Lateral femoral closing wedge osteotomy in genu varum.

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Technical note

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ABSTRACT

The distal femoral valgisation osteotomy has a variety of indications due to enhanced understanding of segmental deformities of the lower limb. Historically, an overall varus deformity was corrected at the tibia, and a valgus deformity at the femur. This approach of performing an "all in the tibia" correction for an overall varus can nevertheless lead to abnormal postoperative morphology because it is non-anatomical; creating joint line obliquity, and potentially shear stress on the cartilage. An original lateral femoral closing wedge osteotomy technique is described, allowing the correction of a genu varum of femoral or mixed origin, in the event of an associated tibial valgisation osteotomy. The detailed technique minimizes the risk of a hinge fracture while improving post-operative outcomes.

1. Introduction

The overall alignment of the lower limb is usually normocentered resulting from a tibial varus of 3–4° and a femoral valgus of 3–4° creating joint line obliquity of 2–3° in two-legged weight-bearing and horizontality during one-legged walking. For 17% of healthy subjects, the overall alignment of the lower limb is in varus (HKA < 177°), with a femoral or mixed (at least 3°) origin of this varus in almost half of the cases (45%) [1].

A recent series, [2] with a minimum follow-up of 5-years, set the threshold from which an oblique joint line of $\geq 4°$ causes functional repercussions. To limit these situations of deleterious tibial corrections, a femoral osteotomy can be performed (isolated or in combination).

In this technical note, we will discuss the technical features of the lateral femoral closing wedge osteotomy.

Abreviations: HKA, Hip-Knee-Ankle angle; mLDFA, Mechanical Lateral Distal Femoral Angle; MPTA, Medial Proximal Tibial Angle.

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2. Indication and planning

Our original indication was the existence of an overall varus deformity of the lower limb with the existence of early medial femoral-tibial osteoarthritis, associated with a substantial extra-articular deformity in the femur. However, "rescue" osteotomy should not be excluded in a young patient with advanced osteoarthritis and a lower femoral deformity.

The existence of an isolated mLDFA (mechanical lateral distal femoral angle) > 90°, or in association with a tibial correction, signify a satisfactory threshold for indication of correction in our clinical practice (normal mLDFA value = 86–87°).

Pre-operative planning must identify several key elements:

- the significance of the global deformity;
- the significance of the femoral, tibial and intra-articular deformities;
- defining the type of correction required;
- defining the ideal cutting plane.

The use of two cutting planes (biplanar osteotomy) has some advantages [3]:

- increased contact area at the osteotomy site;

