Navigated Osteotomies Around the Knee in 170 Patients with Osteoarthritis Secondary to Genu Varum

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abstract

The authors used computer navigation to perform osteotomies around the knee. The purpose of this article is to present the authors' surgical technique and to discuss double-level osteotomy of the femur and tibia to avoid altered joint line obliquity in genu varum deformity. The authors conducted two studies. The first study was a cohort study comparing navigated high tibial osteotomies and conventional high tibial osteotomies. The results showed a 96% reproducibility in achieving a mechanical axis of $184^\circ\pm2^\circ$ in the navigated group compared to a 71% reproducibility in achieving a mechanical axis of $184^\circ\pm2^\circ$ in the conventional osteotomy group ($P<.0015$). The second study was a prospective study on double-level osteotomy and showed that the preoperative goal of $182^\circ\pm2^\circ$ has been achieved in 91% of patients.

Surgeons have used osteotomies around the knee to treat patients with varus and valgus malalignment for $>50$ years.\textsuperscript{1,2} The most commonly used osteotomies are the high tibial osteotomy, which is a valgus tibial osteotomy for genu varum, and the low femoral osteotomy, which is a varus femoral osteotomy for genu valgum. The high tibial osteotomy provides the best results when it is well indicated and the planned correction is reproduced.\textsuperscript{3-9} Normally, surgeons plan an over-correction into valgus of $3^\circ$-$6^\circ$, giving a mechanical axis (center femoral head through center of tibial spines to center of the ankle) of $183^\circ$-$186^\circ$.\textsuperscript{4,6,8,10} Although performing and fixing the initial osteotomy is not difficult, making the correction is complicated regardless of careful preoperative planning.\textsuperscript{10-12} Some surgeons do not control correction intraoperatively. Because of the uncertainty of the result and significant development of total knee arthroplasty (TKA), surgeons have stopped performing osteotomies to avoid the complications of under-correction and the cosmetic, functional, and legal consequences of excessive over-correction.

In addition, high tibial osteotomies expose patients to altered joint line obliquity (Figure 1). Altered joint line obliquity has been mentioned only a few times in the current literature despite the complications it can cause during total knee replacement.\textsuperscript{13} Altered joint line obliquity is common and is all the more important since the varus is important, whether the varus originates from the femur (congenitally curved femur or distal femoral varus) or from the tibia and femur. The hyper-correction required for a good result ($3^\circ$-$6^\circ$) often worsens the joint line obliquity. When hypercorrection is $>10^\circ$, another osteotomy may be required during total knee replacement to correct the malunion and avoid a severe ligamentous imbalance.\textsuperscript{14} The authors have considered performing double-level osteotomies to avoid this complication for a long time, but the difficulties of double-level osteotomies and correction of leg axis have prevented expansion of this technique.

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The authors applied their experience with navigated TKA to osteotomy around the knee. They used the OrthoPilot (B. Braun-Aesculap, Tuttingen, Germany) for the first time when performing a high tibial osteotomy in March 2001 and have since performed 170 osteotomies, including 135 high tibial osteotomies, 24 femoral osteotomies (12 valgus and 12 varus), and 11 double-level osteotomies for extreme genu varum (7% of all indications for genu varum) with this navigation system.

This article discusses the authors' surgical technique for high tibial osteotomy and double-level osteotomy with navigation, the results of a case-controlled study on navigated high tibial osteotomy compared to the results of conventional high tibial osteotomy, and the preliminary results of navigated double-level osteotomy.

**Materials and Methods**

**Case-controlled study on high tibial osteotomy**

The authors' goal was to compare the radiological results of the axial correction in 28 navigated TKAs with the radiological results of the 28 TKAs performed without navigation. Group A included 28 navigated osteotomies performed between March 2001 and April 2002, and group B included 28 conventional osteotomies randomly identified from 140 osteotomies performed between January 1997 and December 2000. The two groups were matched for age (group A, mean: 54 years, range: 35-71 years; group B, mean: 55 years, range: 27-70 years), sex, degree of osteoarthritis according to the modified Ahlbäck criteria (10 patients with stage 1 osteoarthritis with <50% joint narrowing, 32 patients with stage 2 osteoarthritis with 50%-100% narrowing, and 14 patients with stage 3 osteoarthritis with complete loss of joint space without bone loss or instability), and similar degrees of varus (group A, 173.3°±3.8°, range: 169°-178°; group B, 172.79°±3.18°, range: 168°-178°). The mechanical axes of the lower limbs were measured on full-length radiographs according to the Ramader protocol.15

