RESEARCH ARTICLE

Closing-Wedge and Opening-Wedge High Tibial Osteotomy as Successful Treatments of Symptomatic Medial Osteoarthritis of the Knee: A Randomized Controlled Trial

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Abstract

Objectives: Closing-wedge high tibial osteotomy (CWHTO) and opening-wedge high tibial osteotomy (OWHTO) are commonly used osteotomy techniques for the symptomatic knee osteoarthritis treatment. However, there is no consensus on which method provides superior outcomes. In this study, we compared the clinical outcomes, radiologic outcomes, and postoperative complications of these techniques.

Methods: In a randomized controlled trial, 76 patients with medial compartment knee osteoarthritis and associated varus malalignment were randomized into the CWHTO and OWHTO groups (n=38). The primary outcome measures were knee function evaluated by Knee Injury and Osteoarthritis Outcome Score (KOOS) and knee pain assessed by a visual analog scale. The secondary outcome measures were posterior tibial slope (PTS), tibial bone varus angle, and postoperative complications.

Results: Both techniques significantly improved the clinical and radiologic outcome measures. The mean improvement of total KOOS was not significantly different between the CWHTO and OPHTO groups (P=0.55). Moreover, the improvement in various KOOS subscales was not significantly different between the two groups. The mean improvement of Visual Analogue Scale (VAS) was not significantly different between the CWHTO and OWHTO groups (P=0.89). The mean PTS change was not significantly different between the two groups (P=0.34). The mean improvement of the varus angle was not significantly different between the two groups (P=0.28). The rate of postoperative complications was not remarkably different between the CWHTO and OWHTO groups.

Conclusion: Considering no observed superiority of each osteotomy technique over the other one, two techniques could be used interchangeably and based on the surgeon's preference.

Level of evidence: I

Keywords: Closing-wedge, High tibial osteotomy, Opening-wedge, Osteoarthritis

Introduction

Knee osteoarthritis is one of the most common disorders in the elderly population.[1] The affected patients generally develop knee varus deformity, which further overloads the medial compartment and accelerates the degenerative changes in the articular cartilage.[2] High tibial osteotomy (HTO) is the surgical procedure used to treat angular deformity of the knee, thereby preventing the development or progression of knee osteoarthritis.[3] It is done by various techniques. Among them, the closing wedge HTO (CWHTO) and opening wedge HTO (OWHTO) are regarded as the two most frequent HTO techniques.[3]

While favorable results have been reported following both CWHTO and OWHTO, each technique has its own advantages and disadvantages. The CWHTO has the advantage of inherent stability provided by direct bone contact, leading to faster bone healing. The CWHTO drawback is the need for fibular osteotomy or proximal

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tibiofibular joint release, which in turn increases its associated morbidities, such as the risk of peroneal nerve injury.[4] It also carries a higher risk of opposite cortical fracture. The OWHTO has the advantage of less challenging conversion to total knee arthroplasty (TKA) and the disadvantage of a higher non-union rate.[4-7] As a result, neither technique has clinical superiority over the other, and technique selection is largely derived from surgeon preference.[4]

In this dilemma, numerous studies have compared the clinical and radiological outcomes of CWHTO and OWHTO with the goal of finding convincing evidence in favor of one technique. In the majority of earlier investigations, no significant difference was observed between the clinical outcomes of the two techniques. However, a recent study by Filho *et al*. revealed patients who underwent OWHTO had a 3-fold higher risk of failure compared to the patients who underwent CWTHO.[8] In addition, there is some controversy regarding the radiologic outcomes of the CWHTO and OWHTO. While some studies show increased posterior tibial slope (PTS) following OWHTO,[9,10] a study by Bagherifard *et al*. demonstrated no significant effect of OWHTO on PTS.[11] Therefore, further studies are required to resolve the available controversies on the selection of the HTO technique.

In the present study, we performed a randomized controlled trial to compare the clinical and radiologic outcomes of CWHTO and OWHTO. We hypothesized that if both techniques are equivalent in clinical and radiologic outcomes, then an OWHTO could be selected to facilitate future conversion to TKA.

