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Appropriateness of devices in the surgical treatment of femoral shaft fractures

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Summary

Femoral shaft fractures occur mainly due to high-energy traumas. To date, osteosynthesis represents the gold standard for the treatment of such fractures, and may be undertaken with a variety of stabilization methods: endomedullary nailing, plating, external fixation. However, there is no EBM literature unequivocally addressing a treatment for this topic.
In order to appropriately treat femoral shaft fractures the authors believe it is essential to consider the pattern of lesion from an anatomo-pathological viewpoint, to evaluate the fracture pattern and put in relation to the patient's conditions, pointing out that surgical versatility, trauma experience and skills and the appropriateness in choosing the devices of synthesis is essential to approach such lesions.

Key words: femoral shaft, synthesis devices, treatment appropriateness, femoral fractures, surgical versatility

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Introduction

Femoral shaft fractures occur in most cases following high-energy traumas [1].
Over time, the development of new surgical techniques, and the improvement of stabilization devices has brought about a radical change in the approach to and the management of these fractures.
For over 30 years, osteosynthesis has represented the "gold standard" treatment for femoral shaft fractures. This can be undertaken by several means of synthesis: endomedullary nailing, plating, external fixation [2-5].
Addressing the appropriateness of them implies that the topic be approached considering both the appropriateness of the devices (i.e. the choice of the most suitable implant) and the surgery (i.e. in relation to the correct application of the device in the actual case).

Epidemiology and pathogenesis

From an epidemiologic standpoint, femoral shaft fractures are characterized by between 10 and 37 fractures per 100,000 individuals each year. They have a trimodal distribution, with peaks in pediatric age, in young-adult age, and over 65. From a pathogenetic standpoint, such fractures occur in 48% of cases following a high-energy mechanism (road accidents, falls from a height, etc.), and can occasionally be correlated to polytrauma, with a mortality rate before hospital admission around 1.7%. In 35% of cases, femoral shaft fractures are the result of a low-energy trauma, and may thus be correlated with osteoporosis [1].

Classification and management

In the context of management of femoral shaft fractures, it is essential to analyze the clinical conditions of the patient, the potential impact on soft tissues and the fracture's characteristics

In traumatology, the most widely used classifications are the AO classification and the Winquist-Hansen classification. The first consists in associating a series of digits and letters to the fracture. As far as femoral shaft fractures are concerned, the anathomical segment is numbered 32 and the alphanumeric code correlates to the fracture pattern. The second classification is useful in order to evaluate the fracture's comminution, which has a direct relationship with their stability. This classification divides the femur shaft fractures into four types [6,7].

Treatment type

Once the clinical and radiographical framework of the case has been defined, it is possible to plan the most suitable treatment. It should be considered that the anatomical segment being examined has peculiar characteristics, which may affect management of the patient. These characteristics include choice if fixation device, surgical timing, patient age, associated lesions, polytrauma (DCO *vs* ETC treatment), relative frequency of malunions, and atypical fractures [7-12].

While it may be invasive and occasionally generate complications such as infections, device, breakage and consolidation alterations, osteosynthesis has numerous advantages, such as early mobilization, a greater stability at the fracture site, and a limited stay in hospital.

Surgical treatment of the femoral shaft can be achieved by several surgical methods: endomedullary nails, plates and external fixators built in different configurations (axial, circular or ibrid) [6].

Each of these options has advantages and disadvantages.

As for endomedullary nailing (Fig. 1), this is performed in 80% of cases and represents the gold standard for this treatment. The insertion of the nail allows alignment and axial correction, bony segmental length recovery and provides excellent stability [2].

The preference for this system derives from a biomechanical advantage. In fact, the endomedullary nail has a limited lever arm, thus resulting in a reduced "bending moment" ($BM = F \times D$). On the other hand, this parameter increases in the case of plating (Fig. 2) [13].

For a correct and appropriate application of the endomedullary nailing it is essential to consider that careful planning and patient preparation prior to surgery is mandatory in order to reduce potential early or late complications. Before the surgery, correct positioning of the patient on the traction table is essential (some authors prefer supine decubitus without traction). Also, the positioning of the X-ray source, with radiogenic beams orthogonal to the bony segment should be carefully evaluated. This is required to measure the length and the diameter of the medullary canal with dedicated devices and to allow appropriate reduction of the fracture [6,14].

