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Distal femoral fractures: is failure related to the osteosynthesis device?

Alberto Belluati[1], Daniele Barbaro[2], Stefania Paderni[1], Carlo Busatto[1], Carlotta Pari[1]

[1] Orthopaedic and Trauma Department, "Santa Maria delle Croci" Hospital, Ravenna, Italy; [2] Orthopaedic and Trauma Department, University Hospital of Ferrara, Italy

Summary

Distal femoral fractures (DFFs) are challenging injuries. For a long time they were considered difficult to manage and often led to a degree of disability. Until the early 1960s, most of these fractures were treated conservatively, with poor functional outcomes. With the development of new materials and surgical techniques, surgical fixation has gradually become the standard of care for DFFs and has demonstrated better outcomes than non-surgical treatment in terms of fracture healing, alignment and knee motion. The wide variety of surgical options – ranging from osteosynthesis procedures like external fixation, plate fixation, intramedullary nailing to different kinds of knee joint replacement – reflects the complexity in the management of these fractures, which often display comminution of the meta-diaphyseal region and articular involvement. These difficulties become greater when they are associated with elderly patients with multiple comorbidities and poor bone quality, which may not allow to obtain a stable fixation.

Key words: supracondylar, femoral fractures, nonunion, devices failure, distal femur

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Correspondence
Carlotta Pari
Orthopaedic and Trauma Department, "Santa Maria delle Croci" Hospital, Viale Randi 5, Ravenna, Italy.
E-mail: carlotta.pari@alice.it

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Introduction

Distal femoral fractures (DFFs) remain a challenge for both patients and surgeons in terms of disability impact, articular function, soft tissue management, preoperative planning, surgical technique, sequelae and post-operative complications.
DFFs follow a typical bimodal distribution. They may occur as a consequence of a high-energy trauma in young patients with good bone quality, or as a consequence of a low-energy mechanism in elderly patients with frail osteoporotic bone [1-3].
DFFs account for less than 1% of all fractures and between 3 and 6% of all femoral fractures [4-5]. However, their incidence is likely to rise in the near future due to the progressive aging of the population [3].
Until the early 1960s, most of these fractures were treated conservatively, with poor outcomes [6]. With the improvement of materials and surgical techniques, surgical fixation has gradually become the standard of care for DFFs, and has largely proved to be superior to non-surgical treatment in terms of early knee motion, restoration of articular surface, restoration of limb length and alignment [7,8]. The wide variety of surgical options (ranging from osteosynthesis procedures like external fixation, plate fixation, intramedullary nailing to different kinds of knee joint replacement) reflects the complexity in the management of these fractures, which often display comminution of the meta-diaphyseal region and articular involvement. Nonunion counts an estimated prevalence of 5%, and represents the most frequent complica-

tion after surgery for DFFs, followed by malunion, failure of osteosynthesis devices and infections [9,10]. In the elderly population, additional problems that need to be addressed are represented by poor bone quality, which often does not allow to obtain a stable fixation, multiple patient comorbidities and the increasingly frequent incidence of peri-prosthetic fractures of the distal femur in patients with total knee replacement.

Patients and methods

During an 8-year period from January 2013 to December 2020, 72 DFFs were treated at our Orthopaedic Department. All x-ray records were reviewed to assess the treatment performed (intramedullary nailing, internal fixation with locking plate, external fixation followed by nailing or plating) and the differences in fracture healing and post--operative complications. AO/OTA B1/B2/B3 fractures were excluded because they require highly specific surgical options, which differ from those used for the meta-diaphyseal extra-articular fractures (AO/OTA A1/A2/A3) and bicondylar fractures (AO/OTA C1/C2/C3). Additionally, patients who had less than 3-month x-ray follow-ups were excluded, obtaining a final study population of 64 patients. The average x-ray follow-up was 9 months (range 3-31). The mean age at the time of the surgery was 78 years (range 26-101): 19 were young patients who had suffered a high-energy trauma (e.g. motor vehicle accident, workplace accident), and 45 were elderly patients who had undergone a low-energy trauma (e.g. fall from a standing height). Six patients had open fractures (5 in young patients with high-energy trauma, 1 in the group of the elderly), 11 were periprosthetic fractures in elderly patients with total knee replacement. Twenty-nine fractures were treated with intramedullary nailing; 35 fractures were treated with locking plate fixation.

At our Institution, criteria for preferring the use of intramedullary nailing for the treatment of DFFs are:

- extra-articular fractures with meta-diaphyseal comminution (AO/OTA A2/A3);
- bicondylar fractures without significant comminution and displacement of the articular block (AO/OTA C1/C2); additional blocking compression screws are normally used to both facilitate the nail insertion and create compression between the two femoral condyles;
- periprosthetic fractures above the knee prosthesis;
- single-stage treatment of open fractures;
- obese patients, when allowed by the fracture pattern;
- elderly patients with low functional demand, regardless of the fracture pattern, to obtain stability using a minimally invasive technique.

