Rotational femoral osteotomies using an endomedullary saw

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Summary
Introduction: The goal of this retrospective study is to analyze a series of ten patients (11 osteotomies) who underwent closed femoral rotational osteotomy using an endomedullary saw; stabilization was achieved by a locked centromedullary nail. We report the indications, technical aspects, clinical and radiological results as well as intercurrent complications with this surgical technique.

Hypothesis: Femoral endomedullary osteotomy is a safe procedure to correct malrotations.

Patients and methods: Eleven femoral rotational osteotomies using an endomedullary saw were performed on ten patients, between January 1999 and July 2007. The indications were post-traumatic rotational malunions or congenital rotational deformities. The angular deformity averaged 33.5° (24°–52°). They were divided into internal rotation (ten cases) or external rotation (one case). One patient required a bilateral rotational osteotomy because of a congenital femoral malrotation combined to bilateral trochlear dysplasia. Rotational correction was, in two patients, simultaneously associated with a closed lengthening osteotomy. Clinical and radiological follow-up averaged 4 years and 9 months (26–104 months). The angular corrections obtained by these rotation osteotomies were calculated by CAT scans.

Results: Ten out of eleven osteotomies allowed a correction within a 4° range in relation to the physiological femoral neck anteversion values (or to the contralateral side in the case of a healthy opposite lower extremity). There was no bone, joint, skin, or soft tissues infection, no pseudoarthrosis and no delayed outgrowth. We observed a transient neurological complication in the area of the pudendal nerve, during a combined rotational-lengthening osteotomy, as well as a bilateral femoral fracture during the bilateral rotational osteotomy. In all patients, consolidation occurred within a 3- to 5-month delay. The subjective results showed that eight out of nine patients (one was lost to follow-up) were satisfied or very satisfied with their operation, their functional recovery and the aesthetic aspects of their scars.

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Discussion: Closed rotational osteotomies in adults represent a reliable, effective, safe and reproducible procedure for the correction of femoral torsion problems, whether they are post-traumatic or congenital. These results can be obtained only by respecting the indications and by applying a rigorously planned technique, including expertise in centromedullary nailing.

Level of evidence: Level IV, retrospective therapeutic study.

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Introduction

Corrective femoral osteotomy in adults, as a closed procedure with the use of an endomedullary saw, is a tempting, minimally-invasive technique for the correction of lower limb length inequalities or problems of torsion. Convinced of the advantages of a closed procedure (fewer infectious complications, better local environment for bone regrowth by periosteal preservation), Küntscher [1] conceived the first endomedullary saw model in 1962. Before that, the results of early femoral osteotomies with centromedullary nailing but as an open procedure were rather mediocre [2]. Many instrumentation changes, of the endomedullary saw as well as those of the surgical technique itself, were then made by Küntscher, followed by Winquist [3], with a saw designed by the Boeing Company in 1973, and by Grosse et al. [4] much later in 1987. This technique gradually became less invasive, significantly reducing morbidity from corrective femoral and tibial osteotomies (derotation, shortening or lengthening), whether they were extemporaneous [3—6] or progressive with Albizzia nails [7]. Rapid resumption of support for it came, among other things, at the expense of open techniques that often caused a large incision hampered by aggressive exposure and periosteal stripping [8,9]. It has thus become possible to reduce the inconveniences of external fixation and the Ilizarov technique, such as cutaneous or even bone infection, stiffness of over and underlying articulations by the transfixation of soft tissues, pseudoarthrosis, secondary axial deviation of the operated limb, the risk of fracture of the regenerate and discomfort [10—12]. The goal of this retrospective study was to objectively evaluate the indications, advantages and disadvantages of closed femoral derotation osteotomy with endomedullary saw. Our hypothesis was that the technique is safe and allows derotation corresponding to preoperative planning of targeted indications.

Patients and methods

Instrumentation

Femoral derotation osteotomy, seldom coupled with lengthening osteotomy, was performed on an orthopaedic table under fluoroscopic control, sharpened flexible borers, a Stryker® endomedullary saw and cylindrical, locking, hollow and non-split centromedullary Grosse and Kempf (Stryker®) type nails. These specific materials comprised a saw with an eccentric saw (saws of 14, 16 and 17 mm were available). The instrument thus worked via an eccentric action, in a cutting zone of 9 to 25 mm beyond its point of endomedullary contact (Fig. 2a and b). Standard radiographic assessment made it possible to determine the size and width of the final nail and to prepare a workshop-modified centromedullary nail necessary for this type of intervention. The latter thus comprised a proximal oblong locking hole with a 5-mm vertical axis, which acted as a slipping hole and, during support, provided interfragmentary compression at the osteotomy level.