The reduction maneuvers may be conducted with or without dedicated devices (hooks, pins), depending on the entity and the pattern of the fracture's displacement and its maneuverability; this is an important surgical phase for the evaluation and correction of any malalignment's and malrotations of the femur and for the nail measurement in terms of length and diameter. Furthermore, there are "indirect evaluation" systems that should be taken into account: cortical step sign, diameter of the bone segments (diameter difference sign), and shape of the lesser trochanter [14].

The surgical access for the intramedullary nail varies according to the use anterograde or retrograde technique, the indications of which vary mainly in relation to the morphological characteristics of the patient, the fracture pattern or the possible presence of devices of synthesis at the proximal femur level [6,15,16].

The anterograde insertion point starts with a longitudinal incision proximal to the apex of the greater trochanter that provides for three introduction points of the nailing implant according to the design of the device and the morphological characteris-

Figure 1. Healing of proximal femoral shaft fracture treated with intremedullar nailing.

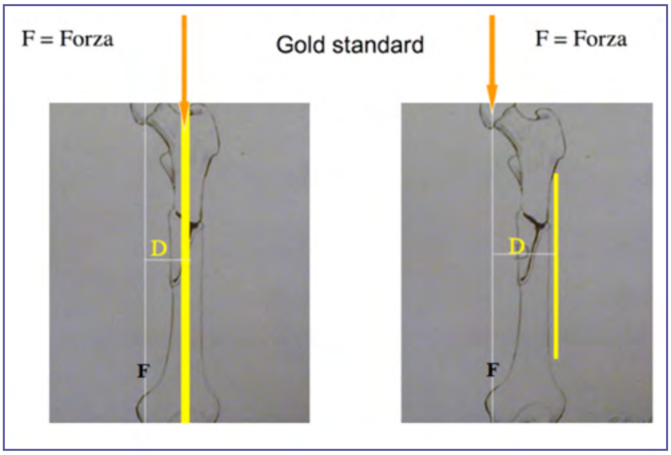

Figure 2. Biomechanical differences between osteosinthesis with plate and screews and osteosinthesis with intramedullar nail: the bending moment concept.

tics of the patient. They are pyriform fossa, apex of the greater trochanter or laterally to the apex of the greater trochanter checked via fluoroscopic control [6,10,15].

Retrograde access starts with an incision at the level of the patellar tendon to identify the entry point located at the top of the intercondylar fossa through fluoroscopic control in 2 orthogonal views (A-P and L-L) [6,17]. In A-P projection, the guide wire must be positioned anteriorly to the insertion of the posterior cruciate ligament and central to the intramedullary canal; while in L-L projection, the guide wire must be positioned at the apex of the Blumensaat line [2,6,17].

Advantages of nailing are mainly represented by the limited surgical invasiveness, leading to a more limited tissue damage, more limited vascular damage (hence a reduction of blood loss), reduced infection rate, early mobilization, and early weight bearing. Disadvantages of this surgical technique are associated with potential malreduction and malalignments of the fracture, as a consequence of failed direct or indirect reduction, and potential iatrogenic lesions related to device insertion (Fig. 3) [2,6,7].

Indications for retrograde nailing are obesity, floating knee, calcifications of the greater trochanter, pregnancy, lameness, tissue lesions and/or burns of the surgical entry point, and previous proximal femoral fractures. It should be considered that this access path may lead to patellar symptoms.

The literature has highlighted the advantages and disadvantages of retrograde nailing. The first are related to the possibility of having a single surgical access for the synthesis at the same time of both a diaphyseal fracture of the femur and tibia in case of "floating knee", and facilitation of osteosynthesis in overweight patients. Among the disadvantages, it should be noted that retrograde nailing has intra-articular access. For this reason, it could be harmful for knee articulations, and could determine an aggression to the extensor mechanism of the knee. This condition may then lead to pain at the patellar tendon [15-17].

Plating is indicated for 32B/32C fractures with trochanteric or condylar extension, children > 8 years where elastic synthesis doesn't produce fracture stability, narrow or deformed medullary canal, medullary canal sclerosis, hypertrophic pseudoarthrosis after osteosynthesis with intramedullary nail, periprosthetic/periimplant fractures, and associated vascular lesions requiring treatment of ipsilateral femoral neck/ipsilateral pelvis fracture (Fig. 4) [18].

As for the previously discussed surgical technique, plating has advantages and disadvantages. The first are related to the possibility of ensuring a greater stability for specific pattern lesions. The latter are related to a greater surgical invasiveness. This condition leads both to greater risk of infection, and to consolidation problems due to periosteal detachment. This technique may also be compounded by surgical device breakage [6].

