Minimally-invasive fixation of distal extra-articular femur fractures with locking plates: Limitations and failures

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Summary
Minimally-invasive fixation using a locking plate and early motion is normal practice. However, technical errors and pitfalls are common. This surgery has a set of rules that encompass both the mechanics of the internal fixation system and the implantation itself. If these rules are not strictly followed, alignment defects and/or early failure of the fixation can occur. We analysed four cases of clinical failure that were encountered after minimally-invasive distal femoral extra-articular fixation with locking plates. The following rules must be followed with this technique: extra-articular fracture, minimally-invasive approach, long plate alternating between locking screw and empty hole (five holes on either side of fracture), bicortical screws, placement of locking screws near a complex fracture but away from a simple fracture. Osteoporotic bone, obesity that interferes with the instrumentation, articular fracture, horizontal fracture line and surgeon experience are all limitations of this minimally-invasive technique.

Introduction
Minimally-invasive fixation with locking plates has been described often and is regularly performed [1–4]. This technique requires strict adherence to mechanical principles and a high-quality technique [2–5] otherwise it will result in mechanical failures. Mechanical failures include non-anatomical reduction because of an alignment defect in the frontal or sagittal plane and/or early failure of the fixation system. Here, we report on clinical observations to highlight technical errors that were the cause of minimally-invasive fixation failures of the distal femur.
These clinical cases of mechanical failure were from a series of more than 60 cases. The femur fractured in native bone or was associated with a hip or knee prosthesis. In our opinion, the problems and treatment principles are the same for a native bone fracture and a periprosthetic fracture.

Clinical cases

Clinical case N° 1

This was a supracondylar femur fracture in the right leg of an 82 year-old female patient (Fig. 1). Post-operative radiographs showed a valgus of more than 10°. The diaphyseal part of the plate was parallel to the lateral femoral cortex. The epiphyseal locking screws were not parallel to the joint line.

In this case, the epiphyseal position of the plate was not optimal because of insufficient reduction. As a direct consequence, the screws were not positioned properly in the epiphysis. The surgeon did not use the principle of parallelism between the epiphyseal screws and joint line to detect the faulty reduction [2,5].

Clinical case N° 2

This was a distal supracondylar femur fracture in a 79 year-old female patient with a history of intertrochanteric fracture treated with an intramedullary hip screw (Fig. 2). Post-operative radiographs showed that the epiphyseal screws were parallel to the joint line, but the diaphyseal part of the plate was not parallel to the lateral femoral cortex in the frontal plane. The consequence was a valgus of more than 10°.

As with the preceding case, the two principles of parallelism must be put together — between the epiphyseal screws and joint line on one hand and the plate and lateral cortex of the femur diaphysis on the other.

Clinical case N° 3

This was a 75-year-old female patient with a complex knee periprosthetic distal femoral fracture classified as SOFCOT B1 [6] (Fig. 3). An incision was made to help with reduction, which demonstrates the challenges of a minimally-invasive surgery when faced with a periprosthetic fracture. The distal epiphyseal purchase included six locking screws and the proximal diaphyseal purchase included four locking screws placed side by side. The consequence was a valgus of more than 10°.

As with the preceding case, the two principles of parallelism must be put together — between the epiphyseal screws and joint line on one hand and the plate and lateral cortex of the femur diaphysis on the other.

Figure 1  Distal supracondylar femur fracture of right leg. a: preoperative radiographs; b: A/P radiographs immediately postoperative after internal fixation with a LISS anatomically femoral distal LCP plate. Epiphyseal valgus of more than 10°. Non-anatomical positioning of plate despite the plate being parallel to the lateral cortex of the femur; the epiphyseal screws are not parallel to the joint line (white line = joint, black line = epiphyseal screw).
been enough [2,5]. The same observation can be made for the upper part of the fixation system where an overly stiff area was created by the surgeon placing four locking screws without spacing them out. The two proximal tangential screws were not mechanically effective. The use of multiple proximal screws, even if they are locking screws, cannot overcome positioning outside the bone. Also the two intermediate screws did not seem to be stable as they were placed in the centre of the fracture. Having overly stiff areas at both ends of the plate in this unstable fracture led to excessive demands on the middle part and early fixation failure after six weeks of mobilisation, even with partial weight-bearing.

**Clinical case N° 4**

This was an 85-year-old female patient with a complex hip periprosthetic fracture classified as SOFCOT type C [7] (Fig. 4). The presence of a third fragment made this technically difficult. The distal epiphyseal bone purchase included five locking screws and the proximal diaphyseal purchase included five locking screws placed side by side. Between these two purchase points, eight holes were left empty. Postoperative radiographs showed that the plate was parallel to the lateral femoral cortex but that the epiphyseal screws were not parallel to the joint line, with incorrect varus positioning. The fixation system broke at the first empty hold below the diaphyseal purchase point after eight weeks. Revision was performed through a standard lateral approach with addition of an autograft and placement of a condylar locking compression plate and two months without weight-bearing. The fracture had consolidated after five months.