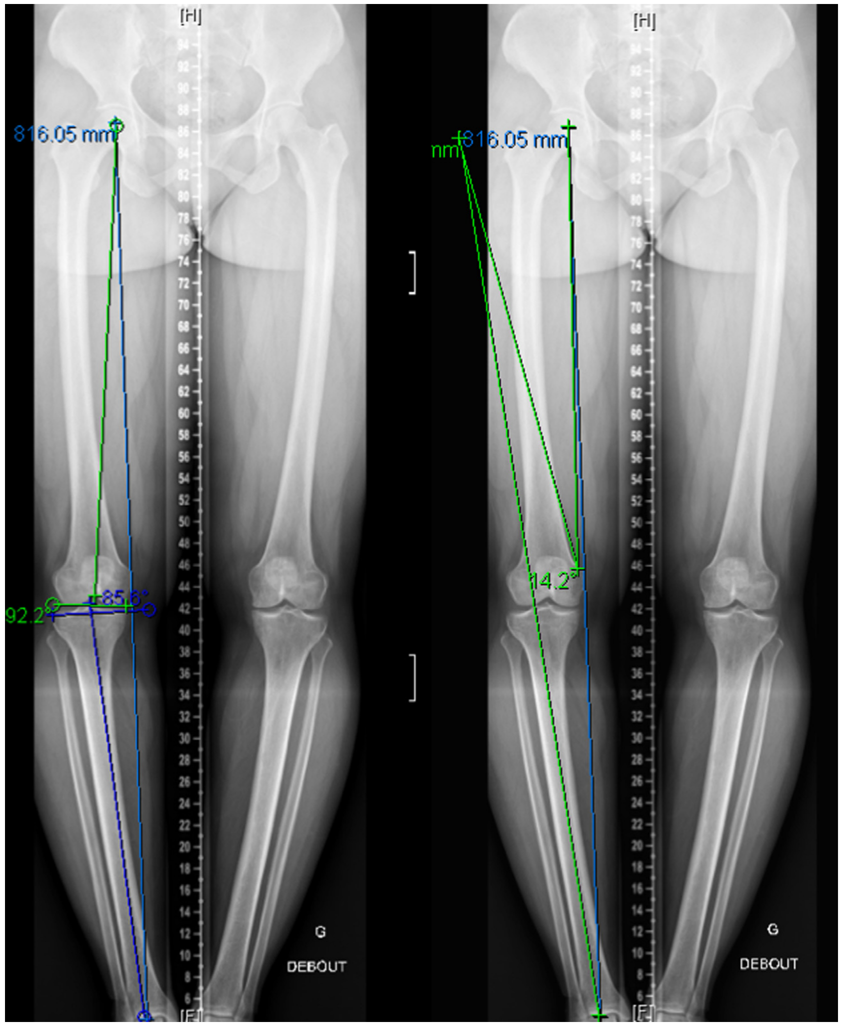

Fig. 1. Patient with a 5° femoral varus (anatomical mLDFA = 87°), a 14° correction is planned according to Miniaci, with the ratio of the patient's mechanical axis to the desired axis crossing the tibial plateau at 55% of its medial edge. A bifocal osteotomy will be performed.

Tips & Advice: How to determine the ideal cutting plane (Fig. 1)

- Undertake careful pre-operative planning, consider segmental bone deformities.
- Be wary of corrections of more than 8° (on a native femur it is exceptional to find a mLDFA > 95°), which are very risky in terms of potential hinge damage and must be avoided.
- Osteotomy cuts should be oblique and of equal length creating an isosceles triangle to allow ideal cortical overlap after closure.
- The cutting plane must be oblique (pay attention to the position of the plate) to help form the isosceles triangle.
- The hinge must be as close as possible to the medial epicondyle for maximum mechanical resistance.

- preservation of the rotary plane in the event of a hinge fracture;
- guided closure by sliding on this anterior cut.

The overall deformity is analysed and the correction is planned according to the Miniaci method [4], the degree of closure corresponds to the degree between the patient's mechanical axis and the planned one, crossing the tibial plateau at 55–57% of its medial edge (Fig. 1). This planning can be done freehand from the patient's pangonogram or by using semi-automated software, e.g. PeekMed software. According to Miniaci [4], planning consists of plotting the angle between the two projections (at the level of a line parallel to the ground, passing through the centre of the femoral head). The first is of the patient's weight-bearing line which passes through the centres of the femoral head and the ankle, and the second is a planned one which passes through the centre the ankle and the tibial plateau at 55–57% of the medial edge, at the level of the hinge of the femoral osteotomy site.

2.1. Hinge fracture

As with their tibial counterparts, femoral hinge fractures are defined by a three-grade classification, with type I being "propagation" fractures which extend from the modified osteotomy line, type II are diaphyseal extension fractures and type III are epiphyseal extension fractures. Notably, the incidence of these fractures is sometimes more than 50% depending on the series [5].

As for the tibia, the use of a protective pin positioned either through a custom cutting guide, or an out-in approach to modify our practice, drastically decreases the incidence of type I fractures without decreasing the occurrence of types II and III.

