Computer-assisted osteotomies for genu varum deformity: which osteotomy for which varus?

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Received: 1 February 2009 / Revised: 15 February 2009 / Accepted: 16 February 2009 / Published online: 21 March 2009
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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. The over-correction, needed to obtain good long-term clinical results, may increase the obliquity even more. To avoid this drawback, the authors suggest use of an accurate and reproducible radiological protocol including at least a standing AP long-leg X-ray to measure not only the hip–knee–ankle (HKA) angle but also the medial distal femoral mechanical angle (MDFMA) and the medial proximal tibial mechanical angle (MPTMA). These measures will guide the surgeon to choose the best indication, including HTO, double level osteotomy (DLO) and distal femoral osteotomy (DFO). Computer-navigation of the osteotomies is the best choice to achieve the preoperative goal. This paper will present the pre- and perioperative protocols of HTO and DLO and the rationale behind this way of thinking.

Introduction

Medial knee osteoarthritis is not uncommon, and high tibial osteotomy (HTO) was described for the first time more than

50 years ago [5, 7, 12]. Nowadays, it remains a good option [2, 3, 6, 9, 10, 13, 16, 17, 22], despite the large increase in total knee replacement (TKR) or the revival of unicompartmental knee prosthesis boosted by the less-invasive surgery concept. It is best 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 demanding surgery with the risk of excessive over- or under-correction leading to earlier failure [17] or oblique joint line (Fig. 1), which may cause difficulties when later performing TKR. This oblique joint line corresponds to an excessive valgus of the tibial mechanical axis [1]. It is all the more frequent when varus is important because of a femoral or a femoral and tibial deformity. The desirable over-correction (3–6°) to achieve a good clinical result increases this oblique joint line even more.

The authors considered 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 consistently.

Drawing on our experience with TKR and HTO navigation [14, 18–21], we used the principles of computer-assisted surgery for double level osteotomy (DLO), hoping to increase the accuracy of this difficult procedure. Our experience is based on 33 DLO performed between August 2001 and December 2008, out of 308 computer-assisted knee osteotomies (10.7%).

The objectives of this article were to present the preoperative radiological assessment, the computer-assisted operative procedure, the indications of HTO, DLO and distal femoral osteotomy (DFO), and to discuss the rationale behind this way of thinking.

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Fig. 1 Severe oblique joint line (right knee) after high tibial osteotomy. Notice the extreme tibial valgus

Radiological assessment

Preoperative standing AP, lateral, and 45-degree PA weightbearing (Rosenberg) views were obtained. AP long-leg standing X-rays to assess the hip–knee–ankle (HKA) angle are also essential for preoperative planning. Ramadier's protocol [15] allows these measurements to be reproducible pre- and postoperatively. This protocol can be described as follows. First, accurately determine 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. Second, turn the image intensifier 90° around the knee to obtain an accurate long-leg AP standing view, the X-ray being perpendicular to the frontal plane. Finally, draw the footprint on 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 repeatedly. The long-leg film is critical since the deformity may not be visible on standard knee films (Fig. 2a,b). The HKA angle, the medial distal femoral mechanical angle (MDFMA) and the medial proximal tibial mechanical angle (MPTMA) must be measured (Fig. 3a–c) in order to plan the level of the osteotomy: femoral, tibial, or both.

Grading of osteoarthritis is typically performed using the modified Ahlbäck classification [20] (grade 1, <50% joint space narrowing; grade 2, 50–100%; grade 3, 100% narrowing without any bone wear; grade 4, bone wear but no lateral instability; grade 5, bone wear with lateral compartment decoaptation +/- posterolateral subluxation).

Fig. 2 **a** Medial osteoarthritis appearing without severe tibial or femoral deformity. **b** Severe genu varum deformity of figure two case with medial femoral mechanical angle of 83° which was not predictable on standard X-ray

Surgical technique

Opening wedge HTO computer-navigated

The software is a derivative of the one used for TKA which has been fully described elsewhere [14, 18, 19] (Orthopilot Navigation System, B-Braun-Aesculap, Tuttlingen, Germany). The same principals of real-time acquisition of the rotation centre of the hip, knee and ankle centres and of the anatomical landmarks at the level of the knee joint line and ankle are applied. They allow 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 pre-planned correction has been established.