Similar to the previous case, the presence of two overly stiff areas on the plate resulted in excessive demands on the middle part of the plate. The fatigue fracture of the plate at the upper hole can be attributed to the bending moments induced when the lower limb was loaded, imbalance in the fixation system and non-anatomical reduction.
Figure 3  Knee peri-prosthesis distal femoral fracture; a: preoperative radiographs: fracture with knee prosthesis, SOFCOT B1 type; b: postoperative radiographs. On A/P view, proximal and distal stiffening due to of a group of locking screws, which cause an imbalance in the stresses (black circle). Two screws seem to be inside the fracture (black arrows) and two screws seem to be tangential to the posterior cortex (white arrows). On lateral view, the reduction is not perfect as the fracture site is curved but the overall alignment of the femur seems to be preserved on A/P and lateral views. c: early failure at the sixth week. The proximal "block" pulled out when the plate and screws ruptured, which confirms the tangential nature of the proximal screws, and the intra-fracture proximal screw pulled out, which confirms that the hold was weak. d: revision with retrograde nailing.
Figure 4  Hip peri-prosthesis distal femoral fracture: a: preoperative radiographs, Vancouver type C fracture; b: postoperative radiographs. Proximal and distal stiffening due to of a group of locking screws, which cause an imbalance in the stresses (white circle). The locking screws are too far away from the site of the complex fracture (long and comminuted), which magnifies the imbalance; c: rupture of plate at eight weeks postoperative in the fragile part of the fracture between the two overly stiff areas. Note that the epiphyseal screws are not parallel to the joint line (black lines); d: postoperative radiographs. Varus persists.
that concentrated the loads at the most proximal open hole. Spacing in the proximal screws would bring the fixation zone closer to the complex fracture site. The principles described by Stoffel et al. [8] were followed by making the fracture area stiffer. The parallelism principles between the plate-cortex and epiphyseal screws-joint line were not followed.

Discussion

These clinical cases demonstrate the need to master the use of new implants that have specialized biomechanics. It is absolutely necessary to understand that the rules of use for these fixation systems are a function of the material and not the fracture type (proximal, mid-shaft, distal, periprosthetic).

In the cases described here, the plate used was anatomically contoured for the distal femur. To take full advantage of this anatomical design, the epiphyseal part must be placed in exactly the right position with the epiphyseal screws parallel to the joint line. The lateral cortex of the diaphysis must be parallel to the plate before the locking screws are inserted. A non-locking screw or a traction system in one of the plate’s holes can be used. This fundamental dual parallelism must be observed otherwise there is a risk of inducing non-anatomical bone alignment (clinical cases 1, 2, 4) [2—5].

Cases 3 and 4 highlight three primary rules of fixation with a locking plate that must be obeyed, no matter the type of fracture. The first is screw position relative to the fracture. These must be placed near the centre of a complex fracture (long oblique, comminuted, long spiral) to increase the stability of the fixation system [8]. Conversely, they must be placed one hole away with a simple fracture (transverse, short oblique, long spiral) [8] to avoid concentrating the loads near the fracture site and to distribute the stresses along the plate as much as possible. The second component is the need to spread out the screws by alternative a screw and an empty hole to distribute the stresses [2—5,9]. In cases 3 and 4, the creation of overly stiff areas concentrated the stresses in the areas devoid of screws. The third component is the number of screws per fragment. Since the lower limb experiences compressive loads, three or even four spaced out screws per fragment are sufficient [2,5]. Adding more does not improve rotation control and the risk increases of adding to the stiffness.

Finally, the locking screws should be placed through both cortexes, which improves the hold in this often fragile bone [10—12].

In terms of materials, the surgical-grade titanium used in traumatology provides improved mechanical properties relative to static or dynamic stresses during repeated loading [13]. Its elasticity allows for beneficial stimulation to the fracture site [1,9]. The titanium itself does not seem to be implicated in these clinical failure cases given the obvious errors found. Another material such as stainless steel would not have provided a greater level of protection relative to fixation failure that occurs from fatigue fracture of the material.

In our practice, we allow weight-bearing as pain allows for these minimally-invasive locking plate fixation cases [1—3] if certain rules are observed:

- extra-articular fracture;
- minimally-invasive surgery;
- long plate alternating between locking screw and empty hole (five holes on either side of fracture);
- bi-cortical screws;
- screws placed close to site of a complex fracture;
- screws placed away from site of a simple fracture.

For elderly patients, we allow weight-bearing if the preoperative level of autonomy is above 3 according to Parker and Palmer [14] and the aforementioned rules are followed.

Certain limitations add to the technical errors. Poor bone quality makes it difficult to use clever reduction approaches such as lever movements, because of the risk of bone fragmentation [2,3]. The LISS instrumentation can be difficult to use in patients with a large thigh circumference. The fracture itself can also be a source of limitations. An articular fracture is a contraindication to minimally-invasive surgery [2,3]; transverse fractures can be hard to manipulate with a minimally invasive approach. The length of the fracture can also be a limitation: the plates used must be long enough so that at least five holes are free on each side of the fracture [2—5,9]. The fracture environment is important. The presence of a femoral implant (prostheses or fixation) is not a limitation. The presence of the prosthesis itself in the femoral shaft and bone stock available for fixation must be taken into account. The applicable mechanical principles are the same as with native bone. An inter-prosthetic femoral fracture would be an extreme case. The surgeon is truly the greatest limitation in this surgical procedure. This person must understand the fixation system materials and mechanical principles, and must proceed with care. A locking screw will not make up for an incorrect fixation system, a purchase point that is tangential to the bone cortex or a position in the fracture site. It should be noted that when the screws are locked into the plate, any potential sensation of a problem with the screw’s hold into bone will be lost. Intra-operative radiological control is a basic requirement. General indications for internal fixation must be observed, especially in cases of periprosthetic fractures were the stability of the implant must be evaluated before suggesting a conservative treatment.

As much as possible, the procedure should be planned by reviewing the rules and limitations of this technique, making sure that the material is available, anticipating the operative steps and establishing a rehabilitation plan.

Conclusion

The minimally-invasive technique associated with these internal fixation implants stabilizes the reduction and allows for immediate mobilisation, which ensures a high-quality functional recovery. It requires experience and technical skill. The mechanical principles and indications for these fixation systems must be well understood and reviewed during preoperative planning.
Disclosure of interest

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