Tibial slope alteration in medial open-wedge high tibial osteotomy with and without a bone graft: a double cohort study

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Introduction

Medial open-wedge high tibial osteotomy (OWHTO) has become one of the most common procedures for correction of varus knee deformities. The need for an autogenous bone graft with its associated morbidity and a change in the posterior tibial slope with its sequelae are some of its potential drawbacks.

Patients and methods

Ninety-two patients with varus deformities and medial compartment osteoarthritis were prospectively divided into two groups: group I, comprising patients who had undergone an OWHTO with an iliac crest graft, and group II, comprising patients who had undergone an OWHTO without a bone graft. These two groups were compared with respect to the posterior tibial slope, radiological outcome, and functional outcome of the two techniques.

Results

There was no significant difference between the two groups with regard to the correction achieved in femorotibial angle or posterior tibial slope. A significant increase was observed in both groups when preoperative and postoperative measurements were compared. Both groups showed improved functional results on the knee society knee scoring system, with no significant difference between them.

Conclusion

OWHTO can be performed without a graft with less operative time and with similar clinical and radiological results in terms of bone union and posterior tibial slope alteration.

Keywords:

high tibial osteotomy, open wedge, posterior tibial slope

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Introduction

High tibial osteotomy is commonly performed as a treatment option for isolated osteoarthritis of the medial tibiofemoral compartment [1] and less commonly for osteochondritis dissecans and medial condylar osteonecrosis in order to unload the joint or to correct malalignment [2].

Many surgical techniques have been described, including the dome, medial open-wedge, and lateral closed-wedge techniques [3–5].

The principal disadvantages of closed-wedge high tibial osteotomy are a relatively long period of rehabilitation, danger of peroneal nerve injury, resection of the fibula, difficulty in acquiring a suitable correction angle, sagittal plane imbalance, hematoma, hamstring issues, pes anserinus bursitis, and medial collateral ligament insufficiency [6].

For the previous reasons, medial open-wedge high tibial osteotomy (OWHTO) has recently become a more popular choice of treatment because of the simplicity of the surgical procedure and the possibility of accurate intraoperative adjustments of the desired correction angle. Other advantages over the closed-wedge procedure include the maintenance of bone stock, and correction of deformities close to their origins in the proximal tibia without the need for a fibular osteotomy [7].

The disadvantages of OWHTO is graft donor site morbidity and theoretical alteration of the posterior tibial slope. Many previous studies [8–10] showed that the posterior tibial slope decreased after closed-wedge high tibial osteotomy and increased after an open-wedge procedure because of the geometry of the proximal tibia, with the operative procedure rather than the implant being cited as the cause.

The purpose of this study was to compare OWHTO with and without graft with respect to the posterior tibial slope, radiological outcome, and functional outcome.

Patients and methods

Between January 2007 and June 2011, we prospectively enrolled 92 patients with varus deformities and medial compartment osteoarthritis. All patients were treated with OWHTO. The patients were divided into two groups according to surgeon preference. In each group, surgery was performed by or under the supervision of two of the authors.

Group I: This group comprised patients who underwent OWHTO with an iliac crest graft.
Group II: This group comprised patients who underwent OWHTO without a bone graft.

Inclusion criteria

Our primary inclusion criterion for the OWHTO procedure was a diagnosis of medial compartment OA. Patients with varus deformity of the leg and who had persistent pain even if they received conservative treatment for 6 months or more were included. There were no age restrictions.

Exclusion criteria

Patients with infection in the knee, severe OA of the patella–femoral joint, a flexion contracture of over 10°, range of motion less than 100° with varus/valgus instability of more than 10°, or with anterior or posterior cruciate ligament insufficiency or a history of tibial fracture were excluded from the study.

The patients' age averaged 48 years (range 28–54 years) in the first group and 46 years (range 29–55 years) in the second group. The duration of follow-up was 44 ± 14 months in group I and 40 ± 15 months in the group II.