Materials and Methods

Study design

This randomized controlled trial (RCT) was approved by the ethics board of our institute under the code IR.MUMS.MEDICAL.REC.1397.451. The protocol of the study was also registered on the Iranian Registry of Clinical Trials under the code IRCT20180408039241N1. Patients provided written informed consent before participation in the study. The study population was selected from the patients who were referred to the knee clinic of our orthopedic department between January 2017 and January 2018 and had an indication for unilateral HTO (medial compartment knee osteoarthritis and associated varus malalignment). The inclusion criteria were grade II-III knee osteoarthritis according to the Kellgren-Lawrence classification,[12] medial joint pain, 6-12º varus deformity, and age of 18-60 years. Patients with a severely narrowed lateral compartment on plain radiography (grade D) according to International Knee Documentation Committee (IKDC) grading,[13] any pathology in meniscus and ligaments, tibiofemoral subluxation > 1 cm, medial compartment bone loss > 3 mm, flexion contracture > 15º, Knee range of motion (ROM) < 90º, inflammatory arthritis, peripheral vascular disorders, venous insufficiency and varicose veins, a history of knee fractures or surgery, and lower limb muscle lesions, obesity (BMI > 35) were excluded from the study [Figure 1]. The clinical examination of the knee instability was evaluated by an orthopedic surgeon who had a subspecialty in the field of sports surgery.[14-21] All patients with knee instability were excluded.

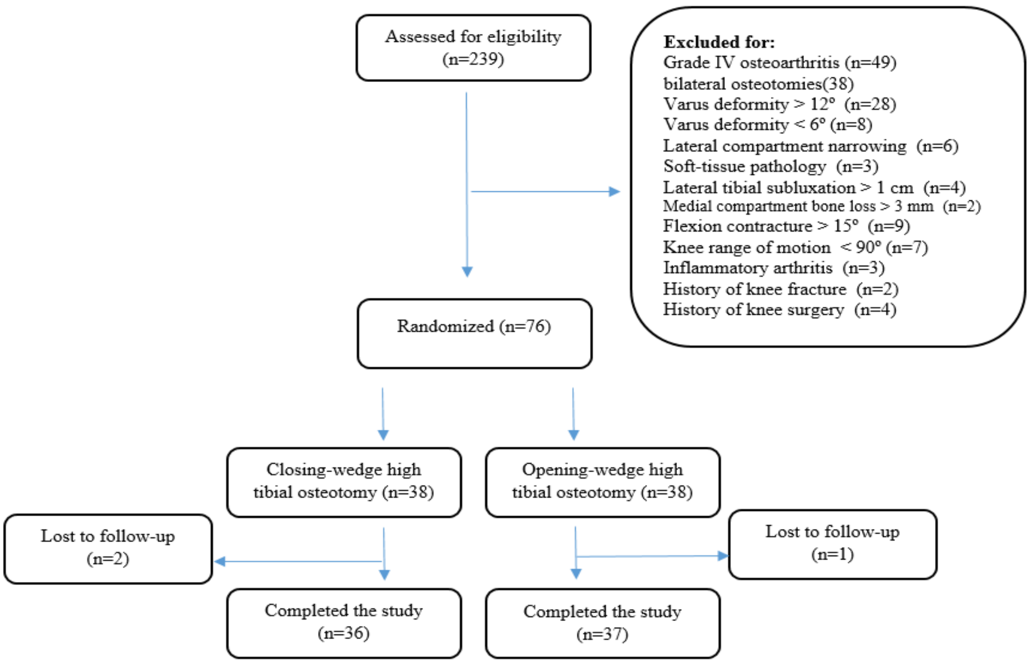

Figure 1. Flow diagram of the study

Tibiofemoral subluxation was evaluated on standing radiography and defined as the distance between the lines drawn tangent to the most lateral articular surface of the lateral femoral condyle and the lateral tibial condyle.[22] Tibiofemoral subluxations were evaluated two times by two knee surgeons, with an interval of two weeks. The inter- and intraobserver reliability of measurements were 0.91 and 0.93, respectively.

