Preoperative Medial Tightness and Narrow Medial Joint Space Are Predictive Factors for Lower Extremity Alignment Change Toward Varus After Opening-Wedge High Tibial Osteotomy

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Investigation performed at Samsung Medical Center, Seoul, Republic of Korea

Background: Time-dependent changes in lower extremity alignment after an opening-wedge high tibial osteotomy (OWHTO) have been poorly investigated. Moreover, few studies have investigated risk factors of postoperative alignment change.

Purposes: To investigate time-dependent alignment changes and identify predictive factors for postoperative alignment change after OWHTO.

Study Design: Case-control study; Level of evidence, 3.

Methods: This study included patients who underwent OWHTO between March 2010 and September 2018. A total of 142 knees with a mean follow-up of 42 months were included and classified as the change group when the amount of hip-knee-ankle (HKA) angle change was $>1^\circ$; if otherwise, then as the no-change group. HKA angle was obtained at 6 time points: preoperatively and at 3 months, 6 months, 1 year, 2 years, and final follow-up postoperatively. Multiple regression analysis was performed to identify the factors that were correlated with the changes in the HKA angle from 3 months to the final follow-up.

Results: Among the 142 knees, 59 (42%) were included in the change group. The overall postoperative HKA angles progressed serially toward varus after OWHTO. The mean angles of the 6 time points were 8.5°, –3.7°, –3.6°, –3.3°, –3.1°, and –2.7°, respectively. The mean HKA angles of the change and no-change groups were 9.1°, –4.3°, –3.4°, –2.8°, –2.0°, and –1.4° and 8.1°, –3.3°, –3.8°, –3.6°, –3.8°, and –3.7°, respectively. Greater change in the HKA angle was predicted by preoperatively greater valgus stress joint line convergence angles and less medial joint space width.

Conclusion: Of the cases of OWHTO, 42% showed correction loss of $>1^\circ$ at a mean follow-up of 42 months. The overall postoperative HKA angles progressed serially to varus angles after OWHTO. Preoperative greater valgus stress joint line convergence angles and less medial joint space width were predictive factors for greater change in alignment toward varus after OWHTO.

Keywords: high tibial osteotomy; alignment change; predictive factor

Opening-wedge high tibial osteotomy (OWHTO) is a well-established surgical option for medial compartmental osteoarthritis of the knee. This procedure involves transferring the mechanical axis from a medial to a slightly more lateral position to decrease the load and subsequently delay the progression of medial compartment degeneration. To date, the 10-year survival rate of high tibial osteotomy has been reported to be in the range of 51% to 93.2%.[1,2,10,34]

Numerous anatomic changes may be observed after OWHTO. For example, the cartilage status of the medial compartment might be improved, degeneration of the lateral compartment or patellofemoral joint could worsen, and the coronal alignment of the ankle joint could change.[5,12,20] Among these changes, the lower extremity alignment over time is also a major question, and several studies have demonstrated that serial changes in the weightbearing line (WBL) showed progression toward varus angles (varus progression) during the follow-up period.[16,21,40] However, there are only a few studies that have quantified how many patients experienced a postoperative alignment change to varus angles.

It is widely accepted that the target of adjusting the mechanical axis of the lower extremity must pass through 62.5% of the tibial plateau from the medial edge of the

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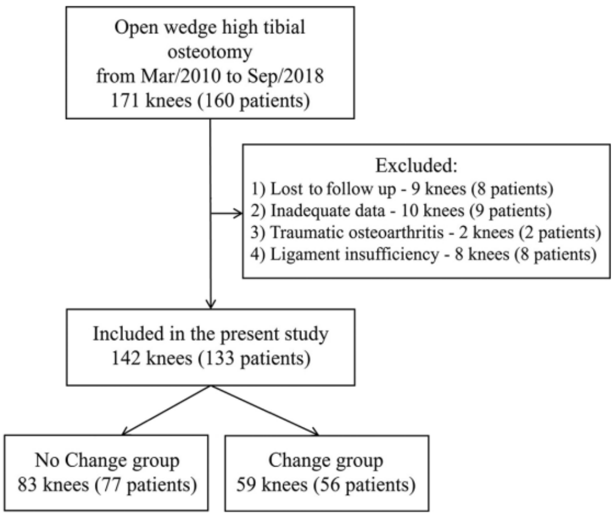

Figure 1. Flowchart describing the patients enrolled in the study.