In all TKAs, an opening wedge medial tibial osteotomy was performed using a tricalcium phosphate wedge and an AO T-plate for fixation. For each of the two groups, a preoperative plan was made on the radiographs that included drawings of the axis, the required hypercorrection, and the opening wedge needed to provide a 2°-6° valgus or 182°-186° mechanical axis (hip-knee-ankle angle).

The perioperative control of correction was evaluated differently in the two groups. In group B, a cardiac electrode was placed on the skin in the center of the femoral head. Under image intensifier guidance, a suture was set from this electrode along the length of the lower limb to the medial malleolus, passing through the center of the knee. In group A, correction was evaluated using the OrthoPilot. All patients had a follow-up radiograph at 3 months with the same protocol used for preoperative evaluation of the goniometry.

**The series of double-level osteotomy**

Between March 2001 and April 2005, 11 double-level osteotomies were performed out of 158 osteotomies for genu varum of the knee (7%). The series included four women and seven men with an average age of 48.5 years (range: 20-62 years). One patient had a gross cosmetic deformity with no evidence of osteoarthritis, and 10 patients had osteoarthritis. According to the modified Ahlbäck criteria, six patients had stage 3 osteoarthritis (complete loss of joint space without bone loss or ligament damage), three patients had stage 4 osteoarthritis (bone loss without lateral joint line opening), and one patient had stage 5 osteoarthritis (bone loss with opening of the lateral joint space±posterolateral subluxation). The average radiological preoperative varus was 167.5°±2.16° (range: 164°-170°), which was higher than the average radiological preoperative data of the high tibial osteotomy groups.

The osteotomies were performed using the following technique. The objective was to obtain a mechanical axis of 182°±2°, a correction slightly less than the correction for the high tibial osteotomy (184°±2°). All patients had a follow-up radiograph at 3 months according to the Ramader protocol.15

**Surgical Technique**

**Navigated High Tibial Osteotomy**

The software used for high tibial osteotomy was derived from the software used for TKA.16-20 The same principles 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 are applied. These principles allow the mechanical axis of the lower limb to be shown dynamically on the screen. Thus, the axis of the lower limb is seen before and after the osteotomy to verify that the preplanned correction has been established (Figures 2-6).

Generally, navigated high tibial osteotomy is performed in the following sequence. The rigid body markers are fixed percutaneously at the level of the distal femur and proximal tibia, allowing acquisition of the centers of the hip, knee, and ankle. The lower limb mechanical axis then appears on the screen and is compared to the preoperative radiological goniometry. The high tibial osteotomy is performed 3 cm below the level of the medial joint line, and the level is
confirmed by the placement of an intra-articular needle. The osteotomy is directed at the fibula head, keeping the saw horizontal to avoid fracturing the lateral tibial plateau.

With the aid of two Pauwels osteotomes inserted along the track of the saw cut, the tibia is placed into valgus. The Pauwels osteotomes are then replaced by a metal spacer, which is inherently stable and allows the amount of correction to be evaluated. If 8° of varus is present, then a surgeon uses a 10 to 11-mm spacer and ensures that an appropriate hypercorrection is produced in real-time on the screen. If the hypercorrection is insufficient, then a thicker spacer is used. A thinner spacer is used if too much hypercorrection is present. The metallic spacer is then replaced with a bioabsorbable tricalcium phosphate wedge of the appropriate thickness. The intervention is completed by plating the proximal tibia (Figure 7).

Double-level Osteotomy

The first stage of double-level osteotomy is the same as the first stage of high tibial osteotomy. Percutaneous insertion of the rigid body markers (high on one level to prevent interference with the femoral osteotomy and low on the other level to avoid interference with the tibial osteotomy) is followed by kinematic acquisition of the hip center, middle of the knee, and tibiotarsal joints to find the mechanical axis of the lower limb.