Radiographic assessment

Each patient underwent standard anteroposterior and lateral radiograghy preoperatively, immediately postoperatively, every month for 6 months postoperatively or until osteotomy union, whichever occurred earlier, and then every 6 months. The degree of frontal plane correction and the posterior tibial slope were recorded in the weight-bearing views. Radiographic measurements of the tibial slope were taken on lateral radiographs of the knee before surgery and at the last follow-up. The tibial slope was measured according to the method of Brazier *et al.* [11], using the tibia's posterior cortex as the sole reference. The tibial slope was measured as the angle formed by the tangent to the medial tibial plateau and the line perpendicular to the tangent at the posterior tibial cortex (`. 1).

For each patient, the preoperative and postoperative hip–knee–ankle angle was measured (defined as the angle between the mechanical axis of the femur and the mechanical axis of the tibia, with both lines crossing at the central point between the tibial spines) with a full-length standing radiograph in the anteroposterior view. Finally, the average value for each measurement was calculated for further analysis.

The degenerative changes to the medial compartment were scored using the Ahlback classification [12] The results were as follows: 32 of 44 patients of group I and 29 of 42 patients of group II were classified as stage I, whereas 12 patients of group I and 13 patients of group II were classified as stage II. The remaining patients were nonarthritic.

Clinical assessment

Functional outcome was assessed with a self-administered rating system such as the Knee Society Score (KSS). The KSS consists of two parts: knee rating and functional assessment. The former provides an objective evaluation of pain, knee stability, and knee range of motion. The latter evaluates how the patient perceives his/her knee function. In both scores, the final score ranges from 0 to 100 points, with higher scores indicating a better function of the knee.

Surgical technique

The semitendinosus and gracilis tendons were subperiostealy dissected at the tibial insertion. In case of flexion contracture, release of the medial collateral ligament is needed. A Hohmann retractor was inserted to protect the neurovascular structures behind the osteotomy site. The first oblique osteotomy commenced at the upper margin of the pes anserinus and ended 5 mm from the lateral cortical margin at the upper level of the proximal tibiofibular joint. The second frontal osteotomy was initiated from 10 mm or more proximal to the insertion of the patellar tendon to the first osteotomy plane (biplanar osteotomy) [7]. The osteotomy site was opened under fluoroscopic control; a postoperative anatomic valgus angulation and full extension had to be achieved. This was achieved using a pudu plate with suitable height according to the varus angle. An iliac crest graft was then inserted at the osteotomy site in the first group but no graft was used in the second group. Changes in the posterior tibial slope were minimized by ensuring the height of the osteotomy was greater at the posteromedial cortex than at the tibial tuberosity [13], the opening gap at the tibial tuberosity was approximately half of the gap at the posteromedial cortex in order to maintain the normal slope [10], and finally by placing the plate as close as possible to the posteromedial corner and performing a complete posterior osteotomy [5]. Soft tissue including semitendinosus and gracilis tendon was resutured back and the drain was left behind.

Postoperative rehabilitation

The day after surgery, active and passive range of motion exercises with the use of a continuous passive motion device, as well as muscle strengthening, were commenced [14]. The patients were instructed on non-weight-bearing exercises for 6 weeks, followed by partial weight-bearing exercises with crutches or a walker for another 6 weeks; they were allowed full weight-bearing thereafter.

Statistics

PASW and PASS were used for sample size calculation and statistical analysis. Assuming a SD of 2 mm, the required sample size after setting the power to 90% to detect a mean difference of 1° difference in the posterior tibial slope between groups as statistically significant at the 5% level was 88. Each group had to have at least 44 participants. To allow for attrition, we increased the sample size by 5%, and hence each group included 46 participants.

Continuous variables were tested for normality. The baseline information, operative time, radiographic angles, and baseline scores were analyzed using two-tailed unpaired *t*-tests. Fisher's exact test was used to compare the number of obese patients, side, and sex distribution.