TABLE 1
Descriptive Data (N = 142 Knees in 133 Patients)[a]

Variable	Value
Age, y	53.1 ± 8.8 (21 to 64)
Sex, M:F	47:95
BMI	26.9 ± 3.9 (19.4 to 41.4)
Direction, right:left	74:68
Follow-up period, mo	42.0 ± 15.0 (24 to 93)
Preoperative HKA angle, deg	8.5 ± 2.8 (4.6 to 15.3)
Postoperative HKA angle (3 mo), deg	–3.7 ± 2.5 (–11.9 to 1.9)
Preoperative tibial slope, deg	79.2 ± 4.0 (67.7 to 88.4)
Preoperative MPTA, deg	83.9 ± 2.8 (73.7 to 89.2)
Preoperative valgus stress JLCA, deg	–0.2 ± 2.2 (–6.3 to 6.2)
Preoperative medial joint space width, mm	1.8 ± 1.2 (0.2 to 5.6)

[a]Data are shown as mean ± SD (range) or No. of knees. BMI, body mass index; F, female; HKA, hip-knee-ankle; JLCA, joint line convergence angle; M, male; MPTA, medial proximal tibial angle.

proximal tibia.[9,14,19] Surgeons can select the target point according to the patient's knee condition rather than just a single fixed point.[15,40] A lesser amount of correction could be indicated for patients with poor cartilage or meniscal status of the lateral compartment, and a larger correction might be selected for patients who are expected to progress to varus deformity after OWHTO. However, few studies have investigated the factors that predict varus progression after this surgery.

The purposes of the present study were to investigate time-dependent alignment changes and to identify the predictive factors for postoperative alignment change after OWHTO. Furthermore, the correlation between postoperative varus progression and clinical outcomes was also investigated. It was hypothesized that the severity of medial compartmental osteoarthritis would be a risk factor affecting varus progression after OWHTO.

METHODS

Patients

This retrospective study included patients who underwent OWHTO between March 2010 and September 2018 in a single institution. The protocol for this study received approval from the institutional review board, and informed consent was obtained from all patients. The surgical indications for OWHTO were as follows: (1) symptomatic medial compartment osteoarthritis or medial femoral condyle (MFC) osteonecrosis, (2) flexion contracture $<15^\circ$, and (3) absence or minimal osteoarthritic changes in the lateral compartment. The inclusion criteria were as follows: (1) patients who underwent OWHTO and (2) those who were clinically followed up for a minimum of 2 years with adequate clinical and radiographic data. In contrast, those who were aged >65 years and underwent concomitant surgeries, such as ligament reconstruction, were excluded from the study. Among the screened patients, 8 patients (8 knees) were excluded owing to a previous history of ligament injury, and 2 patients (2 knees) underwent surgery owing to posttraumatic osteoarthritis. A total of 133 patients (142 knees) were enrolled in this study (Figure 1). The characteristics of the included patients are shown in Table 1.

The patients were divided into 2 groups according to the amount of change in the hip-knee-ankle (HKA) angle from postoperative 3 months to the final follow-up. Based on a previous study,[21] the patients were assigned to the change group when the amount of HKA angle change was $>1^\circ$; otherwise, they were assigned to the no-change group (Figure 2).

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Ethical approval for this study was obtained from Samsung Medical Center (ref No. 2021-12-017).