Series

Our retrospective study included ten patients (11 osteotomies) (four men and six women) treated, between January 1999 and July 2007, by closed femoral osteotomy with a Stryker® endomedullary saw. Average age at surgery was 30 years (17—55 years). Eleven femoral derotation osteotomies were performed, including one bilateral and two combined with lengthening. The rotation problems were related to femoral malunion secondary to fracture initially treated by non-locking centromedullary nailing in eight out of ten cases, and congenital deformations in two cases (patients 8 and 9) (Table 1).

Operative technique

The patient was installed in the dorsal decubitus position on the orthopaedic table, and the limb was operated in traction provided by a strong velcro fastener. Three major precautions were taken: the patella was placed at its zenith, a U support was positioned a few centimeters under the popliteal cavity, and the leg was put in adduction so as not to be obstructed by the patient's flank during introduction of the endomedullary saw. The entry point at the level of the greater trochanter was located by fluoroscopy, and the bore...
guide was inserted. Flexible boring was gentle and progressive until the recommended size of 1 mm above the size of the saw used. The endomedullary saw was introduced with some semicircular movements in the diaphyseal shaft until the limit fixed for the osteotomy, with the blade in the neutral position (cursor at 0°) under fluoroscopic control. The level of the osteotomy was located in the mediodiaphyseal zone, in the lower part of the gluteus maximus muscle insertion and at a distance from the malunion. The blade was gradually deployed by notching of 10°, thanks to the handle cursor. At least three complete rotations of the blade were necessary at each cutting stage, and we did not need to supplement all osteotomies with open osteoclasis. The nail guide and locking centromedullary nail were introduced into the diaphysis, under fluoroscopic control. Adjustment of rotation was facilitated with Kirschner pins, of which one was placed in the lateral femoral condyle and the other in the greater trochanter, with angled metallic squares (Fig. 3). Once the desired correction was made by aligning the two Kirschner pins, the nail was locked “dynamically” (opening of modified proximal locking) to avoid secondary malpositioning in rotation or tipping in varus/valgus [13].

In the two cases of combined lengthening-derotation, lengthening osteotomy was undertaken before derotation. Lengthening was achieved, after a first complete circular osteotomy, by exerting traction, limited to 50 kg, in the lower limb axis. The spongy graft, taken from the iliac crest and directly mixed with the reaming product, was directly installed via the medullary canal with a pleural drain. This extemporaneous technique allowed maximum lengthening of 15 mm, measured directly with a graduated strip introduced endomedullarily. Finally, the centromedullary nail was introduced through the lengthening focus filled by the bone graft, and derotation was safely carried out. The nail was finally locked statically.

Postoperative care

Postoperative care comprised drainage 48 hours, topical icing, analgesic treatment (classes 1 and 3), and anticoagulation until protected, active and complete ambulation. The first time the patient got up was on day 1, support was resumed with two crutches on days 2 and 3, and, at the same time, exercises for knee and hip articular maintenance were performed homolaterally. Resumption of complete support in total load, without a cane, was allowed around the third month, as soon as radiological bone regrowth occurred. The theoretical time of material removal was 18 months after radiological consolidation.

Pre- and postoperative evaluation

Anomalies of rotation were assessed clinically by measuring internal and external rotations, leg in flexion (hip in extension and knee in flexion) and extended (hip and knee

![Figure 2](image1.png)

**Figure 2** Endomedullary saw: blade aspect for an eccentric effect (a), and mechanism of endomedullary action (b).

![Figure 3](image2.png)

**Figure 3** Derotation osteotomy: technique using distal and proximal pins and defined angulation squares, of 35° here (a, b, c). Positioning of the pins before correction, followed by their alignment after derotation (d).
Rotational femoral osteotomies using an endomedullary saw

