Clinical and Radiological Outcomes of Double-Level Osteotomy Versus Open-Wedge High Tibial Osteotomy for Bifocal Varus Deformity

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Background: In bifocal varus deformity, double-level osteotomy (DLO) is advocated to treat lower limb alignment to prevent an adverse increase in joint line obliquity.

Purpose/Hypothesis: The purpose of this study was to compare the clinical and radiological results after DLO and open-wedge high tibial osteotomy (OWHTO) in patients with combined varus deformity. It was hypothesized that DLO would improve clinical results without increasing the complication rate compared with OWHTO.

Study Design: Cohort study; Level of evidence, 3.

Methods: Inclusion criteria were medial tibiofemoral compartment pain, varus knee deformity with an abnormal medial proximal tibial angle $<84^\circ$ and a lateral distal femoral angle $>90^\circ$, a functional anterior cruciate ligament, failure of nonoperative treatment, and a minimum 2-year follow-up with all clinical and radiological data. The rate of return to work or sports; the Knee injury and Osteoarthritis Outcome Score (KOOS); the University of California, Los Angeles (UCLA) activity score; and patient satisfaction were assessed at a minimum of 2 years of follow-up. Statistical comparison of the 2 groups was made using the chi-square or Student *t* test.

Results: A total of 69 consecutive patients were analyzed, of whom 38 underwent OWHTO and 31 underwent DLO surgery. A significant between-group difference was found for all radiological parameters; in particular, there was less joint line obliquity after DLO compared with OWHTO (1.7° vs 5.6°; $P < .001$). DLO provided better outcomes compared with OWHTO regarding the UCLA score (4.3 vs 6.7; $P < .001$) and patient satisfaction (2.6 vs 3.9; $P < .001$), but no significant difference in KOOS or return to work or sports was observed. The OWHTO group had more hinge fractures than the DLO group (34.2% vs 12.9%; $P < .001$).

Conclusion: For combined tibial and femoral varus deformity, DLO produced more physiologic joint line obliquity with slightly improved UCLA and patient satisfaction scores. A greater incidence of hinge fracture was observed after isolated OWHTO compared with DLO due to a larger tibial correction; however, this had little effect on clinical results at the 2-year follow-up.

Keywords: double-level osteotomy; open-wedge high tibial osteotomy; joint line obliquity; clinical outcome; complications

Open-wedge high tibial osteotomy (OWHTO) is a successful procedure in patients experiencing knee osteoarthritis (OA) due to a metaphyseal deformity, with proven good outcomes in young and active patients with early stages of unicompartmental OA.[8,13] A recent study showed that osteotomies around the knee for varus deformity are not correctly planned in approximately half of patients and that these patients may better benefit from a double-level osteotomy (DLO) to avoid excessive postoperative joint line obliquity (JLO).[14] A large OWHTO performed alone, despite an associated femoral deformity, will lead to tibial overcorrection or leave a femoral varus deformity that leads to nonphysiologic JLO. This resulting excessive JLO can lead to poor midterm outcomes, including lower Knee injury and Osteoarthritis Outcome Score (KOOS) values or lateral compartment pain after OWHTO.[9,11] Babis et al[2] reported a 100% survival rate at 10 years after OWHTO for patients with a postoperative tibiofemoral angle of 174° to 180° and lateral JLO $<4^\circ$ with a medial plateau force distribution of 40% to 60%. Patients who did not match these criteria had a significantly lower survival rate, at 70%.