This pin is systematically used in all our lateral closing wedge osteotomies. It is inserted just below the medial epicondyle, in a central anteroposterior position, from inside-out and from distal

Fig. 2. The protective pin is positioned out-in (but can also be positioned through a custom-made cutting guide), to reduce the risk of a "propagation" fracture on the medial cortex (type I fracture). The pin is inserted just below the medial epicondyle, centrally in the anteroposterior plane, from inside out and from distal to proximal to intersect the two transverse wires.

to proximal, to cross the two transverse pins used to achieve the osteotomy (Fig. 2) [6].

3. Implementation

3.1. Patient positioning

The patient is placed in the supine position, we never use a pneumatic tourniquet but it can be positioned at the proximal end of the thigh.

It is necessary to check the neutrality of the limb rotation throughout the operation to avoid losing vision of the osteotomy lines and the path of the pins on the x-rays.

3.2. Approach

Tips & Advice: The approach

- The fascia-lata incision must be central and complete throughout the incision. We extend this incision by 2 cm on both sides with scissors to allow the fixing plate to slide without resistance.
- The dissection of the wide lateral fibres, which must be separated from their expansion on the ilio-tibial band, is done using a finger.
- The vastus lateralis is also dissected from the intermuscular septum, using fingers, taking care to coagulate the perforating arteries. This step must allow the final osteosynthesis plate to slide in contact with the femur without being hindered.
- A careful incision of the aponeurotic insertions of the vastus lateralis on the sharp line at the osteotomy site must protect the posterior face of the femur.
- The surgeon must be able to slide a finger until the femoral insertion of the medial gastrocnemius to ensure that the neurovascular bundle is positioned posteriorly.
- Two curved retractors (ideally radiolucent) protect and allow viewing of the anterior and posterior aspects of the femur.

A 5–6 cm approach is made at the lateral aspect of the thigh. We recommend a proximally wider approach to facilitate the visualization of the lateral femur, it is made distal to the projection of the upper part of the patella on the lateral aspect of the thigh and ascends the "trouser seam", as for a standard lateral femur approach.

We then insert two guide pins from 2 to 2.5 mm (ideally threaded to simplify their positioning), at the beginning of our experiment we used 4 pins (two superior and two inferior, in