The Student *t*-test was used to compare the different radiographic angles and knee score between the two groups, and repeated-measures analysis of variance with the post-hoc test was used for comparing the results in the same group. The difference was considered statistically significant if the P value was less than 0.05.

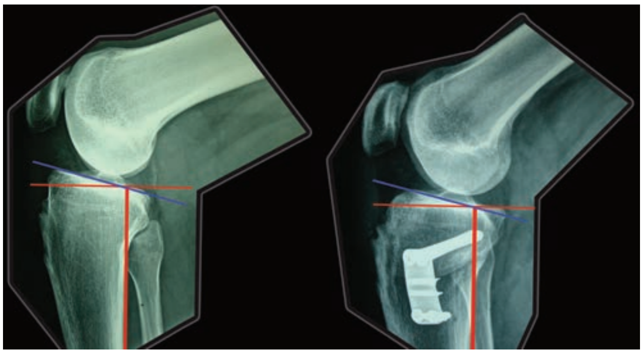
Results

The average follow-up was 44 months (range 18–66 months) in group I and 40 months (range 12–72 months) in group II. There was significant difference between the two groups regarding the operative time, with the average operative time being 88 ± 11 for the first group and 106 ± 13 for the second group ($P < 0.001$) (Figs 2 and 3).

All patients had preoperative varus deformity with an average of 6 ± 1.8° in group I and 5.5 ± 1.7° in group II (Table 1). In the third postoperative month the femorotibial angle was 5.6 ± 1.6° valgus in group I and 5.8 ± 1.4° valgus in group II. However, at final follow-up, the average mechanical axis angle was 3.9 ± 2.3° in group I, with an average loss of 1.5 ± 1.3° over time, and was 4.1 ± 2° with an average loss of 1.7 ± 1.2° in group II. Statistically, there was no significant difference between the two groups (Table 2).

There was significant increase in PTS in both groups on preoperative versus postoperative comparison; however, there was no significant difference between

Figure 1



Tibial slope measurement according to Brazier *et al.* [11].

Table 1 The baseline characteristics of the patients included in both groups

	Group I (19 patients)	Group II (23 patients)	*P* value
Age (years)	48 ± 5	46 ± 6	0.10
Height (m)	1.69 ± 0.10	1.66 ± 0.12	0.21
Weight (kg)	83.5 ± 10	80 ± 13	0.13
BMI (kg/m^2)	29.2 ± 2.1	28.7 ± 1.8	0.25
Sex (male/female)	15/31	19/27	0.26*
Side involved (right/left)	28/18	25/21	0.34*
Obesity (obese/nonobese)	15/31	12/34	0.32*
Preoperative varus angle (mm)	6 ± 1.8	5.5 ± 1.7	0.12
Mechanical FTA	172.9 ± 1.8	173.5 ± 1.6	0.13
Preoperative posterior tibial slope (mm)	9.1 ± 2.6	9.9 ± 2.8	0.2

Data are represented as mean±SD or participant numbers; FTA, femorotibial angle; *Fisher's exact test is used.

Figure 2

Open-wedge high tibial osteotomy: without graft. (a, b) Preoperative radiographs. (c, d) One-month postoperatively. (e, f) Three-month follow-up.

Figure 3

Open-wedge high tibial osteotomy: with graft. (a, b) Preoperative radiographs. (c, d) One-month postoperatively. (e, f) Three-month follow-up.

Figure 4

Bone resorption around the metal.