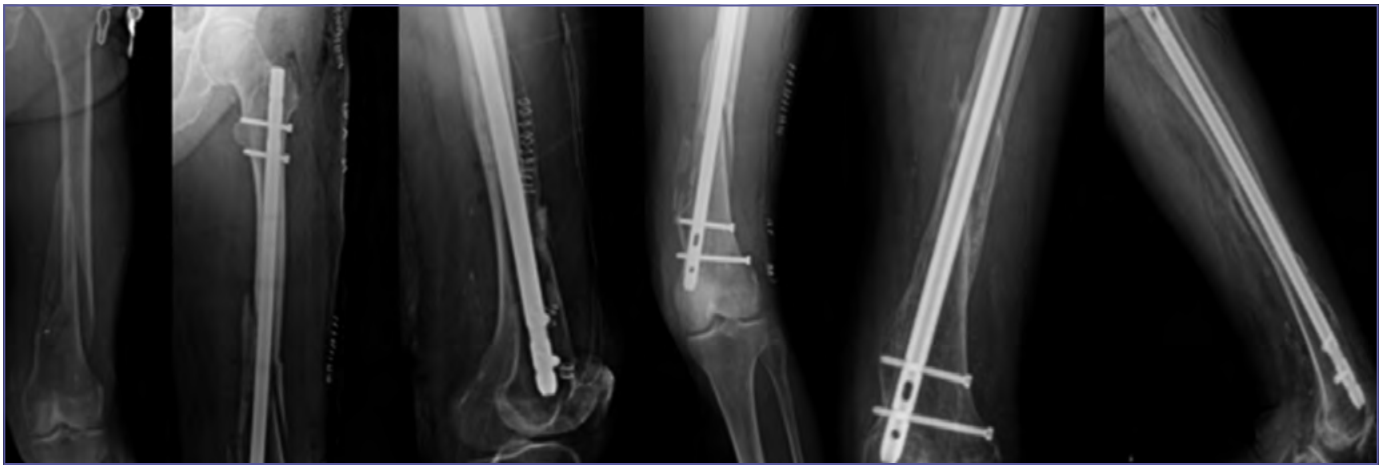

Figure 3. Technically inappropriated use of IMN resulting on malalignment and malrotation.

Figure 4. Complex proximal femural shaft fracture treated with screews and plate.

It is possible to use multiple devices with different types of plates varying on biomechanical terms (anatomical plates, DCP, angular stability, etc.), terms of assembly (single plate or double plate, metal plate + "biological plate") and positioning of the implant (traditional technique or MIPO and bridging plate technique) [3,19,20].

Plating technique has changed over time, always seeking greater respect for the fracture and reducing the risks related to open surgery. The "MIPO" (minimally invasive plate osteosynthesis) technique, having a minimally invasive character, leads to less aggression of soft tissues. Therefore, this surgical technique is advantageous in terms of respect for tissues and bone consolidation. It is used in comminuted fractures for which osteosynthesis with intramedullary nail is contraindicated. The MIPO technique involves a proximal or distal surgical access to the fracture; from the access point, the plate will be subsequently introduced and with a "sliding" movement, pushed along the bone, and then positioned over the fracture respecting as much as possible the biology of the tissues. The "bridging plate" technique allows to avoid acting directly on the fracture site bypassing it and screwing the plate proximal and distal to the fracture restoring length and alignment paying less attention to perfect reduction than to biology (Fig. 5) [3,20].

In term of biomechanical advantages, few scientific works have focused attention on the advantages conferred by a configuration of double plating that is indicated in cases of marked comminution of the femoral shaft or very weak bone.

Some studies, such as that of Gugala et al., believe that the orthogonality of the positioning of the screws in that configuration is more effective than other constructs [21,22].

To improve stability, in some conditions, such as pseudoarthrosis or osteoporosis, it is possible to stabilize the fracture through "biological" fixation. This stabilization technique involves the use of long bone grafts which, like metal implants, (double plate), will ensure greater stability by forming a stable three-dimensional construct and improve regeneration processes (Fig. 6) [23].

Osteosynthesis with external fixator has a significant importance especially in open fractures and in damage control orthopedic (DCO) when a temporary stabilization of the fractures should be achieved rapidly (Fig. 7). This surgical method has various advantages, such as a quick and simple execution technique, respect for soft tissues, reduction of the infection risk (especially in open fractures), temporary stabilization of the fracture in case of an unstable patient that could be converted into definitive treatment in case of maintenance of good reduction and stability of the fracture.