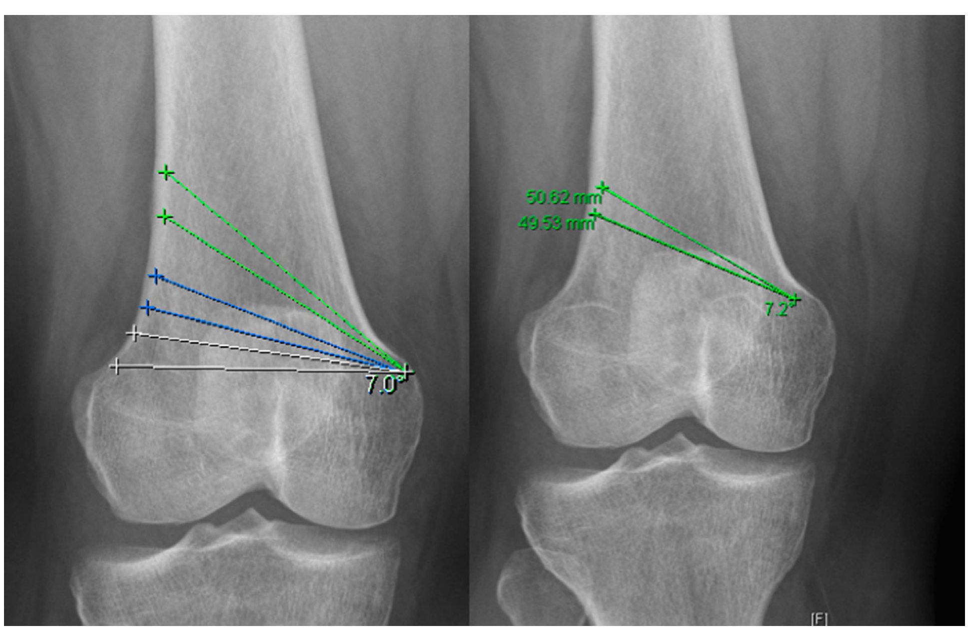

Fig. 3. Representation of the bone sections in a patient planned for a 7° lateral closure, the pins must form an isosceles triangle-shaped path with the apex reaching the top of the epicondyle. The path of the cuts must be oblique, downwards and inwards, the origin of the cuts is therefore preferentially positioned above the distal metaphysis of the femur. If the osteotomy is too proximal, there is a risk of pseudarthrosis, if it is too distal the closure wont overlap because the cutting triangle is not an isosceles.

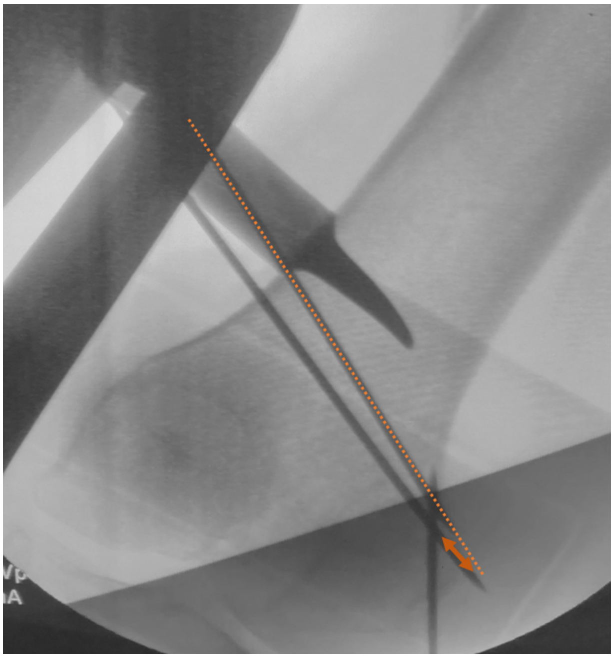

Fig. 4. The proximal and distal pins must intersect 2 to 3 mm after the endpoint of intersection of the cutting planes. If too early, the crossing of the pins limits saw blade advancement and exposes the hinge to fracture risk.

parallel, two by two, to rigidly control the path of the saw in the transverse and sagittal planes).

They are placed obliquely downwards and inwards, starting from the lateral cortex to draw an isosceles triangle whose apex is closest to the medial epicondyle while respecting a 5 mm hinge for the two future saw cuts (Fig. 3).

Beware of crossing of these pins too early, which will prevent the saw blade from advancing to the hinge, leaving it too thick and increasing the risk of fracture (Fig. 4). To do this, it is necessary to imagine and visualize their crossing 2–3 mm farther than the endpoint of the cutting planes.

The length of the cut to be made can be evaluated with a third pin (by removing the 5 mm hinge) to anticipate the depth of the saw blade.

A last pin is put in place from the outside-in, starting from the distal part of the medial condyle and ascending to cross the two transverse pins.

This pin should protect your hinge from a strong saw cut. We leave it in place until the osteotomy site is completely closed to increase the resistance of the hinge against breaking.

The two cuts are then made by sliding on the pins, requiring force to “try to cut the pins” in order to slide the saw blade in the right direction.

The two cutting planes must be parallel to each other and perpendicular to the mechanical axis of the femur. The visualization of the saw as a line and not a rectangle ensures, in our opinion that it is orthogonal to the x-ray and thus the leg is in extension to the mechanical axis of the femur (Fig. 5).

It is imperative to keep an anterior area of the femur (anterior 1/3) intact to subsequently perform the ascending biplanar cut under the femoral trochlea (Fig. 5).

Similarly, the cooling of the saw blade is essential to avoid burning the bony margins.

Frequent scope checks should reassure the operator about the distance to be covered and especially the position of the saw in the frontal (against the guide pin) and sagittal planes. Only a thin line is visible, proof that the saw is perpendicular to the radioscopic electron beams.