Precise analysis of the deformity is essential to decide on the optimal osteotomy level required to restore a horizontal joint line and avoid excessive JLO. Excessive JLO can

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result in accelerated cartilage stress and increase areas of OA.[17,24] In the late 1960s, Benjamin[4] first reported on DLO procedures, which were initially introduced for severe knee deformity, and their outcomes. An optimal postoperative alignment can be achieved after DLO with good clinical outcomes.[22]

Recently, the concept of reserving DLO surgery for severe lower limb deformity has come into question. Traditionally, it has been accepted that a large medial proximal tibial angle (MPTA) may be well tolerated when performing an OWHTO for varus deformity. Feucht et al[7] defined anatomic correction as a postoperative MPTA $\leq 90^\circ$ and slight overcorrection as an MPTA between 90° and 95°. Therefore, corrections that exceed these values should be considered for DLO surgery. There are concerns, however, that DLO remains a challenging procedure with no additional clinical benefit and an increased rate of complications.[6]

The purpose of this study was to compare the clinical and radiological results between isolated OWHTO and DLO in patients with combined varus deformity and to analyze the rate of hinge fractures between these 2 groups. We hypothesized that DLO would improve clinical results without increasing the complication rate compared with OWHTO.

METHODS

Patients

Ethics approval was obtained from our institutional review board. This retrospective multicenter comparative study included patients with complete data who underwent OWHTO or DLO surgery between 2014 and 2020 at 1 of 3 centers that perform >100 osteotomies per year. The inclusion criteria were medial tibiofemoral compartment pain, varus knee with an MPTA <84° and lateral distal femoral angle (LDFA) >90°, a functional anterior cruciate ligament, and failure of nonoperative treatment. The exclusion criteria were knee sagittal or coronal instability; valgus knee deformity; knee OA classified as Ahlbäck grade >3; a history of osteotomy around the knee; and a personal history of trauma, sepsis, tumor, or inflammatory or skeletal disease that could influence the clinical outcomes. The minimal follow-up was 2 years, with clinical and radiological data available for all patients. Patients from the OWHTO group were matched with patients from the DLO group according to sex and age (±3 years).

During the analysis period, 305 knee osteotomies were performed, including 84 patients with bifocal femoral and tibial varus deformity; 6 patients were lost to follow-up and 9 had no possible matching. Ultimately, 38 patients (38 knees) in the OWHTO group were matched with 31 patients (32 knees) in the DLO group (Figure 1).

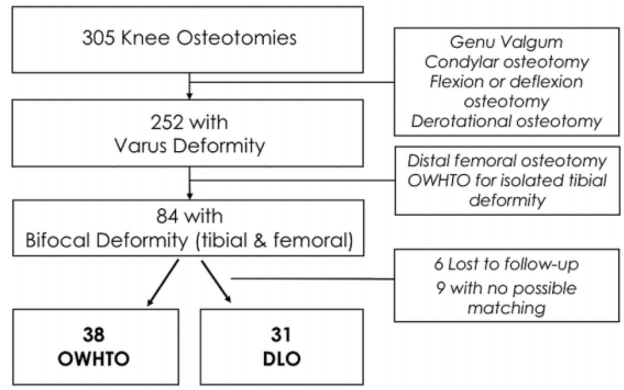

Figure 1. Flowchart of patient inclusion in the study. DLO, double-level osteotomy; OWHTO, open-wedge high tibial osteotomy.

DLO Procedure

The choice of an isolated OWHTO or a DLO was determined according to surgeon preference as well as the surgical approach (medial for the tibial osteotomy and lateral for the femoral osteotomy in all cases).

Lateral Closing-Wedge Distal Femoral Osteotomy. Each patient was placed supine with a tourniquet placed proximally on the limb. A lateral femoral closing-wedge osteotomy[18] was performed with a 5- to 6-cm approach made at the lateral aspect of the thigh extending from the lateral epicondyle proximally. A minimally invasive subvastus approach was performed. Under fluoroscopic control, 2 guide pins were inserted starting from the lateral cortex to create an isosceles triangle with the hinge point angled toward the medial epicondyle and 1 cm away from the contralateral cortex. Careful attention was paid to this step to reduce the risk of hinge fracture. A third K-wire was utilized as a hinge wire to protect the hinge of the femur. The 2 cuts were then made by sliding along the pins, and an anterior ascending cut was made freehand without the addition of a guide pin. Once the biplanar cut was complete, the bone fragment between the 2 main cuts was extracted. To close the osteotomy, gentle pressure was applied on the foot in an axial direction until there was cortical contact on the lateral

