Computer-assisted osteotomies for genu varum deformity: rationale, surgical technique, outcome and return to sports

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ABSTRACT • High tibial osteotomy (HTO) is commonly used for genu varum deformity in young and active patients. Corrective valgus osteotomy may however lead to an oblique joint line in cases of associated femur varum or absence of tibia vara. To avoid this drawback, we use an accurate and reproducible radiological protocol allowing to choose the best indication between HTO, double level osteotomy (DLO) and distal femoral osteotomy (DFO). Computer-navigation of the osteotomies is the best choice to achieve the preoperative goal, above all to avoid too much overcorrection, which could be detrimental to resume sports. In this article, the rationale of this choice, the operative procedures, their results as well as the possibilities to resume sports will be presented.

Keywords: genu varum; navigation; computer; osteotomy; sport

INTRODUCTION

Medial knee osteoarthritis is not uncommon and high tibial osteotomy (HTO) was described for the first time, more than 50 years ago [1-3]. Nowadays, it remains a good option [4-13] despite the large expansion of total knee replacement (TKR) or the revival of unicompartmental knee prosthesis boosted by the less-invasive surgery concept. It is well indicated for “young” and active people (less than 65 years of age) with moderate arthritis (narrowing joint line up to 100% without any bone wear or instability).

Nevertheless, it is a demanding surgery, exposing to excessive over or under correction leading to earlier failure [12] or oblique joint line (Fig. 1) being the cause of difficulties when performing later TKR. This oblique joint line corresponds to an excessive valgus of the tibial mechanical axis [14]. It is all the more frequent when varus is important because of a femoral or a femoral and tibial deformity. The desirable over correction (3° to 6°) to achieve a good clinical result increases even more this oblique joint line.

One can consider combined femoral and tibial osteotomy as a solution to avoid excessive joint line obliquity. However, prior to the advent of computer navigation this was only performed on a limited basis because of the difficulty in obtaining an accurate lower leg axis without any reproducible assistance.

Figure 1. Severe oblique joint line (right knee) after high tibial osteotomy. Notice the extreme tibial valgus.
Drawing on our experience with TKR and HTO navigation [15-19] we used the principles of computer-assisted surgery for double level osteotomy (DLO) hoping to increase the accuracy of this difficult procedure.

The preoperative radiological assessment will be presented as well as the computer-assisted operative procedure, the indications of HTO, DLO and distal femoral osteotomy (DFO). And the rationale behind this line of thought will be discussed. Moreover, return to sporting activity will be discussed knowing that only a few papers have been published about this topic [20-25].

**RADIOLOGICAL ASSESSMENT**

Preoperatively standing AP, lateral, and 45° PA weight-bearing views are obtained. In addition, it is essential to obtain AP long leg standing X-rays to assess the hip knee ankle (HKA) angle for preoperative planning.

Ramadier’s protocol [26] allows these measurements to be reproducible pre- and postoperatively. This protocol can be described as follows: first, to determine accurately the frontal plane by looking for a true lateral view of the knee which is obtained when the posterior margins of the condyles are superimposed; secondly, to turn 90° around the knee the image intensifier to obtain an accurate long leg AP standing view, the X-ray being perpendicular to the frontal plane; finally, to draw the foot print on a cardboard in order to reproduce the same rotation of the lower leg pre- and postoperatively. Using this cardboard by placing the foot in the print, it is easy to do the same view as often as one wants. The long leg film is critical since the deformity may not be visible on standard knee films (Fig. 2 a, b).

The HKA angle, the medial distal femoral mechanical angle (MDFMA) and the medial proximal tibial mechanical angle (MPTMA) must be measured (Fig. 3 a, b, c) in order to plan the level of the osteotomy: tibial, femoral or both.
Grading of osteoarthritis is performed typically using the modified Ahlbäck classification [18]. (Table I)

SURGICAL TECHNIQUES

Opening wedge computer-navigated HTO

The software is a derivative of the one used for TKA which has been fully described in previous articles [15-17] (Orthopilot® Navigation System, B-Braun-Aesculap, Tuttlingen, Germany). The same principals of real time acquisition of the rotation center of the hip, knee and ankle centers and of the anatomical landmarks at the level of the knee joint line and ankle is applied. This allows the mechanical axis of the lower limb to be shown dynamically on the computer screen, i.e. the axis of the lower limb to be seen both pre- and postosteotomy and to check if the preplanned correction has been established.

A tourniquet is placed at the root of the thigh and the procedure follows this sequence: The rigid body markers are fixed at the level of the distal femur and proximal tibia allowing acquisition of the centers of the hip, knee and ankle (Fig. 4). The lower limb mechanical axis then appears on the screen and can be compared with the pre-operative radiological goniometry.