After the two descending cuts are made, fluoroscopy is centred on the hinge, after removal of the pins, to estimate the remaining bone thickness medially. If too thick, it will sometimes be necessary to weaken the hinge area with the saw, scissors or a 2.7 mm drill bit.

The ascending cut is made freehand without the addition of a guide pin.

3.3. *Closure of the osteotomy site*

Once the biplanar cut is complete, the bone fragment between the two transverse lines is easily extracted.

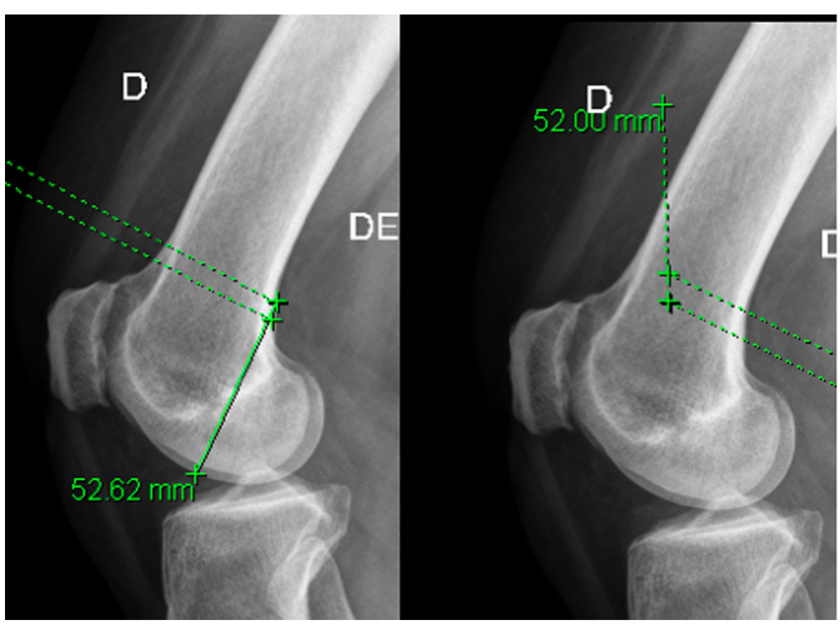

Fig. 5. The two planes are parallel and perpendicular to the mechanical axis of the femur.
The anterior area of the femur (anterior 1/3) is left intact to make the ascending biplanar cut. A monoplanar and more distal cut puts the trochlea at risk of breaking.

Ensure that you take your time not to break the medial hinge by a sudden reduction.

The closure must be done “alone” and especially without constraint. Pressure must be applied to the foot in the axis of the operated leg, without creating a valgus. Once the reduction is achieved, pressure must be kept on the foot to prevent the site from reopening.

Tips & Advice: If the reduction is not simple

- Verify that your upward cut is complete
- Using your finger, check the cut at the level of the posterior cortex, especially close to the epicondyle (arch of the medial gastrocnemius insertion) is complete and if not, complete it (Fig. 6)
- The elasticity of the bone can be improved at this stage, also using medial cortex “pie crusting”, using a 2 mm driller.
- Above all, do not to force the reduction!