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Ethical approval for this study was obtained from the Comité de Protection des Personnes Sud-Méditerranée II.

side. A distal femoral Activmotion DFO Plate (Newclip Technics) with 8 locking screws (4 epiphyseal above and 4 diaphyseal below the osteotomy) was applied to hold the osteotomy. The goal of the lateral closing-wedge distal femoral osteotomy was to obtain a postoperative LDFA between 85° and 89° with the aim of achieving 50% to 55% of the mechanical axis based on preoperative planning.

Medial OWHTO. A 5-cm longitudinal incision was performed distal to the medial joint line at the level of the pes anserinus; the medial tibia was exposed. A periosteal elevator was run along the posterior tibial cortex to create a safe passage for the neurovascular protector after performing a window posterior to the superficial medial collateral ligament.[10] Two guide pins were placed in the tibia at the metaphyseal flare parallel to the tibial slope. These were used to mark the upper border of the osteotomy and aimed toward a hinge point that divided the distance between the lateral tibial border and the tips of the fibular head at a ratio of 65% to 35% proximal to distal. Similar to the femoral osteotomy, a hinge wire was utilized to protect the hinge point. After saw cuts for the osteotomy were made under fluoroscopic control, a biplane cut was made in an ascending fashion. Valgus correction was performed with the aim of achieving 50% to 55% of the mechanical axis based on preoperative planning, and secondary checks were done with an alignment rod intraoperatively. An Activmotion HTO Plate (Newclip Technics) with 6 to 8 locking screws (3 epiphyseal above and 2 diaphyseal below the osteotomy) or Peekpower HTO Plate (Arthrex) was applied to hold the osteotomy open. The graft used was similar in both groups. A wedge of bone was then cut from a femoral head allograft or an autograft from iliac crest to match the size of the correction and placed to fill the osteotomy. In some cases, a bone substitute was used as a tricalcium phosphate wedge.

Rehabilitation. The same perioperative and postoperative protocols were used in both groups. Active and passive physical therapy including progressive range of motion recovery and quadriceps reactivation were started postoperatively. Toe-touch weightbearing for 6 weeks aided with the use of crutches was initially allowed from the day after surgery. Full weightbearing was allowed at 6 weeks, and patients were allowed to return to professional and recreational activities at 6 months. A brace was used in cases of pain during the first 2 weeks, and all patients received thromboprophylaxis with low-molecular-weight heparin postoperatively for 45 days. Bone healing was considered complete after bone ossification in the osteotomy underneath the plate.

Radiological Analysis

Preoperative and postoperative radiographs were reviewed by 2 independent reviewers (A.A., J.-C.E.) blinded to treatment. These included a full-length, standing long-leg anteroposterior (AP) radiograph as well as short, standing AP and lateral knee radiographs. Measurements were performed from these images and included the hip-knee-ankle angle (HKA), MPTA, LDFA, global posterior proximal tibial angle (PPTA), joint line convergence angle (JLCA), and JLO for each knee, following previously described methods.[19] The JLCA was defined as the angle between the tangents to the femoral condyles and the tibial plateau, and the JLO as the angle between the line parallel to the floor and the tibial plateau (Figure 2).

Clinical Evaluation

Clinical follow-up was completed at 3 months, 6 months, 1 year, and every year thereafter. The clinical outcomes were measured using the rate of return to work or sport; KOOS subscales (Pain, Symptoms, Activities of Daily Living [ADL], Sport and Recreation, and Quality of Life);[20] the University of California, Los Angeles (UCLA) activity score;[26] and patient satisfaction on a scale from 0 to 4 (0 = disappointed, 1 = moderately satisfied, 2 = satisfied, 3 = very satisfied, 4 = enthusiastic: would recommend to my family) (Figure 3).