Medial compartment bone loss was evaluated on the anteroposterior (AP) radiograph. For this purpose, a line was drawn from the center of the lateral plateau, perpendicular to the long axis of the tibia, across the joint surface. The distance between this line and the deepest part of the defect in the medial tibial condyle was regarded as bone loss.[23] Medial compartment bone loss was evaluated two times by two knee surgeons, with an interval of two weeks. The inter- and intraobserver reliability of measurements was 0.94 and 0.95, respectively.

Knee flexion contracture and ROM were evaluated using a standard short arm goniometer by a knee surgeon who was not involved in the study design.

Randomization

Patients who met the study criteria were first divided into two categories of males and females, each containing 38 patients. Afterward, for each category, 38 random numbers were selected from a list of random numbers prepared by Excel software (in two categories of even and odd numbers) and placed in sealed opaque envelopes. The envelopes were given to an independent assistant not directly involved in the study, and when the patient was referred for surgery, the envelope was opened, and based on whether the number was odd or even, medial opening-wedge osteotomy or lateral closing-wedge osteotomy was performed on that patient, respectively.

Surgical intervention

Preoperative planning was performed on weight-bearing hip-knee-ankle (HKA) radiographs using the Dugdale method, and the mechanical axis was planned on the Fujisawa point.[24] Both techniques were done under sterile conditions and using general anesthesia. In the CWHTO group, a lateral incision of the proximal tibia was carried out with fluoroscopic guidance. Proximal fibular osteotomy was performed with peroneal nerve preservation. After performing anterior tibial corticotomy approximately 2 cm below the joint line with patellar tendon retaining, medial tibial corticotomy with retaining of the medial collateral ligament (MCL), lateral corticotomy with retaining of lateral collateral ligament, and posterior corticotomy with retaining of the popliteal artery, the lateral wedge osteotomy was stabilized with two genu varum staples. Patients with a closing wedge procedure were supplied with a knee brace. In the OWHTO group, a medial incision of the proximal tibia was carried out to expose the proximal tibia with fluoroscopic guidance. Subsequently, just proximal to the tibial tuberosity, a medial proximal uniplanar osteotomy was performed and opened according to the preoperative plan. The MCL was transected at the site of the osteotomy. A wedge corticocancellous allograft of appropriate size was placed at the osteotomy site, and the proximal tibia was fixed using a TomoFix Medial High Tibia Plate (Osveh Asia Medical Instrument Co, Mashhad, Iran), three proximal 6.5 cancellous screws, and three distal bicortical 4.5 screws. Then the drain was inserted.

Postoperative protocol

In both groups, active and passive knee ROM was started immediately after the operation to achieve 90° of knee flexion before discharge. Partial weight-bearing using crutches was allowed for the first three weeks after the operation. Full weight-bearing as tolerated (using crutches) was allowed for the next three weeks. Follow-up visits were performed at two weeks, six weeks, three months, and six months after the operation. Radiologic follow-ups were performed at six weeks, three months, and six months postoperatively and included standard alignment view, AP, and lateral radiographs.

Outcome measures

The primary outcome measures were knee function and pain. Knee function was evaluated before the operation and six months after the operation using the Persian-translated version of the Knee Injury and Osteoarthritis Outcome Score (KOOS), which included 42 items and five subscales of pain, symptoms, activities of daily living, sport, and knee-related quality of life (QOL).[25] The scores were transformed into a 0 to 100 scale, and a higher score was indicative of fewer knee problems. Knee pain was also evaluated before the operation and in the last follow-up using the visual analog scale (VAS) with two endpoints, including zero (no pain) and ten (worst possible pain).

Secondary outcome measures were PTS, tibial bone varus angle, union, osteoarthritis progression, weight-bearing status, and postoperative complications. Osteoarthritis progression was determined by comparing the preoperative and final osteoarthritis grades.