The second stage of double-level osteotomy includes performing the femoral closing wedge osteotomy in the distal femur (5°-6° alteration, sometimes more in congenital femoral varus) and fixing it with an AO T-plate. A lateral approach with elevation of the vastus lateralis is chosen, and the lateral arthroscopy helps a surgeon 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 fixated with the AO T-plate after the femur is manually placed into valgus. Once this stage is reached, the mechanical axis is re-evaluated so that correction at the level of the tibia can be calculated to achieve the preoperative objectives.

The last stage is to perform the high tibial osteotomy in the manner described above. The definitive axis is then displayed on the screen.

RESULTS

High tibial osteotomy series

The mechanical axis was evaluated with the OrthoPilot perioperatively, and the results matched the radiograph calculations, 173.3° (range: 169°-178°), vs. 172.9° (range: 169°-180°).

The postoperative goniometry in group A resulted in a mean of 183.5° ± 1.26°, a median of 184°, and a range of 180°-186°. Group B had a mean of 184° ± 2.28°, a median of 184°, and a range of 181°-189°. The preoperative aim was attained in 27 of 28 patients in group A (96%), compared to 20 of 28 patients in group B (71%). The difference was statistically significant (Fisher: P = .0248 < .05, student T-test: P = .0015) in favor of the computer-navigated cases. The objective
was achieved and a dispersion of results was avoided (especially in over-correction).

**Double-level Osteotomy Series**

The authors did not have any complications. The average perioperative mechanical axis before the osteotomy was 168.1°±1.1° (range: 164°-170°), an angle comparable to the preoperative radiograph calculation. Following the osteotomy, the mechanical axis on the screen measured 182.7°±1.1° (range: 182°-184°). At 3 months' follow-up, the radiograph evaluation gave an average axis of 180.8°±1.6° (range: 177°-182°).

The preoperative objective was achieved in all patients but one (91%). No radiographs showed an abnormal oblique joint line (Figures 8A-8D).

All osteotomies consolidated in 75 days. After 75 days, the patients were allowed full weight bearing with the aid of a single walking stick. None of the patients had difficulty regaining knee flexion, and had knee mobility equal to preoperative knee mobility at 75 days postoperatively.

**DISCUSSION**

Although it is not difficult to perform and fix a high tibial osteotomy in situ in patients with osteoarthritis with genu varum, it is difficult to attain the preoperative objective. Some surgeons use accurate angular cutting guides. Other surgeons conduct preoperative planning for the angle of resection (when a closing wedge osteotomy is needed) or the opening angle (when an opening wedge osteotomy is needed). Others evaluate the correction intraoperatively with a suture wire or metal rod that is set from the center of the femoral head to the ankle and passes through the middle of the knee. Some surgeons believe that no methods are accurate and sometimes perform osteotomies without a preoperative goniometry.

A hypercorrection of at least 3°-6° is required for a good result. Yet no publication has evaluated methods of achieving hypercorrection, although hypercorrection has a significant effect on the result of the osteotomy.

The authors' study shows that the OrthoPilot facilitates security in osteotomies, permitting the objective to be achieved in 96% of patients (versus 71% of patients in the control group) and significantly decreasing the dispersion of results, especially results of unacceptable over-correction. The OrthoPilot's performance is commendable because the control group received stringent preoperative and perioperative planning and attention to detail. However, the difference in results would have been more impressive if the standard osteotomies were performed in a less controlled manner.

The authors began using opening wedge osteotomies in 1995, after performing closing wedge osteotomies for 15 years, and validated it with more than 100 cases and because it seemed to be well
adapted to computer navigation. Compared to closing wedge osteotomies, opening wedge osteotomies are more precise, more stable with metal spacers, and more reproducible. Opening wedge osteotomies help surgeons make adjustments while performing the correction without compromising stability.