A five to six centimeters long incision is made on the medial upper end of the tibia just at the level of the anterior tuberosity of the tibia. The pes anserinus is incised just above the gracilis tendon and a retractor is placed against the posteromedial corner of the tibia. Then, the superficial medial collateral ligament is released from its tibial insertion to allow an adequate opening of the osteotomy. The HTO is performed three centimeters below the level of the medial joint line, the level confirmed by placing an intra-articular needle. The osteotomy is directed at the fibula head, keeping the saw as horizontal as possible to avoid fracturing the lateral tibial plateau.

With the aid of two osteotomes inserted along the track of the saw cut, the tibia is placed into valgus. These are then replaced by a metal spacer, which is inherently stable and allows the amount of correction to be calmly checked. If there is 8° of varus, we will try a 10-11 mm spacer and make sure that an appropriate hypercorrection is produced real time on the computer screen. If this is insufficient, a thicker spacer may be trialed, and the reverse if the correction is too great. The metallic spacer is then replaced with a bio-absorbable tricalcium phosphate wedge (Biosorb®, SBM Company, Lourdes, France) of the desired thickness, and the intervention completed by plating the proximal tibia with a locking screw plate. Then the accuracy of the osteosynthesis is checked with the image intensifier (Fig. 5) and the wound is closed.

Computer-assisted double level osteotomy

A tourniquet is placed at the root of the thigh and the first stage is essentially the same as for an HTO: insertion of the rigid body markers (high enough not to hamper the femoral osteotomy and low enough on the other level to avoid interfering with the tibial osteotomy), followed by kinematic acquisition of the hip center, middle of the knee and tibio-tarsal joints in order to find the mechanical axis of the lower limb.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 50% joint space narrowing</td>
</tr>
<tr>
<td>2</td>
<td>50-100% joint space narrowing</td>
</tr>
<tr>
<td>3</td>
<td>100% narrowing without any bone wear</td>
</tr>
<tr>
<td>4</td>
<td>Bone wear but no lateral instability</td>
</tr>
<tr>
<td>5</td>
<td>Bone wear with lateral compartment decoaptation ± posterolateral subluxation</td>
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FIGURE 4. Left lower leg with rigid bodies at the level of the femur and the tibia.

FIGURE 5. Radiological result of an HTO (3 months follow-up).
The second stage consists of making the femoral closing osteotomy in the distal femur (in general a 5 to 6° alteration is made, although sometimes more in congenital femoral varus) and fixing it in position with a locking screw plate. A lateral approach with elevation of the vastus lateralis is chosen, the lateral arthrotomy allowing to locate the tip of the trochlea. The track of the osteotomy lies above the trochlea and is directed obliquely from above laterally to below on the medial femoral cortex. A wedge of bone is then excised from the distal femur with a 4-5 mm lateral base, corresponding to a 5-6° correction. The osteotomy is fixed with the plate after placing the femur into valgus manually. Once this stage is reached the mechanical axis is rechecked so that the required correction at the level of the tibia can be calculated in order to achieve the preoperative objectives. Then the wound is closed on a drain.

The last stage is to perform the HTO exactly in the fashion described above. The definitive axis is then displayed on the computer screen and the osteosynthesis is checked with the image intensifier (Fig. 6).

**Computer-assisted distal femoral osteotomy**

The procedure is the same as described previously and we prefer to make a closing wedge osteotomy rather than an opening one because of the difficulty to get good stability after plating the distal femur.

**POSTOPERATIVE MANAGEMENT**

The patient can stand up the day after the operation and walk with two crutches. Partial weight bearing is allowed for 30 to 45 days when performing an HTO and 45 to 60 days when performing DLO. Full range of motion is regained quickly after HTO (extra articular procedure) and after 45 to 60 days for DLO, because of the distal femoral osteotomy, which slows down rehabilitation. It is much more than after HTO but the authors have never seen problems with stiffness in their experience.

**INDICATIONS**

The best indication for osteotomy is a patient with a low arthritis grade [4, 6, 14] and below 60 to 65 years. In some cases (very active patients under the age of 50 years) it is possible to perform double level osteotomy for grades 4 and 5 with a good result [19] but this is far from being the rule.

**DISCUSSION**

The mechanical axis of the lower limb was described by Kapandji [27] and later taken up by Hungerford and Krackow [28]; it should be 180° with a MDFMA of 93° and a MPTMA of 87° resulting in a joint line perfectly parallel to the ground. However, this assumption is not confirmed in case of osteoarthritis with varus misalignment, because, in a personal unpublished series of 89 TKR, we found a MDFMA of 93° in only 43.8% of the cases.

It was at 90° in 33.7% of the cases, below 90° in 13.5%, and above 93° in 9%.