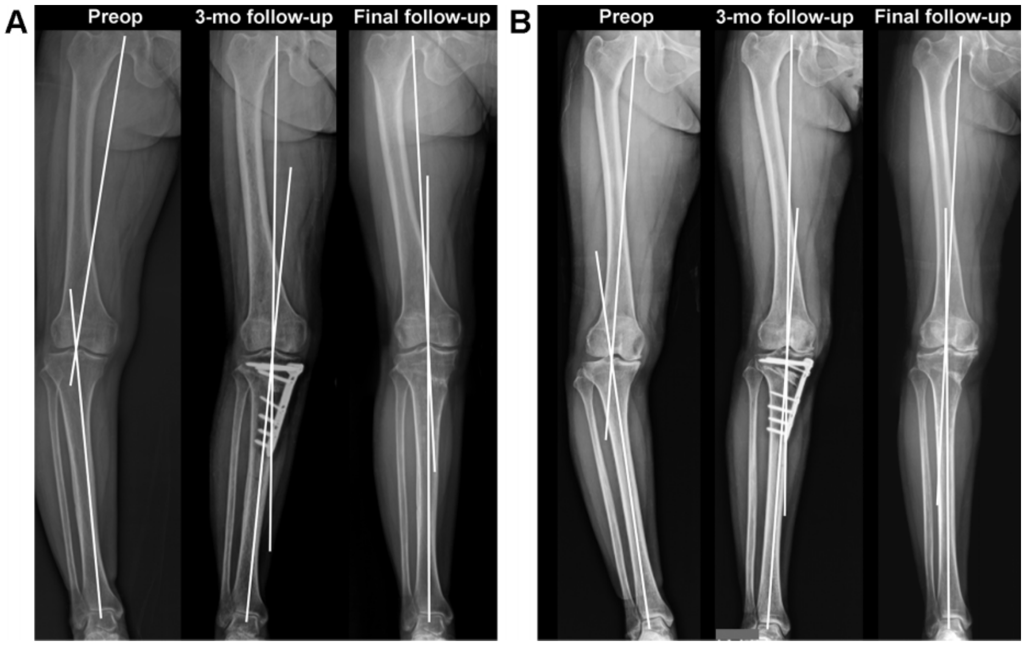

Figure 2. Whole-leg standing radiographs showing the hip-knee-ankle angle at the preoperative (Preop), 3-month postoperative, and 39-month postoperative stages of 2 patients from the change group: (A) varus, 13.2°; valgus, 6.6°; and valgus, 1.9°, respectively; and (B) varus, 12.5°; valgus, 4.7°; and varus, 3.5°, respectively. Varus deformity recurred after 41 months in the patient in B.

Surgical Technique

All surgeries were performed by a senior surgeon (J.H.W.) at a single institution. Usually, the target postoperative HKA angle was 3° valgus or when the WBL passed through 62.5% of the tibial plateau from the medial edge.[14,39] If the medial compartment exhibited grade 4 chondral defect on both femoral and tibial sides, then 4° to 5° valgus was the target. The correction angle was estimated using the Miniaci method.[24] Knee arthroscopy was performed before osteotomy surgery to evaluate the cartilage status of the MFC and medial tibial plateau (MTP) and medial meniscal status. The status of the cartilage on the MFC and MTP was scored using the International Cartilage Regeneration & Joint Preservation Society grading system.[31] The status of the medial meniscal tear was divided into 3 grades as defined in a previous study.[22] A surgical incision was made transversely on the superomedial side of the tibia. After the pes anserinus and superficial medial collateral ligament were released, biplanar osteotomy was performed on all knees. The superficial medial collateral ligament was completely transected using an electrocautery device at a level just below the osteotomy area. The osteotomy was fixed using a T-shaped locking plate (TomoFix; Synthes), and an allogenic chip bone graft was inserted into the gap.

Immediately after OWHTO, the patients were allowed to walk using partial weightbearing on the operated limb, and full range of motion exercises were encouraged from postoperative day 2. Full weightbearing, as well as the ability to remove the hinged brace, was allowed 6 weeks after surgery. Plate removal was performed at least 18 months after OWHTO surgery if patients wanted a removal surgery after an explanation of the advantages and disadvantages.