A sterile tourniquet is placed at the root of the thigh, then the rigid body markers are fixed percutaneously at the level of the distal femur and proximal tibia allowing acquisition of the centres of the hip, knee and ankle (Fig. 4). The lower limb mechanical axis then appears on the screen and can be compared with the preoperative radiological goniometry.

A 5–6-cm long incision is made on the medial upper end of the tibia 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 postero medial 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 3 cm below the level of the medial joint line, the level confirmed by placing an intraarticular needle. The osteotomy is directed

Fig. 3 A 40-year-old male patient. **a** Medial osteoarthritis with necrosis of the medial condyle. **b** Severe varus deformity. **c** Centred X-rays with a hip–knee–ankle (HKA) angle of 164° , medial distal femoral mechanical angle (MDFMA) of 83° and the medial proximal tibial mechanical angle (MPTMA) of 85° . **d** Radiological result.

Notice after six-months follow-up, no malunion of the distal femur and proximal tibia and the good healing of the osteotomies as well as the osteonecrosis of the medial condyle. **e** Postoperative goniometry of the patient after undergoing a double level osteotomy (DLO). Notice the HKA angle of 184°

at the fibula head, keeping the saw as horizontal as possible to avoid fracturing the lateral tibial plateau.

With the aid of two Pauwels osteotomies 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 was 8° of varus one would try a 10–11 mm spacer and make sure that an appropriate hypercorrection is produced on the computer screen. If this is insufficient a thicker spacer is tried, and the reverse if the correction is too great. The metallic spacer is then replaced with a bio-absorbable Tricalcium phosphate wedge (Biosorb, B-Braun-Aesculap, Boulogne, France) of the desired thickness, and the intervention is

completed by plating the proximal tibia. 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 sterile tourniquet is placed at the root of the thigh and the first stage is essentially the same as for that of an HTO, i.e. percutaneous insertion of the rigid body markers (high enough not to hamper the femoral osteotomy and low

Fig. 4 Left lower leg with rigid bodies at the level of the femur and the tibia

Fig. 5 Radiological result of an high tibial osteotomy (HTO) (three-month follow-up)

enough on the other level to avoid interfering with the tibial osteotomy), followed by kinematic acquisition of the hip centre, middle of the knee and tibio-tarsal joints in order to find the mechanical axis of the lower limb.

The second stage consists of making the femoral closing wedge osteotomy in the distal femur (in general a 5–6° alteration is made, although sometimes more in congenital femoral varus) and fixing it in position with a T-plate (AO/Synthes). A lateral approach with elevation of the vastus lateralis is chosen, the lateral arthrotomy allowing identification of the location of 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 T-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 an image intensifier (Fig. 6).

Fig. 6 Radiological result of a double level osteotomy (DLO) (three-month follow-up)

Computer-assisted distal femoral osteotomy

For the 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 in achieving 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 30–45 days when performing an HTO and 60–75 days when performing DLO. Full range of motion is regained quickly after HTO (extra articular procedure) and after 45–60 days for DLO because of the distal femoral osteotomy which slows down rehabilitation. This is much more so than after HTO but we have never seen problems with stiffness in our experience.

Indications

The best indication for osteotomy is a non-sedentary patient with a low arthritis grade (1, 2, 3) and below 60–65 years of age. In some cases (very active patients under the age of 50 years) we have performed double level osteotomy for grades 4 and 5 with good results [21], but this is far from being the rule.

Discussion

When should double level osteotomy be performed? If we consider the “normal” mechanical axis of the lower limb as described by Kapandji [8] and later taken up by Hungerford and Krackow [4], it should be 180° with an MDFMA of 93° and an MPTMA of 87° resulting in a joint line perfectly parallel to the ground. However, this state of affairs is not the case in cases of osteoarthritis with varus misalignment because, in a personal unpublished series of 89 TKR, we found an MDFMA of 93° in only 43.8% of the cases. Furthermore, 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 (Fig. 3a–c). Lateral instability testing has become less important than it once was, since the indications for osteotomy in this setting have become rare. In cases of femoral valgus (MDFMA >90°), it is