Thus, before performing high tibial osteotomy, it is crucial to have high quality and reproducible full-length AP radiographs of the lower limb, according to a specific protocol. The HKA angle, the MDFMA and the MPTMA should be determined on this goniometry (cf. Fig. 3 a, b, c). Lateral instability testing has become less important than it once was, since indications for osteotomy in this setting have become rare. In case of femoral valgus (MDFMA > 90°), it is illogical to perform a femoral osteotomy. If the femur is in varus or at 90°, the best is to proceed with a femoral osteotomy to achieve a MDFMA of around 93° (93° ± 2°), and then complete it with a tibial osteotomy to achieve an HKA angle of 182° ± 2° in order to avoid too much overcorrection (Fig. 3 d, e). Overcorrection, whether femoral or tibial, can distort the anatomy and lead to a much more complicated TKR. However, a longer follow-up is needed to prove that overcorrection by ± 2° is enough for a lasting good result. If the tibia is not in varus (MPTMA over 88°), it is better to perform a femoral osteotomy especially if the femur is at 90° or in varus, or contraindicate any osteotomy if it leads to joint line obliquity of more than 5°. Combined distal femoral and proximal tibial

**FIGURE 6.** Radiological result of a DLO (3 months follow-up).
osteoarticular surgery allows to assess the femorotibial axis (HKA angle) at every step of the procedure and thus makes it more accurate. The first results obtained in a comparative cohort study of computer-assisted versus conventional HTO, a 96% reproducibility in achieving a mechanical axis of $184^\circ \pm 2^\circ$ in the computer-navigated group versus 71% in the conventional osteotomy group ($p < 0.0015$) [17]. In another series including 42 cases of DLO [19], the authors showed 92.7% success in reaching the preoperative goal for HKA angle, and 88.1% success in reaching the desired MPTMA ($90^\circ \pm 2^\circ$), which in terms of performance is remarkable.

Regarding return to sport after osteotomy, little have been published in the literature [20-25]. It is well known that osteotomies allow to return to sport but it has not yet be determined if too much overcorrection or an oblique joint line is compatible with different sporting activities. The best morphotype to play running-based sports (soccer, jogging, tennis, etc.) is neutral or genu varum. When performing an osteotomy getting too much overcorrection, the patient will never be able to play at the same level or will have to change to another sport like golf, cycling, swimming, etc. On the other hand, if few degrees of varus are left, the ability to return to running-based sports may be better but it is riskier regarding pain removal. In other words, the patient must be informed that after surgery he could have pain after strenuous activity [24]. In a personal series of 83 patients operated on using navigation [25], at a mean follow-up of $5.75 \pm 1.3$ years (five to nine years), 71 patients (85.5%) resumed sporting activities and 66 (79.5%) felt they had found a sporting level equal to the level prior surgery. The mean Lysholm score increased from $62.51 \pm 15.53$ points (30-100) preoperatively to $90.49 \pm 8.62$ points (55-100) postoperatively ($p < 0.001$). The Tegner and UCLA scores didn’t decrease significantly after surgery (4.53 and 7.14 preoperatively versus 4.1 and 6.55 postoperatively, $p = 0.07$ and 0.09). The mean postoperative KOO score was $73.52 \pm 17.20$. The frequency of sports sessions per week ($2.36 \pm 1.6$) did not decrease significantly after surgery (2.13 sessions, $p = 0.34$). On the other hand, the duration of activities decreased significantly from $4.68$ hours/week $\pm 4.25$ to $3.48$ hours/week ($p = 0.04$). Of the patients who practiced running before surgery 85% (17 of 20) were able to resume this activity. No patient returned to a competitive sport. Many patients were able to do activities such as downhill skiing or mountain biking but very few were able to jog or run.

*KOQ: knee injury & osteoarthritis outcome
CONCLUSION

“Young” patient genu varum deformity can be corrected by high tibial valgus osteotomy, but it is not the sole option. The indication is based on an accurate and reproducible radiological protocol including at least standing AP long leg X-ray. It is useful to measure not only the HKA angle but also the medial distal femoral mechanical (MDFMA) and medial proximal tibial mechanical (MPTMA) angles. These measures will guide the surgeon to choose the best indication. When the MDFMA is in varus (≥ 93°) and the MPTMA in varus (< 88°) the best one is HTO. When the MD-FMA is in varus (≥ 90°) and the MPTMA in varus (< 88°) the best indication is DLO. Finally, when the MDFMA is in varus and the MPTMA > 88° the best indication is DFO. This way of thinking should avoid too much oblique joint line, which is a difficult condition when performing revision to TKA. Regarding return to sport activity, HTO and DLO allow it, but the patient must be informed that residual pain during strenuous sports is not exceptional especially if the osteotomy leaves some undercorrection.

REFERENCES


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