Radiographic and Clinical Assessments

Whole-leg standing radiographs with the patella facing forward, standing knee radiographs in the anteroposterior view and lateral view, and valgus stress knee radiographs were assessed. A telometer (DST-1000; Daiseung Medical Co) was used to check the valgus stress radiographs. During the examination, a valgus force of 150 N was loaded onto the knee joint at 20° of flexion.

The HKA angle was defined as the angle subtended by a line drawn from the center of the femoral head to the center of the knee and a line drawn from the center of the knee to the center of the talus on whole-leg standing radiographs, with a positive and negative HKA angle indicating varus and valgus, respectively[11,30] (Figure 2). To investigate the gradual changes in the HKA angle, we measured this angle at 6 time points: preoperatively and at 3 months, 6 months, 1 year, 2 years, and final follow-up postoperatively. The change in the HKA angle from the 3-month to final follow-up was calculated to investigate the varus progression. The medial proximal tibial angle (MPTA) was defined as the angle between the tibial mechanical axis and articular surface of the proximal tibia.[29,33,40] The tibial slope was measured as the angle between the line perpendicular to the middiaphysis of the tibia and the line depicting the posterior inclination of the tibial plateau in the lateral view.[23] The medial joint space width was measured from the center of the MFC to the center of the MTP on the

Rosenberg view, as described in a previous study.[17] The valgus stress joint line convergence angle (JLCA) was defined as the angle between 2 articular tangential lines of the distal femur and proximal tibia.[35,39] It was measured on valgus stress radiographs (valgus stress JLCA). The values were recorded as positive when the apex of the angle was medial (varus) and negative when the apex of the angle was lateral (valgus) (Figure 3).

Patient age, sex, body mass index (BMI), follow-up period, preoperative HKA angle, tibial slope, MPTA, valgus stress JLCA, medial joint space, and HKA angle at postoperative 3 months were considered as potential predictive factors for varus progression. Preoperative and final follow-up radiographic data were compared. The comparison was also performed between the change and no-change groups. All radiographic parameters were measured by 2 orthopedic surgeons (Y.K.L. and I.S.K.) twice with at least 6-week intervals between each measurement, using a picture archiving and communication system (Centricity PACS Viewer; GE Healthcare Co). Intraclass correlation coefficients (ICCs) were used for intraobserver and interobserver reliabilities.

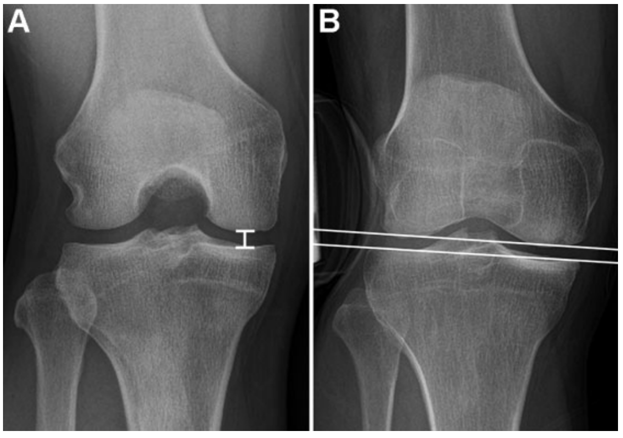

Figure 3. Measurement of (A) medial joint space width on Rosenberg view and (B) valgus stress joint line convergence angle on valgus stress radiographs.

Clinical outcomes, including range of motion, International Knee Documentation Committee (IKDC) subjective score,[3] and Knee injury and Osteoarthritis Outcome Score (KOOS)[32] were investigated preoperatively and at the final follow-up. Clinical outcomes were compared between the groups. Preoperative and postoperative clinical outcomes were also compared between the groups.