Statistical Analysis

Before initiation of the study, a sample-size analysis was performed to estimate the number of patients necessary to obtain a statistical power of 80%. A post hoc analysis confirmed that with 30 patients in each group, it was possible to evaluate the differences between groups, superior to the published minimal clinically important difference of the KOOS (8-10 points ± 10 points[5]).

Data were reported as mean values with standard deviations or as counts with percentages. Chi-square tests were used to compare qualitative variables, and Student t tests were used to compare quantitative variables between the 2 groups. Between-group comparisons of preoperative to 2-year postoperative changes (Δ) in the MPTA, PPTA, and KOOS subscales were conducted using the chi-square test. The threshold for significance was set at $P < .05$. Statistical analyses were performed with use of SSPS version 20 software (IBM).

The intraclass correlation coefficient was used to calculate interrater and intrarater reliability for the radiographic measurements. The values were >0.8 for each measurement, indicating excellent reliability.

RESULTS

The mean follow-up period for all patients was 3.6 ± 1.3 years. The demographic, radiographic, and clinical preoperative data of the 2 groups were comparable, except for HKA and JLCA; the DLO group had significantly more varus deformity and higher JLCA (Table 1). Preoperatively, no difference was observed between the 2 groups for clinical scores (Table 2), except for the KOOS-ADL subscale, which was worse for the OWHTO group (Δ = 7.9).

Radiological Outcomes

The postoperative radiological results are shown in Table 3. Postoperative HKA and MPTA were significantly more valgus in the OWHTO group (Δ = 2.8° and Δ = 4.4°,

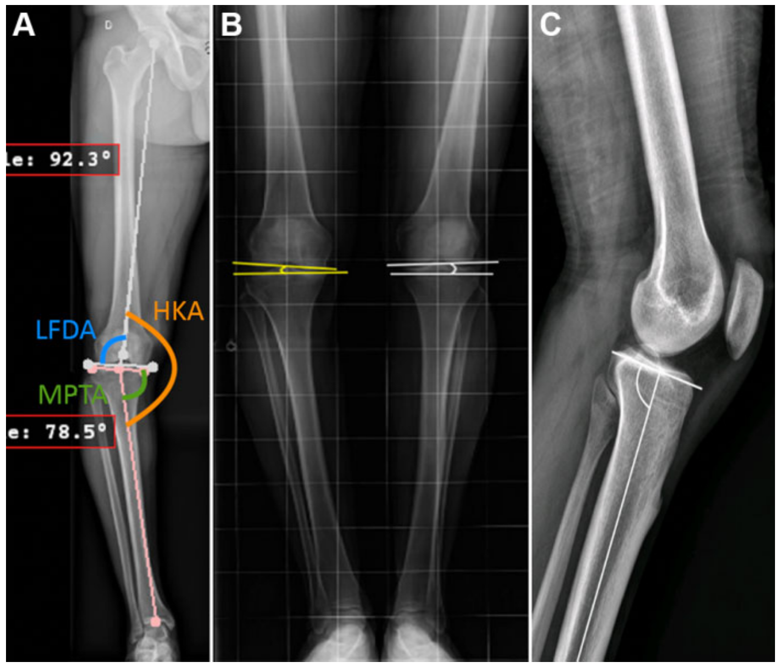

Figure 2. Measurements as shown on preoperative weightbearing long-leg and sagittal view radiographs. (A) Hip-knee-ankle angle (HKA), medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA). (B) Joint line convergence angle (in yellow), joint line obliquity (in white). (C) Posterior proximal tibial angle.

