type D fracture cannot be extrapolated to other cases. The operative technique also has a few limitations, particularly regarding the length of available plates and the LISS targeting device, which is not well suited to very long plates and may be difficult to use in obese patients. Finally, axis control is difficult to achieve with minimally invasive approaches. Nevertheless, the clinical and radiological outcomes in our study establish the feasibility of our technique.

To the best of our knowledge, none of the previously published studies of interprosthetic fractures consistently used a minimally invasive technique. O’Toole et al. [21] and Ricci et al. [22] reported a few cases of interprosthetic

Figure 2 Minimally invasive cerclage at a site where the intramedullary femoral component of a hip prosthesis prevented the insertion of bicortical screws. a: intra-operative view; b: final intra-operative fluoroscopic view.

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fractures managed with minimally invasive surgery but did not describe the outcomes in detail. Platter et al. [17] and Mamczak et al. [18] lumped together conventional fixations and prosthesis revisions, and Sah et al. [20] reported 22 cases managed with locked-plate fixation but via a lateral approach. Compared to our study, all three previous series had similar rates of fracture healing (86% [17] to 100% [18,20]) and inadequate reduction (18% [17] and 11.5% [18]). Thus, the use of a conventional approach does not seem to improve the quality of the reduction. The minimally invasive approach used in our patients not only preserved the fracture haematoma, but also contributed to minimise the risk of infection. The good holding power of the material allowed immediate mobilisation (with weight bearing as tolerated in five of eight patients), which seemed beneficial, as no patients experienced general complications or complications related to immobility [23,24]. The decrease in the Parker-Palmer [12] score is ascribable not only to the fracture, but also to the aging of our population (mean follow-up was 3 years) and to comorbidities.

Locking-plate fixation via a minimally invasive approach has been proven effective for the treatment of periprosthetic femoral fractures [7,11,21—25]. Periprosthetic screw fixation produces a highly secure construct but can damage the cement mantle [26]. In patients with interprosthetic fractures, the main objective is protection of the entire femur to avoid the creation of stress riser zones [18,20,27], thereby preventing the occurrence of secondary fractures, which can be life threatening in elderly patients [3—5]. The existence of a stress riser zone in the femur between the femoral stem of a hip prosthesis and the femoral extension stem of a knee prosthesis carries a risk of mechanical complications [3—27]. To avoid weakness at this site, the fixation device must overlap the two prostheses by at least twice the diameter of the femoral diaphysis. However, a study suggests that high peak stresses may be chiefly ascribable to cortical thinning rather than to the presence of an implant-free femoral zone [28].

**Conclusion**

When managing interprosthetic fractures, the entire femur must be taken into consideration in order to prevent mechanical failure. If internal fixation is in order, a femur-spanning construct eliminates the stress riser zone, thereby preventing secondary fractures. Minimally invasive surgery well suited to these fractures and provides high healing rates, satisfactory functional recovery, and low morbidity rates. However, this technique has a learning curve, as mechanical failure or insufficient reduction may occur. The results reported here establish the efficacy of this technique in the treatment of types B and C interprosthetic fractures.

**Disclosure of interest**

Matthieu Ehlinger and Philippe Adam perform occasional consultancy work for Synthes; Jaroslav Czekaj, David Brinkert, Guillaume Ducrot, and François Bonnomet have no conflicts of interest related to this article; and François Bonnomet is a training consultant for Zimmer.

**References**

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