Table 2 Radiographic and functional results of patients included in both group

	Group I (46 patients)	Group II (46 patients)	*P* value[a]
Follow-up (months)	44 ± 14	40 ± 15	0.27
Operative duration (min)	106 ± 13	88 ± 11	<0.001
Osteotomy gap size	11 ± 2.1	10 ± 1.8	0.15
Femorotibial angle (FTA)			
Preoperative (varus)	6 ± 1.8	5.5 ± 1.7	0.12
Third month postoperative (valgus)	5.6 ± 1.6[b]	5.8 ± 1.4[b]	0.86
Final follow-up (valgus)	3.9 ± 2.3[b]	4.1 ± 2[b]	0.70
P value[c]	<0.001	<0.001	
Frontal plane angle loss	1.5 ± 1.3	1.7 ± 1.2	0.69
Posterior tibial slope (mm)			
Preoperative	9.1 ± 2.6	9.9 ± 2.8	0.2
Third month postoperative	11 ± 2.7[b]	12 ± 2.7[b]	0.11
Final follow-up	11.6 ± 2.5[b]	12.7 ± 3[b]	0.08
P value[c]	<0.001	<0.001	
Sagittal plane angle loss (mm)	0.6 ± 0.79	0.7 ± 1.1	0.59
Knee Society Scoring (KSS) k			
Preoperative	44 ± 10	47 ± 11	0.18
Final	86 ± 8	83 ± 9	0.15
P value	<0.001	<0.001	
KSSf			
Preoperative	65 ± 14	62 ± 14	0.22
Final	91 ± 8	87 ± 10	0.07
P value	<0.001	<0.001	

Data are represented as mean ± SD; [a]Student *t*-test is used; [b]Significantly different from the preceding time period; [c]Repeated-measures ANOVA with post-hoc analysis was used.

them. The average preoperative posterior tibial slope angle was 9.1 ± 2.6° in group I and 9.9 ± 2.8° in group II, and in the third postoperative month the angle was 11 ± 2.7° in group I and 12 ± 2.7° in group II. The slope was increased by an average of 1.9° in group I and 2.1° in group II. However, at final follow-up, the average posterior tibial slope angle was 11.6 ± 2.5° in group I and 12.7 ± 3° in group II. The average sagittal plane angle loss at final follow-up in comparison with the third postoperative month was 0.6 ± 0.79° in group I and 0.7 ± 1.1° in group II. Finally, the total average increase in slope from before surgery to final follow-up was 2.5° in group I and 2.8° in group II.

There was significant increase in the KSS score in both groups but there was no satistically significant difference between them. Average preoperative KSS knee (KSSk) score was 44 ± 10 in group I and 47 ± 11 in group II and function score (KSSf) was 65 ± 14 in group I and 62 ± 14 in group II. At final follow-up the KSSk score was 86 ± 8 in group I and 83 ± 9 in group II and the KSSf score was 91 ± 8 in group I and 87 ± 10 in group II. There was an improvement in the knee score by 42 and 36 points and in the function score by 26 and 25 points in both groups, respectively.

The osteotomy gap size was 11 ± 2.2 mm in group I versus 10 ± 1.8 mm in group II (P = 0.15), and all osteotomies healed at an average of 3.8 ± 0.8 months in group I versus 4.2 ± 0.9 months in group II (P = 0.08).

Correlation analyses were used to investigate the relationship of the correction rate with the difference in the posterior tibial slope before and after operation. Increase in posterior tibial slope would result in correction loss in the frontal plane after medial OWHTO (R = 1.9; P = 0.001; 95% confidence interval: 1.76–2.2).

Complications

There was no significant difference between the two groups with regard to complications. Five cases (two in group 1) had bone resorption around the metal because of metal reaction, as shown in Fig. 4, which was managed by removing the metal after bone union and intake of calcitonin together with calcium for 6 months. Five superficial infections occurred (three in group 1), which were treated with systemic antibiotics and local wound care, and 10 participants (six in group 1) developed hematomata, which was evacuated. Four cases (three in group 1) developed deep venous thrombosis, which was treated with anticoagulants. There was no incidence of broken plate, intra-articular fracture, breakage of the lateral cortex, or nonunion.

Discussion

The results of the current nonrandomized double cohort study prove that OWHTO can be performed without a graft, thus saving operative time and avoiding potential donor site morbidity. Both techniques had comparable clinical improvement and comparable radiological results with respect to the correction achieved, bone union, and posterior tibial slope alteration.