TABLE 1
Preoperative Demographic and Radiographic Characteristics Between Groups[a]

Variable	OWHTO Group (n = 38)	DLO Group (n = 31)	*P*
Sex, female/male	32 (84.2)/6 (15.8)	26 (83.9)/5 (16.1)	NS
Side affected, right/left	14 (36.8)/24 (63.2)	15 (48.4)/16 (51.6)	NS
Body mass index	25.2 ± 3.2	27.4 ± 6.1	.57
Age, y	52.2 ± 9.2	55.4 ± 5.8	.67
Follow-up, y	3.7 ± 1.1	3.4 ± 1.8	.54
Radiologic characteristics			
HKA	170.6 ± 3.2	168.2 ± 3.1	**.002**
LDFA	92.3 ± 2.4	92.8 ± 1.9	.42
MPTA	84.9 ± 4.0	84.4 ± 2.7	.36
JLCA	2.9 ± 1.4	3.7 ± 1.4	**.02**
JLO	3.0 ± 2.2	3.7 ± 1.7	.16
PPTA	81.5 ± 4.1	83 ± 2.5	.31

[a]Data are reported as n (%) or mean ± SD. Boldface *P* values indicate a statistically significant difference between groups ($P < .05$). DLO, double-level osteotomy; HKA, hip-knee-ankle angle; JLCA, joint line convergence angle; JLO, joint line obliquity; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; NS, nonsignificant; OWHTO, open-wedge high tibial osteotomy; PPTA, proximal posterior tibial angle.

respectively; both $P < .01$). Postoperative JLCA was significant greater ($\Delta = 1.3°$; $P < .001$) in the DLO group, whereas JLO ($\Delta = 3.9°$; $P < .001$) was significantly diminished in the same group. The change in MPTA correction was more important for the OWHTO group ($\Delta = 3.6°$; $P < .001$).

Clinical Outcomes

Postoperatively, no significant difference was observed between the 2 groups on any of the KOOS subscales. The UCLA score was significantly higher in the DLO group ($\Delta = 2.4$; $P < .001$), as were the number of patients who replied they were very satisfied or enthusiastic (28/31 in the DLO group vs 21/38 in the OWHTO group; $\Delta = 1.3$; $P = .001$). No differences were observed between groups concerning time to return to work or sport after the surgery (Table 4). The hinge fracture was identified according to the Takeuchi classification perioperatively or postoperatively with a computed tomography (CT) scan in cases of strong suspicion of hinge fracture not visible on radiograph.[25]

TABLE 2
Preoperative Functional Outcomes[a]

Variable	OWHTO Group (n = 38)	DLO Group (n = 31)	*P*
KOOS–Pain	52.8 ± 8.6	56.8 ± 16.4	.77
KOOS–Symptoms	50.2 ± 8.2	43.8 ± 19.1	.62
KOOS-ADL	51.0 ± 14.2	58.9 ± 15.5	.03
KOOS-QOL	40.2 ± 17.8	35.7 ± 17.5	.54
KOOS–Sport/Rec	41.1 ± 10.9	37.2 ± 18.1	.66
UCLA	5.1 ± 0.9	4.6 ± 1.9	.73

[a]Data are reported as mean ± SD. Boldface *P* value indicates a statistically significant difference between groups ($P < .05$). ADL, Activities of Daily Living; DLO, double-level osteotomy; KOOS, Knee injury and Osteoarthritis Outcome Score; OWHTO, open-wedge high tibial osteotomy; QOL, Quality of Life; Sport/Rec, Sport and Recreation; UCLA, University of California Los Angeles.

TABLE 3
Postoperative Radiological Outcomes[a]

Variable	OWHTO Group (n = 38)	DLO Group (n = 31)	*P*
HKA	182.9 ± 5.7	180.1 ± 2.3	**.01**
LDFA	92.3 ± 2.4	88.3 ± 1.5	**<.001**
MPTA	95.7 ± 4.3	91.3 ± 1.9	**<.001**
JLCA	1.8 ± 1.1	3.1 ± 1.5	**<.001**
JLO	5.6 ± 2.2	1.7 ± 1.3	**<.001**
PPTA	80.5 ± 4.5	83.1 ± 2.6	**<.001**
ΔMPTA	10.5 ± 1.2	6.9 ± 2.4	**<.001**
ΔPPTA	1.5 ± 0.4	0.1 ± 1.5	**.01**

[a]Data are reported as mean ± SD. Boldface *P* values indicate a statistically significant difference between groups ($P < .05$). Δ, difference between preoperative and postoperative values; DLO, double-level osteotomy; HKA, hip-knee-ankle angle; LDFA, lateral distal femoral angle; JLCA, joint line convergence angle; JLO, joint line obliquity; MPTA, medial proximal tibial angle; OWHTO, open-wedge high tibial osteotomy; PPTA, posterior proximal tibial angle.