illogical to perform a femoral osteotomy because we do not want to create the same error in the femur which we are trying to avoid in the tibia. If the femur is in varus or at 90° , we believe that we should proceed with a femoral osteotomy to achieve an MDFMA of around 93° ($93^\circ \pm 2^\circ$) and then complete a tibial osteotomy to achieve an HKA angle of $182^\circ \pm 2^\circ$. In our experience, it is useless to overcorrect more than this to obtain satisfactory results (Fig. 3d,e). Overcorrection, whether femoral or tibial, can distort the anatomy and lead to a much more complicated revision TKR. However, we think that a longer follow-up is needed to prove that overcorrection by $\pm 2^\circ$ is enough for a lasting good result. If the tibia is not in varus (MPTMA over 88°), we should 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° . If we stick strictly to these criteria, indications for double level osteotomy will probably increase with the development of navigation systems, especially since, as we said before, femurs in varus are not rare, and more so, those at 90° .

Combined distal femoral and proximal tibial osteotomy in the treatment of genu varum is technically difficult. Little has been said about this technique in the literature and we could find only one paper reporting it [1]. In their paper Babis et al. [1] reported on 24 patients (29 knees) operated up on using a conventional technique (two closing wedge osteotomies). The mean preoperative HKA angle was 193.3° (that is 13.3° of varus), and they used a computer-aided analysis of the mechanical status of the knee for preoperative planning. This was limited to preoperative evaluation, and the reliability of the preoperative radiographic evaluation was not assessed. The results showed a mean postoperative HKA angle of 176.9° (range 169.4 – 184.9°). They had a residual varus in two cases (4.6° and 4.9°), and an over-correction of more than 4° in ten cases and more than 6° in five cases. It is known that an under-correction may lead to failure of the operative procedure and excessive overcorrection to cosmetic failure.

The difficulty of the technique comes from the fact that once the first osteotomy is performed, whether femoral or tibial, landmarks change and the ability to achieve a satisfactory alignment with the second osteotomy becomes challenging in the absence of reliable intraoperative landmarks. Martres et al. [11] suggested performing this operation in two different stages to improve its accuracy and reproducibility. It is also reasonable to consider that complication occurring at both osteotomy sites could lead to disastrous results. On the other hand, every surgeon operating osteoarthritic knees should be aware of the risk of malunion in the proximal tibia, for a procedure that is often considered temporary, particularly when performing an

isolated HTO. In fact, every osteotomy in a young adult could subsequently lead to a TKR, and it is thus essential to plan ahead for the possible revision.

Computer-assisted surgery allows monitoring of the femoro-tibial axis (HKA angle) at every step of the procedure making it more accurate. Our first results [18] in a comparative cohort study of computer-assisted versus conventional HTO showed 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 ($p < 0.0015$). In another prospective series including 16 cases of DLO [21] we showed 87.5% success in reaching our preoperative goal for HKA angle, and 100% success in reaching the desired MPTMA ($90^\circ \pm 2^\circ$), which in terms of performance is remarkable. At the femoral level, results were less accurate (75% of MDFMA at $95^\circ \pm 2^\circ$). This could be related to the closing wedge osteotomy, which is less straightforward. Moreover, with the Orthopilot device (kinematic model without pre-op imaging), control of the MDFMA and the MPTMA following the two osteotomies is not possible because a large arthrotomy would be required to identify and palpate specific landmarks similar to the ones used for TKA.

Thus, the only navigated parameter is the HKA angle, the others are calculated from pre and postoperative X-rays using the most rigorous planning.

Finally, despite our trust in opening wedge osteotomies, we think that, at the femoral level, one should perform a closing wedge osteotomy to avoid excessive lengthening of the limb when performing DLO (double opening) and also to improve stability of the fixation.

Conclusion

Young patient genu varum deformity can be corrected by high tibial valgus osteotomy, but it is not the only method. The indication is based on an accurate and reproducible radiological protocol including at least standing AP long-leg X-ray. One must measure not only the HKA angle but also the medial distal femoral mechanical angle (MDFMA) and the medial proximal tibial mechanical angle (MPTMA). These measures will guide the surgeon to choose the best procedure. When the MDFMA is in valgus (93° or more) and the MPTMA in varus (below 88°) the best method is HTO. When the MDFMA is in varus (90° or less) and the MPTMA in varus (below 88°) the best solution is DLO. Finally, when the MDFMA is in varus and the MPTMA above 88° the best procedure is DFO. This methodology should avoid the complication of the oblique joint line, which gives rise to difficulties when performing a revision to TKA.

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