Theoretically, the posterior tibial slope increases after OWHTO. This is because the anteromedial cortex of the proximal tibia has an angle of 45° to the posterior cortex, unlike the lateral cortex, which is nearly perpendicular to the posterior cortex of the tibia. When performing medial open-wedge osteotomy with equal anterior tibial and posteromedial gaps the tibial slope will increase [10]. Improper dissection of soft tissues posteriorly leads to improper osteotomy of the posterolateral cortex.

The consequences of changes in the tibial slope after high tibial osteotomy were shown by Hernigou *et al.* [5]. Their study demonstrated that changes in the angle of inclination of the tibial plateau cause instability and excessive tibial translation in the sagittal plane, which may later lead to osteoarthritis. There are three main effects of changes in slope after high tibial osteotomy. Agneskirchner *et al.* [9] and Giffin *et al.* [13] showed that, the greater the angle of the slope, the greater the anterior tibial translation in ACL-intact and ACL-deficient knees. The second effect is a change in distribution of the mechanical load on the articular surface with anterior shift of the tibiofemoral contact area with decompression of the posterior femoral condyle [9]. The third effect is on extension of the knee, which is reduced after open wedge. This effect should be considered preoperatively in patients with limited extension [15].

Radiographs that are not truly lateral may include errors. The posterior tibial slope measured with a conventional technique shows variations depending on the rotation of the tibia in the lateral view [16].

The magnitude of bony correction in the frontal plane has no significant effect on the postoperative posterior tibial slope. To minimize the change in posterior tibial slope after high tibial osteotomy Giffin *et al.* [13] recommended that the height of the osteotomy should always be greater at the posteromedial cortex than at the tibial tuberosity.

Despite the routine addition of bone graft as a part of the OWHTO procedure, a previous study [17] showed that OWHTO up to 14 mm without a bone graft gave good results with shortened operative time and avoidance of unnecessary morbidity.

Noyes *et al.* [10] advised that the opening gap at the tibial tuberosity should be approximately half of the gap at the posteromedial cortex to maintain the normal slope. Earlier, Hernigou *et al.* [5] emphasized that to minimize changes in the posterior tibial slope it is necessary to place the plate as close as possible to the posteromedial corner and perform a complete posterior osteotomy.

Our results are similar, but with smaller average increases compared with those of Giffin *et al.* [13], Marti *et al.* [18], and Ozalay *et al.* [19], who demonstrated increases in the posterior tibial slope of 3.5–4.2° in OWHTO.

Hinterwimmer *et al.* [20] stated that OWHTO can be performed without significant changes in patellar height or posterior tibial slope if specific intraoperative methods are used to prevent their occurrence.

Chae *et al.* [21] demonstrated insignificant change in the posterior tibial slope after OWHTO using an autologous tricortical iliac bone graft. Esenkaya and Unay [22] showed statistical changes in posterior tibial slope, but this was only 1° and thus unlikely to influence the outcome. Ducat *et al.* [23] showed changes in posterior tibial slope with increase of only 0.6 ± 4.2°. El-Azab *et al.* [24] showed an increase of 2.1 ± 3.6° in PTS after OWHTO.

Although we made an a-priori power analysis for this study to have adequate sample size for our primary objective, this study has some limitations. Being nonrandomized it could have some bias in patient selection, although we tried to avoid this bias by creating two surgical teams, each consisting of two authors who were responsible for one cohort. However, if we looked at the relation between osteotomy gap size and healing time we found that to achieve a similar healing time the tendency was toward not using bigger sizes in the nongraft group. Another limitation is that we could not evaluate the survival rate from osteotomy because of the relatively short follow-up period (40 months). However, it is generally accepted that the most important predictor of failure is the correction achieved.

Conclusion

OWHTO can be performed without a graft with less operative time and with similar clinical and radiological results regarding bone union and posterior tibial slope alteration.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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