The varus angle was evaluated on the alignment view radiograph. The PTS was evaluated on the lateral radiographs and according to the proximal tibial anatomic axis.[26]

The osteotomy site in CWHTO was fixed rigidly with a plate. The osteotomy site in OWHTO was filled with impaction allograft and was fixed with a plate. No micromotion was observed at the osteotomy site during the surgery. The union was periodically evaluated clinically and radiologically. The absence of pain and the absence of bone callus at the osteotomy site indicated the union. In case of any doubt about the union a CT scan was performed.[27,28]

Sample size calculation

The sample size was calculated based on the difference between femoral and tibial angles in the two techniques, reported by Pourfeiz.[29] Accordingly, 34 patients in each group were identified to be enough to find a significant difference using an independent t-test. Taking into account a drop-out rate of 10%, 38 individuals were included in each study group.

Statistical analysis

The SPSS for windows (version 16, SPSS Inc., Chicago, Ill., USA) was used for statistical evaluations. Descriptive data were demonstrated by the mean and standard deviation for quantitative variables and by number and percentage for qualitative variables. The normality of distribution was checked with a Kolmogorov–Smirnov test. A paired t-test or its nonparametric counterpart (Wilcoxon signed rank test) was used to compare dependent mean values. An independent t-test or its nonparametric counterpart (Mann-Whitney U test) was used to compare independent mean values. A Chi-Square or Fisher exact test was used to compare qualitative variables. A P-value < 0.05 was considered statistically significant.

Results

Baseline characteristics

Seventy-three patients, including 38 females and 35 males, with a mean age of 36.9 ± 12.1, completed the study. The number of participants who completed the study in the CWHTO and OWHTO was 36 and 36 patients, respectively. No significant difference was observed between the baseline characteristic features of the two study groups [Table 1].

Table 1. Baseline characteristic features of patients in the closing-wedge and opening-wedge high tibial osteotomy groups

Variables	Closing-wedge (n=36)	Opening-wedge (n=37)	*P*-value
Age (years)	37.2±12.2	36.7±10.1	0.34
BMI (kg/m²)	26.8±4.4	25.9±5.6	0.16
Gender			
• Male	17 (47.2)	18 (48.6)	0.82
• Female	19 (52.8)	19 (51.4)	
Laterality			
• Right	21 (58.3)	20 (54)	0.87
• Left	15 (41.7)	17 (46)	
Stability			
• Stable	34 (94.4)	34 (91.9)	0.68
• Anterior-posterior instability	1 (2.8)	3 (8.1)	
• Medial-lateral instabitlity	1 (2.8)	0 (0.0)	
Osteoarthritis grade			
• II	27 (75)	30 (83.3)	0.72
• III	9 (25)	7 (18.9)	
Patellofemoral osteoarthritis	5 (13.8)	4 (10.8)	0.59

BMI: Body mass index. Data are presented with mean ± standard deviation or number (%). A P<0.05 is considered statistically significant

Primary outcome measure

In the CWHTO group, the mean total KOOS was 50.5 ± 10.9 before the operation and 82.3 ± 11.5 six months after the operation (P<0.001). In the OWHTO group, the mean total KOOS was 51.3 ± 10.6 before the operation and 83.5 ±11.1 six months after the operation (P<0.001). The mean improvement of total KOOS was not significantly different before the operation and six months after the operation, respectively (P<0.001). The mean improvement of VAS was between the CWHTO and OPHTO groups (P=0.55). Moreover, the improvement in various KOOS subscales was not significantly different between the two groups [Table 2].

In the CWHTO group, the mean VAS for pain was 6.3 ± 2.9 and 3.2 ± 2.3 before the operation and six months after the operation, respectively (P<0.001). In the OWHTO group, the mean VAS for pain was measured at 5.7 ± 2.3 and 2.7 ± 2.2 not significantly different between the CWHTO and OWHTO groups (P=0.89).