Compared to other navigation systems, the OrthoPilot is well adapted, reliable, and reproducible. The principle of navigation based on kinematic acquisition of the centers of the hip, knee, and ankle without preoperative imaging allows the authors to forgo intra-articular palpation and perform osteotomies without arthroscopy. The OrthoPilot performs best when the ligaments are intact, which is usually the case with genu varum, and osteoarthritis is moderate without bone loss or stiffness. When ligaments are intact and osteoarthritis is moderate, the kinematic model is strongest for the knee.18

Although double-level osteotomy is a difficult intervention, it is mentioned in only one publication.13 The double-level osteotomy was first described by Benjamin21 in 1969, but he did not mention hip-knee-ankle or joint line angles. The intervention is difficult because the landmarks (femoral or tibial) change after the first osteotomy is made. Unreliable peroperative landmarks may prevent a surgeon from achieving the desired axis in the second osteotomy.

Moreover, the potential creation of a difficult situation above the tibia for a temporizing procedure must be called into question by all surgeons who operated on patients with osteoarthritis. Because all osteotomies in young adults will eventually require revision, surgeons should be concerned about temporizing surgery.

Computer navigation allows permanent control of the femorotibial axis at each stage of the double-level osteotomy, reducing the likelihood of complications in the intervention. The authors' results show that 91% of the objectives were attained, a remarkable reproducibility in the presence of a relatively small series. When analyzing the results in detail, a difference between the peroperative goniometry (182.7°±1.1°) and the final radiographic axis postoperatively (180.8°±1.6°) was evident. After the femoral osteotomy, the authors made no further acquisition of the new femorotibial axis and based the correction for the tibial osteotomy on the initial axis. The modification in the orientation of the femoral epiphysis is likely to produce this 1.8.2.2° change of angle. Therefore, it is preferable to repeat the acquisition of the mechanical axis before proceeding with the tibial osteotomy.

It is important to determine if a double-level osteotomy should be performed. Before proposing any osteotomy, it is essential to have a reliable goniometry measurement according to a well-defined and reproducible protocol. With this goniometry, a surgeon must measure the mechanical axes of the femur and the tibia as well as the hip-knee-ankle angle. It is less important to measure laxity of the lateral side because an osteotomy is rarely indicated in this situation. If the mechanical axis of the femur is in valgus, which is the normal morphotype according to Hungerford and Krackow,24 then a high tibial osteotomy for the varus of the tibial epiphysis should be performed instead of a femoral osteotomy. If the femur is in varus or at 90°, then a double-level osteotomy is indicated, giving 4°-5° valgus to the femur and correcting the tibia to obtain a 182°±2° axis. In the authors' experience, it is not necessary to perform a large correction to gain a good result. If the tibia does not have an epiphyseal varus and the tibial axis is 90°, then a femoral osteotomy is necessary, and a high tibial osteotomy is contraindicated if it leads to a joint line obliquity of >5°. If these criteria are respected, then it is possible that the indications for a double-level osteotomy will increase with the development of navigation because severe varus (>10°), femur varum, and femurs at 90° without appreciable tibial epiphyseal varus are not rare.

The risk of nonunion in femoral osteotomy can be minimized by using an epiphyseal plate, which results in a solid, stable fixation (the authors found the blade plate too rigid to be useful). Breakage of the opposite peristeal hinge must be avoided, and the bony surface correctly opposed. Despite the authors' confidence in the opening wedge osteotomy for the tibia, the authors prefer the closing wedge osteotomy to avoid excessive leg shortening (double opening in spite of one closing wedge osteotomy and one opening wedge osteotomy) in the femur.

The navigated high tibial osteotomy for osteoarthritis secondary to genu varum is a reliable and reproducible technique that has helped the authors to achieve preoperative objectives in 96% of patients. The characteristics of the OrthoPilot, which are kinematic rather than image-based, are well adapted to help surgeons perform osteotomies without arthroscopy in the majority of patients. The development of such techniques should encourage surgeons to perform osteotomies in patients with unicompartmental osteoarthritis.

Navigated double-level osteotomy is reliable, precise, and reproducible for treating patients with excessive genu varum of the tibia and femur. Navigation simplifies double-level osteotomies, enabling surgeons to meet preoperatively defined objectives. The development of these techniques helps surgeons avoid altered joint line mechanics, which cause difficulties in performing total knee replacement.

REFERENCES