On the contrary, criteria for preferring the use of distal locking plates are:

- extra-articular simple pattern fractures (AO/OTA A1), to obtain compression at the fracture site;
- significant displacement/comminution of the articular block, which requires anatomical reconstruction;
- young patients, to avoid damage at the femoral articular surface - when allowed by the fracture pattern, minimal invasive technique using the LISS system is preferable.

Within the "nail group" (n = 29), 4 were periprosthetic fractures around the knee and 4 were Gustilo 2 open fractures treated in a single-stage with intramedullary nailing.

Within the "locking plate group" (n = 35), 22 fractures were approached with minimal invasive technique, while the remaining 13 were approached with a classic open technique. Also within the "locking plate group", 7 were periprosthetic fractures around the knee and 2 were Gustilo 3 open fractures in high-energy trauma young patients, who were first treated with a temporary external fixator and then turned into plate fixation at 15 and 18 days after the first surgery, respectively.

Results

All cases were retrospectively reviewed to assess x-ray fracture healing and complications. The average x-ray fracture healing was 4 months, ranging from a minimum of 2 to a maximum of 8 months, both for the "nail group" and the "locking plate group". The overall percentage of complications was 10.9% and consists of:

- 3 cases of nonunion (4.7%): 2 cases occurred in the "locking plate" group, 1 case occurred in the "nail group". They all required major revision surgery, including device removal and new osteosynthesis with complementary bone graft;
- 3 cases of osteosynthesis device breakage (4.7%): 1 case of distal screws plate breakage (Fig. 1) – which required major revision surgery – and 2 cases of distal locking screws breakage in the "nail group", which required minor revision surgery to remove the free ends of the split screws;
- 1 case (1.6%) of nail penetration of the knee joint in osteoporotic bone, which resulted in implant removal.

No case of post-operative infection was found, and none in patients with open fractures.

Discussion

The treatment of DFFs continues to evolve with the purpose of finding state of the art osteosynthesis devices, which could allow the optimal management of these complex injuries. Over time, surgical fixation has evolved to the conclusion that non-operative treatment leads to greater risks of complications, making surgical intervention the option of choice in the majority of such fractures. Surgical fixation has demonstrated better outcomes than non-surgical treatment in terms of fracture healing, alignment and knee motion [7-8,11]. Butt et al. [8] in 1996 - in a prospective study comparing surgical and non-operative treatment in the elderly – reported good results in 53% of patients treated surgically. On the contrary, they reported only 31% of success rate in patients treated conservatively. Cass et

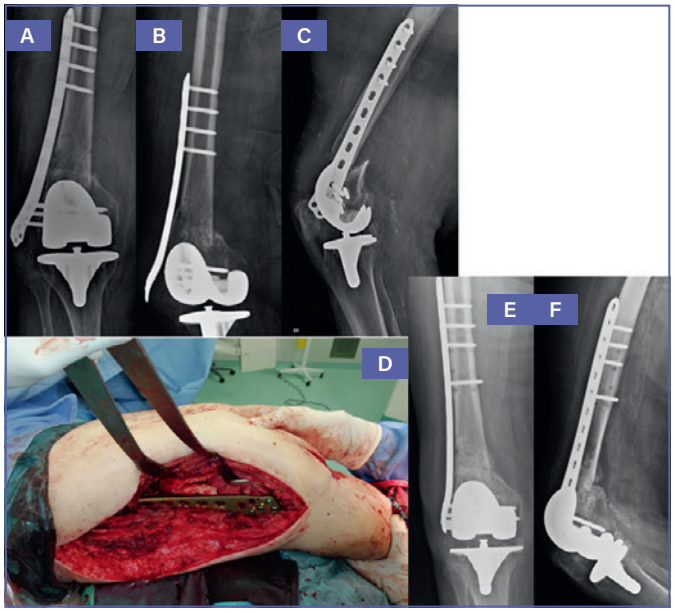

Figure 1. (A-C) a case of distal screws locking plate breakage; (D) revision surgery: plate removal, intra-lesional bone graft from a cadaveric donor, osteosynthesis with a new locking plate; (E-F) post-operative 3-month follow-up.

al. [11] in 2008 compared surgical and non-surgical treatment in a study population of non-ambulatory patients with spinal cord injuries. Despite a union rate of 90%, which was similar for both groups, they observed skin and soft tissue complications in patients treated conservatively and no significant wound complications in patients treated operatively.

Nowadays, conservative management of DFFs is only applicable to stable and minimally displaced fractures, non-ambulatory patients and those with severe comorbidities, which contraindicate a surgical approach [3].