Statistical Analysis

The time-dependent HKA angle changes were analyzed using repeated-measures analysis of variance, and post hoc comparisons between the mean HKA angles of all pairs of points in time were performed. Stepwise multiple regression analysis was performed to identify which of the following factors were correlated with changes in the HKA angle from 3 months to the final follow-up. The independent factors were patient age, sex, BMI, follow-up period, preoperative HKA angle, tibial slope, MPTA, valgus stress JLCA, medial joint space, HKA angle at postoperative 3 months, chondral status of MFC and MTP, and meniscal tear grade. The Shapiro-Wilk test was used to evaluate the normality of distribution. To compare preoperative and final follow-up outcomes, we used the paired *t* test for continuous variables and chi-square test for categorical variables. To compare the preoperative, intraoperative, and postoperative data between the 2 groups, we used the Student *t* test or chi-square test. All data were analyzed using SPSS Version 27.0 (IBM Corp), and statistical significance was set at $P < .05$. It would take a statistical power of 98% to detect a difference of at least 1° with a standard deviation of 3° in HKA angle change from before surgery to after surgery ($\alpha = .05$).

RESULTS

All inter- and intraobserver ICCs showed good agreement with respect to the reliability of the radiographic measurement (>0.80) (Table 2).

TABLE 2
ICCs of Interobserver and Intraobserver Errors in Assessing Radiographic Measurements[a]

Measurements	Interobserver ICC	Intraobserver ICC	
		Observer 1	Observer 2
Preoperative HKA angle	0.89	0.901	0.887
Postoperative HKA angle (3 mo)	0.833	0.865	0.846
Postoperative HKA angle (final follow-up)	0.866	0.813	0.83
Preoperative tibial slope	0.913	0.887	0.891
Postoperative tibial slope	0.922	0.91	0.905
Preoperative MPTA	0.895	0.837	0.864
Postoperative MPTA	0.884	0.9	0.875
Preoperative JLCA	0.88	0.886	0.836
Postoperative JLCA	0.917	0.923	0.918
Preoperative medial joint space width	0.881	0.897	0.905
Postoperative medial joint space width	0.923	0.896	0.89

[a]HKA, hip-knee-ankle; ICC, intraclass correlation coefficient; JLCA, joint line convergence angle; MPTA, medial proximal tibial angle.

The overall postoperative HKA angles progressed serially toward varus angles after OWHTO. For all patients, the mean HKA values preoperatively and at 3 months, 6 months, 1 year, 2 years, and the final follow-up postoperatively were 8.5°, –3.7°, –3.6°, –3.3°, –3.1°, and –2.7°, respectively (change group: 9.1°, –4.3°, –3.4°, –2.8°, –2.0°, –1.4°; no-change group: 8.1°, –3.3°, –3.8°, –3.6°, –3.8°, –3.7°) (Figure 4). Compared with the value at 3 months postoperatively, the overall HKA angles were significantly greater (ie, more varus) at 1 year (P = .012), 2 years (P < .001), and final follow-up (P < .001). The mean change in HKA angle from 3-month to final follow-up was 1.0° ± 2.2° for all patients and 2.8° ± 1.6° for patients in the change group.

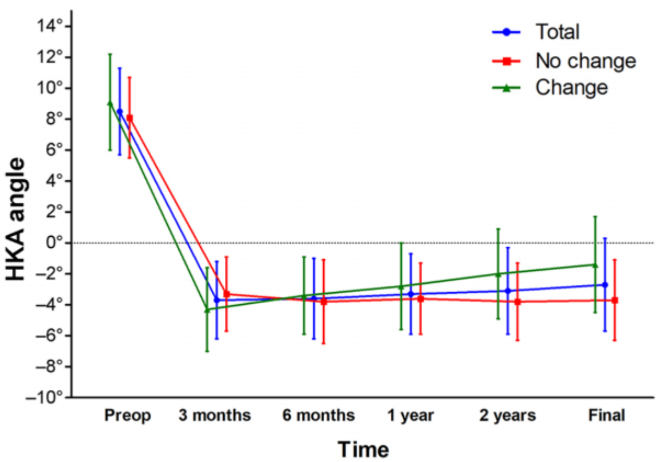

Figure 4. Hip-knee-ankle (HKA) angle measurements by time for all patients (blue line), the change group (green line), and the no-change group (red line). Preop, preoperative.