Table 1

Summary of ten patients.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>MU IR 30</th>
<th>MU IR 35</th>
<th>Age at surgery</th>
<th>Initial deformation</th>
<th>MU IR 30 R</th>
<th>MU IR 35 L</th>
<th>Fem shortening</th>
<th>Etiology</th>
<th>Operating time (min)</th>
<th>Blood loss (per- + postop)</th>
<th>Transfusion</th>
<th>Consolidation</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td></td>
<td></td>
<td>20 years</td>
<td>30° R</td>
<td>120</td>
<td>120</td>
<td>20mm</td>
<td>Post-trauma</td>
<td>190</td>
<td>1210 ml (1100 + 110)</td>
<td>0</td>
<td>3 months</td>
<td>26 months</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td></td>
<td></td>
<td>31 years</td>
<td>35° L</td>
<td>630</td>
<td>630</td>
<td>20mm</td>
<td>Post-DLCMN</td>
<td>145</td>
<td>1700 ml (1600 + 160)</td>
<td>0</td>
<td>4 months</td>
<td>32 months</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td></td>
<td></td>
<td>27 years</td>
<td>30° L</td>
<td>300</td>
<td>300</td>
<td>20mm</td>
<td>Post-nailing</td>
<td>245</td>
<td>4140 ml (3000 + 1140)</td>
<td>0</td>
<td>30 months</td>
<td>78 months</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td></td>
<td></td>
<td>40 years</td>
<td>35° R</td>
<td>1400</td>
<td>1400</td>
<td>20mm</td>
<td>Post-SLCMN</td>
<td>230</td>
<td>500 ml (500 + 0)</td>
<td>0</td>
<td>0</td>
<td>104 months</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td></td>
<td></td>
<td>23 years</td>
<td>30° L</td>
<td>1000</td>
<td>1000</td>
<td>20mm</td>
<td>Post-SLCMN</td>
<td>195</td>
<td>4140 ml (3000 + 1140)</td>
<td>0</td>
<td>4 months</td>
<td>32 months</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td></td>
<td></td>
<td>40 years</td>
<td>35° R</td>
<td>120</td>
<td>120</td>
<td>20mm</td>
<td>Post-SLCMN</td>
<td>200</td>
<td>2400 ml (2000 + 400)</td>
<td>0</td>
<td>0</td>
<td>30 months</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td></td>
<td></td>
<td>23 years</td>
<td>30° L</td>
<td>1000</td>
<td>1000</td>
<td>20mm</td>
<td>Post-SLCMN</td>
<td>150</td>
<td>1850 ml (1450 + 400)</td>
<td>0</td>
<td>4 months</td>
<td>32 months</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td></td>
<td></td>
<td>55 years</td>
<td>35° L</td>
<td>3120</td>
<td>3120</td>
<td>20mm</td>
<td>Post-SLCMN</td>
<td>105</td>
<td>680 ml (300 + 380)</td>
<td>0</td>
<td>0</td>
<td>104 months</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td></td>
<td></td>
<td>21 years</td>
<td>30° L</td>
<td>1200</td>
<td>1200</td>
<td>20mm</td>
<td>Post-SLCMN</td>
<td>95</td>
<td>1230 ml (600 + 30)</td>
<td>0</td>
<td>4 months</td>
<td>32 months</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td></td>
<td></td>
<td>17 years</td>
<td>30° L</td>
<td>1200</td>
<td>1200</td>
<td>20mm</td>
<td>Post-DLCMN</td>
<td>45</td>
<td>440 ml (200 + 240)</td>
<td>0</td>
<td>0</td>
<td>30 months</td>
</tr>
</tbody>
</table>

MU: malunion; IR: internal rotation; ER: external rotation; R: right; L: left; SLCMN: statically-locked centromedullary nailing; DLCMN: dynamically-locked centromedullary nailing; CHD: congenital hip dislocation.

Ilizarov assembly [14].

utation of lengthening techniques by external fixation and technique appeared important to us, given the poor rep-
satisfied, very satisfied. Aesthetic evaluation of this closed technique appeared important to us, given the poor reputation of lengthening techniques by external fixation and Ilizarov assembly [14].