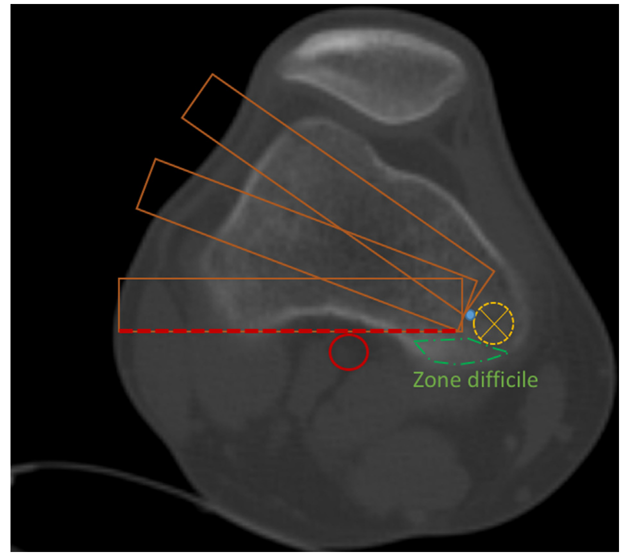

Fig. 6. We verify that the cut at the level of the posterior cortex is complete, especially at the level of insertion of the medial gastrocnemius, which represents a more difficult to access area because of its associated risks (neurovascular bundle in the axis of the cutting plane). Zone difficile = difficult area.

3.4. Osteosynthesis

Start by checking the overall alignment with an alignment rod that should pass through the Fujisawa point, which corresponds to the intersection of the load line with the previously selected tibial plateau (in our experiment 55–57% is the apex of the lateral spine) [7,8]. Then slide the plate, put in place a distal locked screw, then a proximal cortical screw applied by hand, keeping the osteotomy site closed by applying pressure on the foot. Complete the placement of the distal locked screws. The last two proximal screws can be monocortical to limit the rigidity of the assembly.

We prefer plates in descending directions for the distal screws because they avoid the crossing of the screws in the osteotomy site and especially since they can be positioned high enough to avoid a conflict with the fascia lata at the level of the distal femoral metaphysis (Fig. 7).

3.5. Operational follow-up

We suggest partial support for 2 weeks (20 kg maximum) to our patients with walking aided by an English cane for 1 month (maximum of 50% body weight).

No limitation to the range of motion is necessary, nor any splint.

Cryo-pressotherapy, available to patients for 4 weeks is very useful, as is the use of systematic tranexamic acid during the procedure. Hematomas are, in our experience, the most common and disabling complication postoperatively.

The resumption of professional activities is generally possible at 3 months and unrestricted sports activities at 6 months.

3.6. Our series

We operated across three centres, performing 75 lateral femoral closing wedge osteotomies in 3 years (with a mean follow-up of 25 ± 11 months). The mean pre-operative femoral varus value (mLDFA) was 91 ± 2° for an expected correction of 6 ± 2°. The post-operative mLDFA was 85 ± 3°.

This procedure was performed in isolation in 19% of cases (14 knees), there was an associated tibial osteotomy in 76% of cases (57 knees) and ligamentoplasty of the anterior cruciate ligament in 9% (7 cases). A cartilaginous or meniscal intervention was associated in 45% of cases (34 knees).