According to the literature, definitive stabilization in progress of DCO is desirable in 5-7 days, after evaluation of the patient's clinical and tissue conditions. The disadvantages of external fixation are reduced stability of the fracture and possible mobilization of pins [4,5,11].

Figure 5. Healing of femoral shaft fracture treated with bridging plate technique and MIPO.

Discussion

AO highlights the concept of "lesion entity", embedding the evaluation of the patient's clinical conditions, the potential impact on soft tissues, and the evaluation of the fracture's pattern. This philosophy is related to clinical and technical appropriateness in the use of devices for femoral shaft fracture treatment. For this reason, it is necessary to assess peculiarities, advantages, and disadvantages of each method. In fact, there are no EBM studies or reviews in the literature that define unanimously accepted treatment guidelines for diaphyseal fractures of the adult. In some specific cases, it is necessary to break out of the nailing-plating-external fixator scheme and find an integrated solution based on a careful examination of the anatomy of the lesion, as well as of locally associated osteoarticular pathologies (Fig. 8).

Additionally, some specific topics related to different indications, timing and technical execution in device application of various surgical techniques are still debated.

However, it is accepted that endomedullary nailing is the most widely used surgical technique for femoral shaft fracture, although some controversy remains on reaming or not reaming the femoral canal, a condition that is responsible for potential local and/or systemic effects. Among local effects reported in the literature, we may recall the transitory reduction of endosteal flow, transitory cortical thermal increase, intramedullary pres-

Figure 6. Diaphyseal pseudoarthrosis of femur shaft: implant removal and stabilization with plate and bone transplant.

Figure 7. DCO with external fixator.

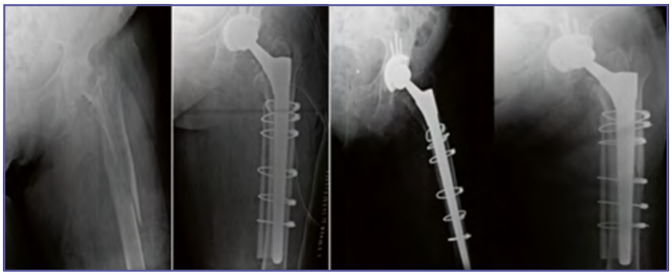

Figure 8. Spiral diaphyseal femur secondary to arthritic hip arthrodesis: treatment with hip arthroplasty, long stem, bone transplant and metal cerclage.

sure increase, compartment pressure increase and osteoinductive effect within the canal. Among systemic effects, the potential development of fat embolism with the patient's potential exitus must be considered [24].

Some authors support the intramedullary reaming technique, highlighting the improvement of consolidation processes, reduction of the risk of intraoperative fractures, and reduction of the rate of infections. However, debate persists regarding thromboembolic risk and compartment syndrome [25,26].

Concerning surgical timing, controversies have arisen with the birth of DCO, as opposed to the philosophy of early total care (ETC), relying on the immediate treatment of fractures [27].

ETC is not recommended in cases of polytrauma in a hemodynamically unstable patient and high blood levels of lactates.

Therefore, within the DCO, external fixation could guarantee the albeit transient stabilization of the fracture, avoiding further aggravating the patient's clinical condition. However, there is no clear scientific evidence that ETC causes an increase in complications in patients with polytrauma.

Some papers highlight how effective ETC is in polytraumatized patients in whom "aggressive" support of vital functions related to acidosis is implemented. Furthermore, some authors observe that the percentage of complications and death in polytraumatized patients is mainly linked to the severity of lung lesions, which would be the only true risk factor [5,11,12].

Osteosynthesis with plate and screws, considering the advantages and disadvantages inherent to the method, could represent the choice for complex clinical cases, such as multi-fragmentary fractures, pseudarthrosis, periprosthetic fractures or fracture following failed intramedullary nail. The use of plating has increased since the development of minimally invasive surgical techniques and the presence on the market of dedicated devices have reduced the intrinsic complications of the treatment.

On the other hand, the possibility of applying double plates, which increase fracture stability, could expand the indications for plating. The use of structural bone transplants to obtain greater stability and better biological response, especially in cases of bone fragility, should also be considered.

Conclusions

In conclusion, the authors believe that it is essential, for an appropriate treatment of diaphyseal femur fractures, to thoroughly understand the lesion from an anatomopathological point of view, evaluate the fracture pattern and contextualize it to the patient's condition keeping in mind that the surgical versatility and the appropriateness of choice of device and application is essential to approach these injuries.

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