Results

Average follow-up was 4 years and 9 months (26—104 months). One patient was lost to follow-up. No postoperative hematoma was noted. One patient (combined lengthening-derotation osteotomy) presented pudendal nerve compression (internal pudendal nerve), because of peroperative pubic support, and suffered perineal paresthesia with erectile problems for nearly 1 year. He has currently completely recovered full perineal sensitivity. The duration of surgery in this patient (No. 3) was the longest (245 minutes). Finally, one patient (No. 9) incurred bilateral peroperative femur fractures during bilateral derotation osteotomy. Preoperative radiological assessment revealed pronounced sagittal curves and medullary femoral narrowing, limiting access of the 14-mm diameter endomedullary saw. These fractures, however, did not prevent derotation surgery and the two static locking centromedullary nails. Full regrowth of the fracture and osteotomy centers then occurred in 3 months, and the patient was satisfied with her surgery. No postoperative cutaneous (infection, disunion, etc.), thromboembolic complications (phlebitis, pulmonary embolism, fat embolism, etc.) or osteoarticular events (osteitis, osteoarthritis, pseudoarthrosis, etc.) were observed in these ten patients. No materiovigilance incidents (broken nails, screws), even of the endomedullary saw, were encountered peroperatively and postoperatively. Average blood loss (per- and postoperatively) was 986.7 ml (500—2400 ml) in pure derotation osteotomies, and 3000 ml (1860—4140 ml) in osteotomies combining derotation and

in extension). All patients underwent pre- and postoperative radiological examination. Standard radiographs of the anterior femur and profile, scale 1/1, were necessary, the profile providing information on the sagittal curve and possible difficulties encountered at the time of nail passage. The APview made it possible to appreciate two fundamental elements of the therapeutic strategy: the length of the centromedullary nail required and the width of the medullary canal. Indeed, this was imperative to obtain a diameter sufficient for 14.5 mm reaming to pass the smallest size endomedullary saw (14 mm) and a Grosse and Kempf nail of 13 mm diameter. If this was not the case, we opted for the classical diaphyseal open osteotomy technique, and fixation by screwed plate. Tomodensitometry of the hips and knees in bilateral helicoidal axial cuts and in bone sequences was undertaken to define the femoral torsional anomalies and articular axes and thus precisely calculate angular surgical correction. In the event of bilateral malformation, we compared the measured anteversion of the femoral necks with physiological anteversion of 15°. The quality of the correction was assessed by comparing the rotational values (expressed in degrees) preoperatively and postoperatively. The functional and cosmetic global results were evaluated from simple clinical data and on a scale indicating that the patient was: dissatisfied, not very satisfied, satisfied, very satisfied. Aesthetic evaluation of this closed technique appeared important to us, given the poor reputation of lengthening techniques by external fixation and Ilizarov assembly [14].
limb lengthening. The relationship between the amount of bleeding and operating time for each type of intervention was established by an index ratio (I/R) of derotation I/R = 6.73 and combined I/R = 12.63. Table 1 reports the number of red blood cell packs (RBCP) administered peri- and postoperatively for each patient. Regrowth occurred in all patients within an average of 3½ months (3–5 months). Eight out of nine patients (one was lost to follow-up) were satisfied or very satisfied as much with the functional as the aesthetic results. These nine patients admitted having fully recovered their muscular capacity between 8 and 12 months on average (Table 2).

Preoperatively, rotational anomalies were mostly internal (ten malunions in internal rotation versus one malunion in external rotation) and were between 24° and 52° with an average of 33.5°. In the case of isolated derotation osteotomies, eight out of nine achieved correction to nearly 4° (Fig. 4, Table 2). Only one patient (No. 9) was 9° hypercorrected relative to initial objectives, during bilateral femoral derotation osteotomy, complicated by bilateral femoral fracture.

**Discussion**

Retrospective analysis of these results showed that post-traumatic rotational anomalies (with an incidence close to 45%) [15] or congenital femur disorders are good indications for corrective femoral osteotomies [16]. They may be performed with closed technique thanks to endomedullary saws and stabilized by dynamically-locked, reamed centromedullary nails. Osteotomy with endomedullary saw addresses not only isolated rotation problems but also cases of frontal or sagittal femoral malunion [4]. A major technical limitation of this method is found in the framework of post-traumatic malunion, because complete cortical sectioning is sometimes impossible by the endomedullary approach, especially if osteotomy is attempted at the level of the malunion. Even if that was not the case in our series, since we performed our osteotomies at a distance from the malunion, it is sometimes necessary to complement a closed osteotomy with an open lateral cortical osteotomy, with a short incision of 1 to 2 cm, controlled with fluoroscopy. Whether the problem is congenital or post-traumatic, most cases involve excess antetorsion, situated between 35 and 60° maximum [3,15,17]. Taking our encouraging clinical and radiological data into consideration, we have thus fixed our upper limit of correction of a torsional problem in adult skeletons at 50°. Itoman et al. [17] obtained satisfactory clinical and radiological results in a case of rotation disorder of 60° corrected to nearly 5°. Complete recovery of muscle function occurred only within 8 to 12 months, even if Eyres et al. [6] reported recovery of the quadriceps muscle in less than 1 week in a similar study.