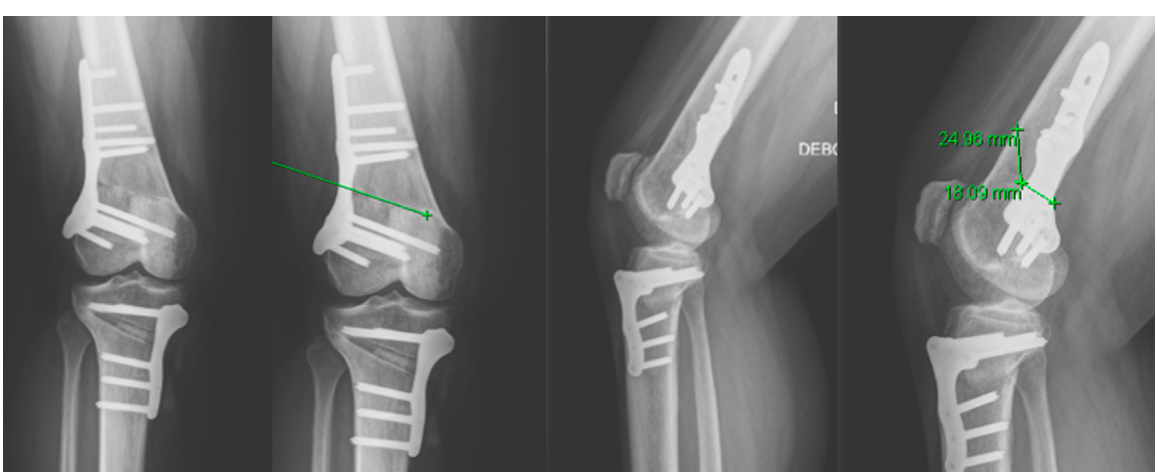

Fig. 7. Locked plate osteosynthesis with placement of monocortical screws by pressure on the foot. The downwards direction of the distal screws is important to avoid the path of the osteotomy.

Table 1
Post-operative functional outcomes by KOOS sub-categories.

	Preoperative (average % ±SD) [min–max)]	Postoperative (average % ±SD) [min–max)]	Δ	p
Pain	56.4 ± 10.3 [22.5–70]	93.0 ± 11.6 [54–100]	32.5 ± 11.2	< 0.0001
Other symptoms	49.2 ± 16.2 [20–70]	82.0 ± 15.9 [51–100]	36.5 ± 18.9	< 0.0001
Function in daily life	54.0 ± 13.1 [20.3–70]	85.7 ± 15.0 [41.2–100]	30.3 ± 21.1	< 0.0001
Activities, sport and leisure	36.4 ± 19.1 [1.3–73]	76.8 ± 21.2 [24–100]	19.2 ± 28.8	< 0.0001
Quality of life	43.9 ± 14.0 [7.5–61]	79.8 ± 19 [40.8–100]	34.7 ± 20.1	< 0.0001

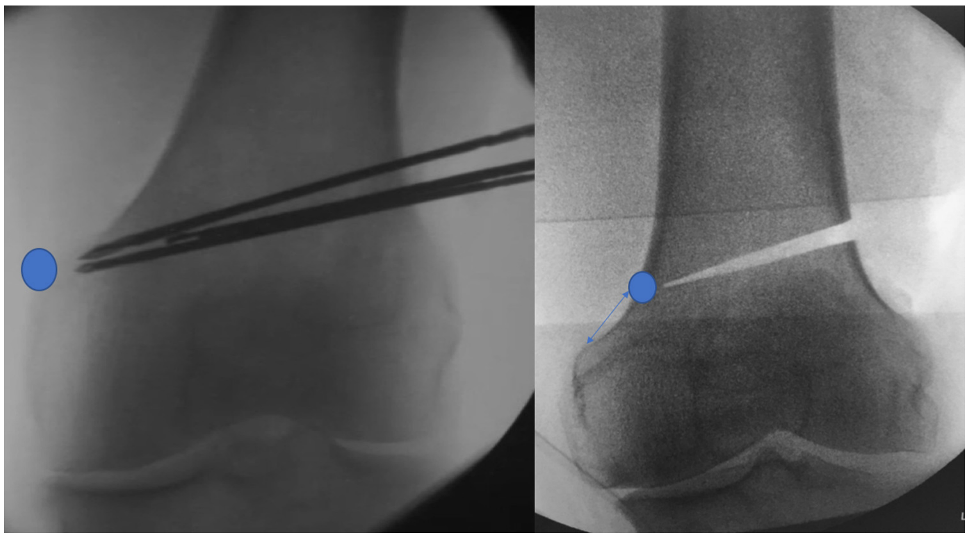

Fig. 8. The position of the hinge is defined close to the medial epicondyle, the thinned cortex at this level helps to limit the risk of fracture of "propagation".

All KOOS sub-scores were significantly improved (all $p < 0.0001$) at the last follow-up (Table 1).

Resumption of professional and sporting activities were possible at 3 ± 2 months and 7 ± 3 months respectively.