Hinge Fracture

The total rate of hinge fractures (in either the femur or the tibia) was 34.2% in the OWTHO group (9 type 1 fractures, 3 type 2 fractures, and 1 type 3 fracture) and 12.9% in the DLO group (2 femoral and 2 type 2 tibial fractures). The rate of hinge fracture in the tibia was significantly higher in the OWHTO group (13/38 [34.2%] vs 4/31 [12.9%]; OR, 3.5; 95% CI, 1.3-11.7; $P = .004$).

At 6 months, complete osteotomy healing (both femur and tibia) was found in 93.5% of the DLO group versus 74.7% of the OWHTO group ($P = .04$). At 2 years of follow-up, there were no nonunions.

DISCUSSION

The main finding of this study was that performing a DLO for combined femoral and tibial deformity for varus malalignment better restored the JLO compared with OWHTO. Patients with DLO had better activity and satisfaction levels, but the KOOS was similar between the OWHTO and DLO groups and fewer hinge fractures were observed in the DLO group.

Akamatsu et al[1] found no significant differences in the Knee Society Score and KOOS between the DLO and OWHTO groups but a significantly higher Lysholm score in the DLO group. There were, however, areas of bias that may affect the clinical results, such as the inclusion of high-grade OA and older patients. The rate of satisfaction in the present study was high, as also seen by Schröter et al,[22] who found that all patients would like to have the DLO procedure again. The ULCA score in this study was reliable for distinguishing individuals returning to impact sport and the frequency after DLO and OWHTO.

DLO was first introduced with the purpose of restoring a physiologic knee joint alignment in cases of severe varus knee OA with more anatomic JLO.[16] The literature shows that JLO can be significantly higher after surgery in OWTHO alone compared with DLO,[1] but to our knowledge, no study has evaluated the clinical outcomes of DLO compared with OWTHO as well as the risk of hinge fractures after DLO.

The literature has demonstrated the benefit of preventing an adverse JLO, as it reflects on poorer clinical functional outcomes. In a computer-simulated model, Nakayama et al[17] reported that in cases of large correction after OWHTO, the laterally directed shear stress in the tibial cartilage increased to almost twice as high for models with obliquity of 5° or more. Another study recently showed that pain in the lateral compartment was experienced significantly more frequently in patients with medial OWHTO with postoperative MPTA >95%.[9] No study to date has compared the survival rates at long-term follow-up between DLO and OWHTO. However, Babis et al[3] did demonstrate a 96% survival rate at 8 years after DLO when the postoperative JLO was ≤4°. Thus, in this series, DLO helps to prevent the excessive obliquity of the joint line and restore an optimal lower limb alignment. The results are similar to those found in Schröter et al.[22] This study included 28 knees undergoing DLO surgery; the authors observed postoperative anatomic angular values (MPTA at 89° ± 2° and mechanical LDFA 87° ± 2°) without an increased JLO. In the present study, restoration of more physiologic JLO after DLO did not influence the KOOS values.

This postoperative excessive JLO after OWHTO indirectly implies a larger correction in cases of isolated tibial osteotomy for the same postoperative target compared with DLO, which may explain the larger rate of hinge fractures and the higher rate of delayed bone union at 6 months in this series (Figure 4). Nevertheless, DLO remains a daunting prospect for some surgeons, as the literature lacks evidence about global results after DLO.