We also showed that derotation osteotomy may be coupled with lengthening osteotomy at the same operating time and always as a closed technique. This extemporaneous lengthening is, however, hampered by significant bleeding (three liters on average), which makes it necessary to anticipate such deleterious effects by using a Cell-saver or maintaining controlled hypotension peroperatively. Furthermore, this extemporaneous technique only

<table>
<thead>
<tr>
<th>Patient</th>
<th>Initial anteversion of femoral necks (TDM)</th>
<th>Final anteversion of femoral necks (TDM)</th>
<th>Clinical correction</th>
<th>Rotational correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L: +71°, R: +18°</td>
<td>L: +11°, R: +0°</td>
<td>25 ER</td>
<td>28 ER</td>
</tr>
<tr>
<td>2</td>
<td>L: +19°, R: +5°</td>
<td>L: +1°, R: +0°</td>
<td>20 ER</td>
<td>23 ER</td>
</tr>
<tr>
<td>3</td>
<td>L: +35°, R: +0°</td>
<td>L: +4°, R: +0°</td>
<td>15 ER</td>
<td>18 ER</td>
</tr>
<tr>
<td>4</td>
<td>L: +48°, R: +3°</td>
<td>L: +2°, R: +0°</td>
<td>10 ER</td>
<td>13 ER</td>
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<tr>
<td>5</td>
<td>L: +56°, R: +1°</td>
<td>L: +0°, R: +0°</td>
<td>5 ER</td>
<td>8 ER</td>
</tr>
<tr>
<td>6</td>
<td>L: +56°, R: +1°</td>
<td>L: +0°, R: +0°</td>
<td>5 ER</td>
<td>8 ER</td>
</tr>
<tr>
<td>7</td>
<td>L: +56°, R: +1°</td>
<td>L: +0°, R: +0°</td>
<td>5 ER</td>
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<td>10</td>
<td>L: +56°, R: +1°</td>
<td>L: +0°, R: +0°</td>
<td>5 ER</td>
<td>8 ER</td>
</tr>
</tbody>
</table>

TDM: tomodensitometry; IR: internal rotation; ER: external rotation; L: left; R: right; Diff: difference.
allowed maximal lengthening of 15 mm in our two patients, for maximal values of 20 to 25 mm [4], far from the values obtained during progressive lengthening with Albizzia nails, for example [7,18]. Nailing has the advantage of a better biomechanical result, and endomedullary femoral osteotomies, performed as a closed or open technique and fixed by a locking nail, demonstrated their superiority over assemblies with screwed plates [8,19]. They also showed higher consolidation rates than open techniques [4] with less morbidity, and without impacting the quality and precision of correction. Nevertheless, they presented specific morbidity as reflected in our series. The risk of fracture should be taken into consideration through preliminary radiographs of the operated anterior femur and profile. Neurological complications occurred, in the context of prolonged traction exceeding 4 hours (245 minutes in our combined osteotomy case).

In conclusion, the present study confirmed our hypothesis: this demanding technique, requiring proficiency with closed centromedullary nailing and endomedullary saws [6], is safe and makes it possible to reliably correct torsional problems, whether they are rotational malunions or congenital anomalies with the proviso of respecting the recommendations arising from our retrospective study. The advantages of such a technique, compared to open methods, are faster functional recovery with less pain, a lower morbidity, and without impacting the quality and precision of correction. Nevertheless, they presented specific morbidity as reflected in our series. The risk of fracture should be taken into consideration through preliminary radiographs of the operated anterior femur and profile. Neurological complications occurred, in the context of prolonged traction exceeding 4 hours (245 minutes in our combined osteotomy case).

References