Table 2. Comparison of the outcome measures between the closing-wedge and opening-wedge high tibial osteotomy groups

Variables	Closing-wedge (n=36)	Opening-wedge (n=37)	*P*-value
KOOS improvement			
• **Pain**	31.5±9.8	32±8.7	0.63
• **Symptom**	33.3±8.6	34.1±8.9	0.32
• **Activities of daily living**	28.9±8.3	29.2±8.5	0.44
• **Sport**	35.3±10.2	34.8±9.7	0.51
• **Knee-related quality of life**	29.9±9.2	31.3±7.9	0.71
• **Total**	31.8±9.9	32.2±9.5	0.55
Improvement of visual analoque scale	3.1±1.6	3±1.5	0.89
Change of posterior tibial slope (°)	1.8±1.1	1.6±1	0.34
Improvement of tibial bone varus angle (°)	6.2±2.9	5.9±2.7	0.28

Data are present with mean ± standard deviation. P<0.05 is considered significant

Secondary outcome measures

In the CWHTO group, the mean PTS was 8.1 ± 3.1º before the operation and 6.3 ± 3.2º six months after the operation (P=0.021). In the OWHTO group, the mean PTS was 10.3 ± 4.4º before the operation and 8.9 ± 3.6º six months after the operation (P=0.028). The mean PTS change was not significantly different between the two groups [P=0.34; Table 2].

In the CWHTO group, the mean tibial varus angle was 8.8 ± 4.7º before the operation and 2.6 ± 3.7º six months after the operation (P<0.001). In the OWHTO group, the mean tibial varus angle was calculated at 9.4 ± 4.5º before the operation and 3.5 ± 3.8º six months after the operation (P<0.001). The mean improvement of the varus angle was not significantly different between the two groups [P=0.28; Table 2].

Postoperative complications

Union of the osteotomy site was observed in all patients. However, in one patient of the OWHTO group, the union was delayed. Six months after the operation, one patient in the CWHTO group had limited knee ROM (119º), while no patient in the OWTHO group showed limited ROM. Osteoarthritis progression was not seen in any patients of the two study groups. Two patients in the CWHTO group were incapable of full weight-bearing in the last follow-up, whereas all patients in the OWHTO group had full weight-bearing. One patient in the CWHTO group experienced immediate failed varus correction immediately. Postoperative infection occurred in one patient of each group. One case of intra-articular fracture occurred in the OWHTO group immediately after the operation. In this patient, the varus malalignment was not corrected as expected. Two patients in the OWHTO group experienced lateral hinge fractures. Deep vein thrombosis occurred in one patient of the OWHTO two weeks after the surgery [Table 3].

Table 3. Comparison of postoperative complication between the closing-wedge and opening-wedge high tibial osteotomy

Complication	Closing-wedge (n=36)	Opening-wedge (n=37)
Delayed healing	0	1 (2.7)
Limited range of motion	1 (2.8)	0
Limited wight-bearing	2 (5.5)	0
Failed varus correction	1 (2.8)	0
Infection	1 (2.8)	1 (2.7)
Intra-articular fracture	0	1 (2.7)
Lateral hinge fracture	0	2 (5.4)
Deep vein thrombosis	0	1 (2.7)

Data are presented as numbers (%)

Discussion

In this study, we compared the clinical outcomes, radiologic outcomes, and postoperative complications of CWHTO with OWHTO in patients with symptomatic medial osteoarthritis and varus deformity of the knee. Six months after the operation, no significant difference was found between the improvement of KOOS (total and subscales) in the two study groups. Additionally, radiologic outcomes, including the improvement of varus angle and PTS change, were not significantly different between the two groups. Postoperative complications were not remarkably different between the two groups, as well.

Numerous studies have compared the outcomes of CWHTO with OWHTO. Furthermore, several meta-analyses have been conducted in this regard. In 2011, Smith et al. performed a meta-analysis to compare the clinical and radiological outcomes of CWHTO with OWHTO. Twelve studies (nine clinical trials) comparing 324 patients in the OWHTO group and 318 patients in the CWHTO group were included. No significant difference was found between the clinical outcomes and postoperative complications of the two groups. However, PTS, mean angle of correction, reduced patellar height, and HKA angle correction were significantly greater after OWHTO.[10] Similar to the study of Smith et al., we found no significant difference between the clinical outcomes and postoperative complications of the two groups. The mean final PTS of the patients was significantly higher in the OWHTO group of the present study. However, it was due to the higher preoperative PTS in the OWHTO group, as the mean change of PTS was not significantly different between the two groups.