The association between the osteotomy gap and lateral hinge fractures has been studied in the literature. Nakamura et al[15] found a significant difference between the mean wedge opening distance in the fracture group compared with the nonfracture group (11.9 and 10.6 mm, respectively) in a study with 111 patients undergoing

TABLE 4
Postoperative Functional Outcomes[a]

	OWHTO Group (n = 38)	DLO Group (n = 31)	*P*
Return to work, mo	4.7 ± 2.6	5.0 ± 2.4	.12
Working, no/yes	4 (10.5)/34 (89.5)	0 (0)/31 (100)	.18
Return to sport, mo	6.1 ± 3.3	6.9 ± 2.4	.36
Playing sports, yes/no	32 (84.2)/6 (15.8)	29 (93.5)/2 (6.5)	.14
KOOS–Pain	86.3 ± 14.4	89.1 ± 12.9	.53
KOOS–Symptoms	83.1 ± 16.9	83.1 ± 14.6	.37
KOOS-ADL	78.0 ± 20.8	85.8 ± 12.9	.23
KOOS-QOL	81.4 ± 16.4	82.7 ± 20.5	.31
KOOS–Sport/Rec	78.4 ± 21.1	86.4 ± 15.0	.27
UCLA	4.3 ± 2.2	6.7 ± 1.1	**<.001**
Satisfaction score, mean	2.6	3.9	**<.001**
ΔKOOS–Pain	34.8 ± 14.8	32.4 ± 19.7	.45
ΔKOOS–Symptoms	32.5 ± 18.2	39.3 ± 22.3	.36
ΔKOOS-ADL	32.4 ± 21.7	26.9 ± 18.0	.23
ΔKOOS-QOL	41.2 ± 23.1	45.5 ± 20.5	.38
ΔKOOS–Sport/Rec	38.6 ± 24.4	50.7 ± 25.7	.32

[a]Data are reported as n (%) or mean ± SD unless otherwise indicated. Boldface *P* values indicate a statistically significant difference between groups ($P < .05$). Δ, difference between preoperative and postoperative values; ADL, Activities of Daily Living; DLO, double-level osteotomy; KOOS, Knee injury and Osteoarthritis Outcome Score; OWHTO, open-wedge high tibial osteotomy; QOL, Quality of Life; Sport/Rec, Sport and Recreation; UCLA, University of California Los Angeles.