The rate of hinge fracture in our series is relatively high (12%): 6 patients suffered an ascending fracture and 3 had "propagation" fractures in the continuity of the line. From our experience in this series, we modified the position of our hinge, bringing it closer to the medial epicondyle to practice the rotation of the distal fragment on a softer and thicker hinge (Fig. 8).

No revision was performed after a maximum follow-up of 3 years, but six patients (8%) presented consolidation delays of more than 6 months, without leading to pseudarthroses.

4. Discussion

If a varus deformity of femoral origin is corrected by tibial osteotomy, the axis of the limb will be corrected at the expense of the joint line becoming oblique [9–11].

A recent finite element (3D) analysis showed that an obliquity of the joint line > 5° would induce excessive shear stresses on the joint cartilage [12]. Similarly, Akamastu et al. found greater oblique lines and poorer functional outcomes in patients who had undergone significant tibial correction [13].

In our experience, the frequent use of femoral osteotomy has opened our eyes to the unfavourable outcomes of patients with "everything in the tibia" corrected. A recent study based on planned osteotomies with custom-made cutting guides reported a correction site error in 50% of procedures performed with the creation of very abnormal bone morphology [14].

To date, there is no formal evidence regarding the clinical superiority of femoral osteotomy over tibial osteotomy, or regarding the benefit of a double corrective osteotomy. Thus, some authors do not find any clinical difference between patients having tibial over-correction (MPTA > 95°) and normally corrected patients (MPTA < 95°); explained by probable compensation mechanisms in the hip and ankle [15], while other authors argue that functional scores, including KOOS sport, are higher in patients with a MPTA < 95°. It is therefore essential to analyse the site of the deformity to justify the indication for femoral valgisation osteotomy. If the femoral deformity is predominant, a correction limited to the tibia does not seem logical. In case of large preoperative deformity (> 14°), an inaccuracy related to the correction of a single site, with more than 7° of tilting of the line, can be observed. Line obliquity can thus be anticipated before the osteotomy by analyzing the direction of the line preoperatively on a weight-bearing pangonogram and by projecting its direction after correction; A femoral valgisation osteotomy will modify the line downwards and inwards, while a tibial valgisation osteotomy will modify the line spacing downwards and outwards.

Human anatomy completely excludes large valgus deformities of the tibial metaphysis which do not occur naturally and are therefore purely iatrogenic [1]. This femoral osteotomy may also be associated with a total prosthetic knee replacement when the extra-articular deformity is significant [16].

The literature also does not make it possible to define the optimal strategy between femoral osteotomy by lateral closure or medial opening. Nevertheless, the possibility of immediate weight-bearing and the stable character of the reduction provided by closing wedge osteotomies led us to abandon (except in cases of preoperative unequal, symptomatic length) medial opening wedge osteotomies in femoral varus [17]. Performing a lateral femoral closing wedge osteotomy is considered technically difficult because the surgeon must rely on the precision of the bone resection [18].

It is imperative to check the correction made using the alignment rod, in fact two elements impact the precision of the action; the thickness of the saw blade and the position of the pins in relation to the preoperative plan.

There is also no formal evidence of the value of biplanar cuts compared to monoplanar cuts. However, the level of certainty they offer in relation to hinge management counterbalances, without doubt, the apparent simplicity of the medial opening wedge, which infers a high risk of serious complications inherent to single transverse, cuts on a cylindrical body.

Ethics approval

The local ethics committee has approved our study protocol.

Informed consent

Not required.

Disclosure of interest

M.F.A. and G.M. declare that they have no competing interest.

L.H. is a consultant for Arthrex. M.O., M.E. and K.K. are consultants for Newclip.

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Contribution of the authors

M.O. and K.K. designed the protocol and carried out the statistical analysis. M.F.A. and M.E. collected the data. M.O., L.H. and K.K. drafted the initial project and carried out revisions of the various projects. M.O., M.E., M.F.A. and G.M. corrected the various versions of the project. G.M., M.E. and M.O. participated in the writing and revisions of the manuscript. All authors approved the final version.

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