In 2017, Sun et al. performed a meta-analysis to compare the clinical outcomes, radiologic outcomes, and complications of OWHTO with CWHTO. Twenty-three studies, including 19 RCTs, were included in this meta-analysis. No significant difference was observed between the clinical outcomes of the two groups. However, OWHTO led to greater PTS and limb length and smaller patellar height. In addition, the accuracy of correction was higher in the OWHTO group. On the other hand, CWHTO was associated with a higher incidence of opposite cortical fracture.[7] While clinical outcomes of the two-osteotomy technique were similar in our study, no case of opposite cortical fracture was observed in this series, which could be attributed to the short-term follow-up of the study. In addition, our result does not support a greater PTS and more accurate correction by OWHTO.

In 2018, Wang et al. performed a meta-analysis of available RCTs to determine whether OWHTO is superior to CWHTO in the treatment of unicompartmental osteoarthritis. Nine RCTs (599 patients) were included. No significant difference was found between the VAS for pain, Hospital for Special Surgery Knee-Rating Scale, walking distances, HKA angles, complications, and survival rates of the two-osteotomy techniques. However, the PTS was significantly greater in the OWHTO group. They suggested considering this difference to individualize osteotomy type based on the patient's need.[9]

In 2019, Cheng et al. performed a metanalysis to compare the changes in the clinical and radiological variables between the CWHTO and OWHTO groups. Twenty-eight trials involving 2,840 knees were included in this analysis. Improvement of clinical scores, HKA, and anatomical femorotibial angle was not significantly different between the two groups. However, OWHTO was associated with increased PTS and decreased patellar height. Accordingly, they suggested personalizing the osteotomy technique using the specific situation of each patient.[30]

Kim et al., in a meta-analysis, compared the survival of the CWHTO with OWHTO. Twenty-three studies were included in this analysis. The majority of them (20 of 23) were of level IV evidence. The pooled 5-year survival was not significantly different between the two groups (95.1% for OWHTO vs. 93.9% for CWHTO). The pooled 10-year survival was significantly greater for the OWHTO group (91.6% for OWHTO vs. 85.4% for CWHTO).[31] Due to the short-term follow-up of the patients, survival analysis was not performed in the present study.

Altogether, the results of the current study, in line with the results of earlier studies, show no significant difference between the clinical outcomes and postoperative complications of the two osteotomy techniques. Although the majority of earlier studies have reported a greater PTS following the OWHTO, the mean PTS was significantly reduced in both groups of the present study. Additionally, the mean reduction of PTS was not significantly different between the two groups. Meanwhile, the study of Bagherifard et al. revealed a negligible PTS reduction of less than 1º OWHTO.[11] These inconsistencies could be attributed to the characteristic features of the included patients, and future standard studies are required to further evaluate the effect of CWHTO and OWHTO on PTS.

The present study was not without limitations. The main limitation of the study was its short follow-up. The small sample size could be regarded as the other limitation of this study. Therefore, future studies with longer follow-ups and larger patient numbers are required to confirm the results of the present study. In addition, patellar height, which is a useful assessment method in comparing the two osteotomy techniques,[32] was not investigated in the present study.

The clinical outcomes, radiologic outcomes, and postoperative complications of CWHTO and OWHTO are not significantly different, at least in short-term follow-up. According to these results, OWHTO is not superior to CWHTO in the treatment of symptomatic medial osteoarthritis and varus deformity of the knee, and the osteotomy technique can be selected based on the surgeon's preference.

Conclusion

The clinical outcomes, radiologic outcomes, and postoperative complications of CWHTO and OWHTO are not significantly different, at least in short-term follow-up. According to these results, OWHTO is not superior to CWHTO in the treatment of symptomatic medial osteoarthritis and varus deformity of the knee , and the osteotomy technique can be selected based on the surgeon's preference.

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