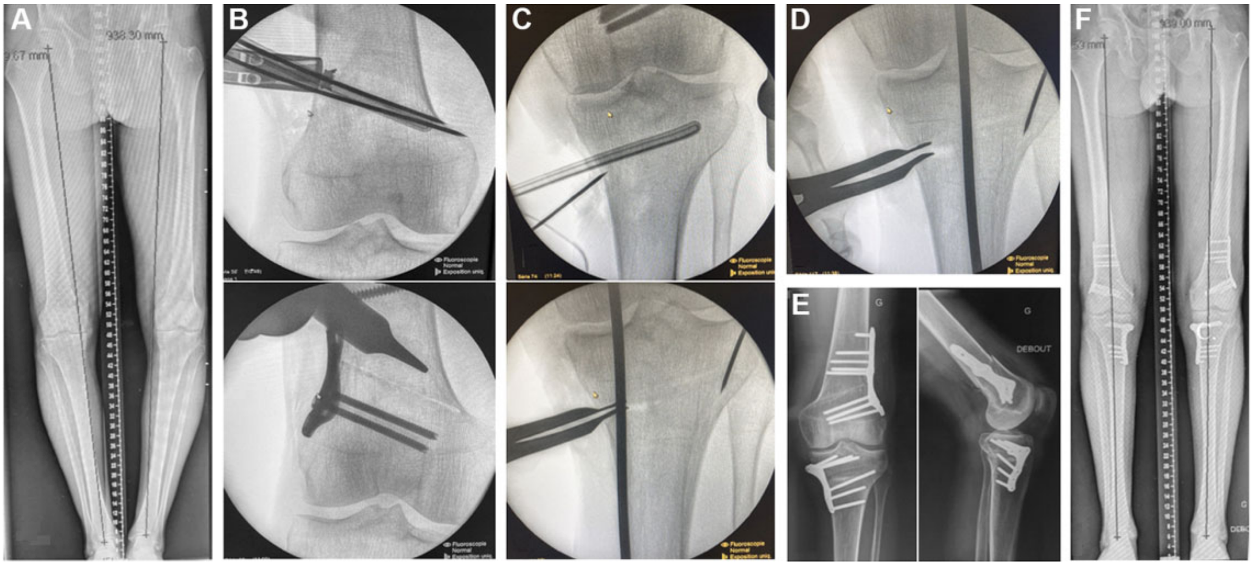

Figure 3. Bilateral double-level osteotomy in 2 sessions. (A) Image obtained in a patient with a combined preoperative femoral and tibial varus deformity on both sides. (B) First, a lateral closing distal femoral osteotomy was performed. (C) Then, the mechanical axis still passing through the medial tibial plateau was shifted laterally by the open-wedge high tibial osteotomy, (D) with the goal to obtain a mechanical axis crossing the tibial plateau from 50% to 55% of the medial tibial border. (E and F) Postoperative results showed a joint line obliquity parallel to the ground with a bilateral neutral mechanical axis.

OWTHO. Similarly, Lee et al[12] reported a significant difference between mean medial opening gaps in knees with and without lateral hinge fractures on CT (11.7 and 9.5 mm, respectively). However, the majority of hinge fractures observed by Lee et al were type 1, with few clinical consequences.

Schenke et al[21] published a study with a diverse population of 1003 patients, with the purpose of documenting complications resulting from osteotomies, having adjusted for demographics of the population, the level of osteotomy, and the technical elements of the surgery. They observed a higher incidence of vascular complications in OWTHOs, but no significant difference for superficial and deep infections between tibial and femoral osteotomies, and pointed out that nerve injuries were more likely to occur in correction of the proximal tibia. This was particularly observed in

Figure 4. Postoperative hinge fracture after isolated OWHTO in a patient with both femoral and tibial varus deformity. (A) Image obtained in a patient with a combined preoperative femoral and tibial varus deformity. (B) An isolated OWHTO was performed with an overcorrection at the tibial side resulting in a joint line obliquity of 4° with a perioperative hinge fracture (asterisk on the anteroposterior view). An iatrogenic excessive slope can also be seen on the lateral view. OWHTO, open-wedge high tibial osteotomy.

patients undergoing a high closing angle >15° in a lateral closed-wedge high tibial osteotomy, leading to nerve compression by postoperative hematoma.

DLO could have some negative aspects. As both femoral and tibial osteotomies are performed within a single procedure, there is theoretically an increased risk of infection, vascular injury, nonunion, or other osteotomy-related complications. Contrary to what one may expect, however, DLO does not increase the risk of hinge fracture and even seems to be better by decreasing the tibial opening height. Our study suggests a 3-fold increase in the risk of hinge fracture in performing a large OWHTO correction compared with DLO surgery. The literature also shows that a tibial opening ≥10° has been associated with delayed consolidation ($P = .002$) or nonunion ($P > .01$).[23]

Limitations

There are several limitations to our study. First, the sizes of the 2 groups were relatively small. Indeed, we only included patients with early-stage extra-articular OA, with a deformity located on both the femur and the tibia, which represent a small part of all the deformities around the knee. We decided to select our population among 3 specialized centers to even out the bias of reproducibility, but the patients were not randomized. Second, the final time of follow-up did not allow us to further see the radiological and functional impact of DLO in the long term. Indeed, we cannot confirm in this study that DLO will reduce the rate at which OA develops compared with OWHTO. The length of the study also did not allow us to deduce the potential complications that may be encountered in performing total knee replacement surgery after previous DLO compared with OWHTO.

For combined tibial and femoral varus deformity, DLO produced a more physiologic JLO with slightly improved UCLA scores and patient satisfaction results. A greater incidence of hinge fracture was observed after isolated OWHTO compared with DLO due to a larger tibial correction; however, this had little effect on clinical results at the 2-year follow-up.

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