The goal of surgical treatment is to restore physiological alignment, rotation and length of the femur, as well as restore the articular surface and obtain a stable fixation, which allows early knee motion and rehabilitation. The femoral shaft is oriented between 6° and 11° of valgus in relation to the joint line. Several muscle groups can create deformities across the fracture. In the lateral view, quadriceps commonly cause shortening, while gastrocnemius typically cause posterior angulation of the distal fragment. Additionally, the two heads of the same muscle may create malrotation of the femoral condyles in case of intercondylar split (AO/OTA C fractures). In the AP view, abductors and the ileotibial band may cause a varus/valgus deformity. These anatomical principles should guide all surgical procedures, because restoring of the mechanical axis, both in coronal and sagittal planes, is crucial to preserve the function and longevity of the knee joint [3,12].

A fixed angle blade plate was the first implant device to revolutionise the surgical management of DFFs, with its ability to provide stable fixation and alignment in multiple plans. The fixed angle concept was successively developed into a sliding screw with a side plate design to allow compression between condyles in case of intercondylar split. Drawbacks of this system are the wide surgical exposure needed, poor fixation in osteoporotic bones and inability to dominate the fracture in the coronal plane [13,14].

Modern locking lateral plates offer several advantages and allow to better address fractures in osteoporotic bones and fractures with high comminution, also involving the articular surface. Locked screws intensify the stability of the construct, reducing micro-motion at the plate-bone interface and lending more strength to resist pull-out. However, making a construct too stiff, as may occur using these plates, might inhibit callus formation and slow the fracture healing [6,15]. In order to avoid excessive stiffness some precautions can be put into practice. The use of titanium plates instead of stainless-steel plates allows more flexibility, which may aid callus formation [15]. Positioning locking screws at the proximal end of the plate is reported to be related with thigh pain and increasing risk of peri-implant fractures due to high stress concentration. Indeed, some authors suggest the use of a non-locking end screw in osteoporotic bones [16]. Finally, using far cortical locking screws, which engage only the far diaphyseal cortex, can improve healing by creating a more symmetric compression at the fracture site while loading [17]. Moreover, the development of Less Invasive Stabilization Systems (LISS), which allows to apply these plates submuscular through small incisions, have amply reduced soft tissue disruption. Therefore, modern locking plates have proven to be biomechanically superior to fixed angle blade plates in cadaveric and in vitro studies [13,18,19].

Over time, another technique that has progressively enlarged its indications in the management of DFFs is retrograde intramedullary nailing (RIM). Newer nails offer multiple distal screw position options, which make them suitable for reconstruction even in intra-articular fractures. A tangible advantage of intramedullary devices is that they can offer, with soft tissue friendly small incisions, and earlier weight bearing because the implant can be load sharing. This prevents complications related to prolonged immobilisation and makes the RIM technique particularly suited to elderly patients and polytrauma patients [12]. However, poor fracture reduction, inaccurate starting point and eccentric reaming may lead to fracture malalignment. To minimise these potential complications, blocking screws can be placed to guide the nail trajectory during its insertion and the starting point should meticulously be identified with fluoroscopy. Long nails are recommended by some authors in order to prevent periprosthetic fractures at the proximal tip of the nail and to obtain an optimal isthmic fit, improving stability and load distribution [19,20]. Several studies in the literature have compared RIM with conventional locking plates [9,13,21-23].

RIM seems to be superior in terms of lower blood loss, lower non-union rate and lower infection rate. No significant differences in axial and torsional strength have been reported. In the authors' limited case series no significant differences were found between the plate and the nail population.
We do not have experience in acute total knee arthroplasty (TKA) for DFFs. Nevertheless, in the literature some authors suggest TKA as a valid alternative for elderly patients with baseline osteoarthritis of the knee joint and extensive intra-articular involvement [24-27]. Based on the fracture pattern implant, the options include: unstemmed TKA, stemmed TKA, hinged models, mega-prosthesis for fractures with meta-diaphyseal extension, revision surgery in periprosthetic fractures and non-union of supracondylar fractures [27]. TKA also represents a valuable salvage procedure for the management of failed internal fixations and nonunions [28].
Lastly, we are aware of the limitations of this study, which include its retrospective design, no data on functional scores and an heterogeneous population in terms of age and fracture patterns.

Conclusions

DFFs are serious injuries. For a long time, they were considered difficult to address and often led to substantial disability. Due to the development of internal fixation techniques and the broad implementation of replacement surgery, several improvements have been made in terms of treatment and patient recovery. However, DFFs remain a challenging issue, and the difficulties also become greater when they are associated with elderly patients.
Thus, is failure related to the osteosynthesis device? Failure depends on several factors, including fracture pattern, bone quality, patient characteristics – age, comorbidities, functional demands – and the surgeon's experience. The ideal implant has still not been found, and surgeons will unlikely be able to completely avoid fracture-related complications. However, supported by medical engineering and technology, they will be able to increasingly reduce the rate of these complications.

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Authors' contributions
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Ethical consideration
This is a literature review article and does not require an ethics committee.

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