Regarding the correlation between change in the HKA angle from 3-month to final follow-up and potential predictive factors, greater valgus stress JLCA and less medial joint space width were correlated with greater HKA angle change (adjusted $R^2 = 0.133$). In other words, a substantial change in the HKA angle was predicted by preoperative medial collateral ligament tightness and narrow medial joint space (Table 3).

Clinical outcomes, including the IKDC subjective score (P < .001) and KOOS (all subscales; P < .001), improved significantly after OWHTO at a mean follow-up duration of 42 months (Table 4). Overall, the valgus stress JLCA postoperatively was significantly greater than that during the preoperative period (P = .001). Valgus stress JLCA postoperatively was shown to be of greater value than that during the preoperative period for both groups; however, only the change group exhibited statistical significance (Figure 5).

Among the 142 knees, 59 (42%) were included in the change group, and 83 (58%) were included in the no-change group. With respect to the comparison of preoperative outcomes between both groups, most of the outcomes were not statistically significant except for valgus stress JLCA, medial joint space width, and intraoperative cartilage status of the MFC and MTP. Greater valgus stress JLCA (P = .001) and less medial joint space width (P < .001) were observed in the change group. Higher-grade chondral lesions of MFC (P = .009) and MTP (P = .021) were found in the change group (Table 5).

The postoperative IKDC subjective scores were similar between the 2 groups. On the other hand, 3 KOOS subscales (Symptoms, Activities of Daily Living, and Sport and Recreation) were significantly inferior in the change group (Table 6). The change group was significantly overcorrected at the 3-month follow-up (HKA angle: no-change group, –3.3° vs change group, –4.3°; P = .026) but showed significant varus progression at the final follow-up (no-change group, –3.7° vs change group, –1.4°; P < .001).

TABLE 3

Multiple Regression Analysis of Factors Correlated With the Change in HKA Angle From 3-Month to Final Follow-up[a]

Independent Variables	Nonstandardized Coefficient B	Nonstandardized Coefficient SE	Standardized Coefficient B	P
Age	0.091	0.022	—	.997
Sex	0.405	0.371	—	.277
Body mass index	0.022	0.044	—	.616
Follow-up period	0.004	0.011	—	.756
Preoperative HKA angle	0.118	0.063	—	.065
Postoperative HKA angle (3 mo)	–0.085	0.072	—	.238
Preoperative tibial slope	0.023	0.042	—	.579
Preoperative MPTA	0.058	0.07	—	.41
Preoperative valgus stress JLCA	0.257	0.082	–0.263	**.002**
Preoperative medial joint space width	–0.325	0.144	–0.188	**.026**
ICRS grade of MFC	0.105	0.318	—	.206
ICRS grade of MTP	0.014	0.276	—	.959
Meniscal tear grade	–0.142	0.361	—	.694

[a]Boldface P values indicate significant association with dependent variable (change in HKA angle from 3-month to final follow-up; P < .05). HKA, hip-knee-ankle; ICRS, International Cartilage Regeneration & Joint Preservation Society; JLCA, joint line convergence angle; MFC, medial femoral condyle; MPTA, medial proximal tibial angle; MTP, medial tibial plateau.

TABLE 4
Preoperative and Final Follow-up Values of Clinical and Radiographic Outcomes[a]

	Preoperative	Final Follow-up	*P*
Range of motion, deg	135.7 ± 12.0	136.0 ± 8.5	.773
IKDC subjective score	36.6 ± 19.0	56.5 ± 19.1	**<.001**
KOOS			
Pain	51.6 ± 20.5	69.5 ± 22.1	**<.001**
Symptoms	56.3 ± 20.5	73.4 ± 18.3	**<.001**
Activities of Daily Living	56.7 ± 22.7	76.9 ± 20.0	**<.001**
Sport and Recreation	26.6 ± 25.0	46.5 ± 26.3	**<.001**
Quality of Life	35.6 ± 22.5	58.7 ± 24.3	**<.001**
Tibial slope, deg	79.2 ± 4.0	78.2 ± 10.3	.271
MPTA, deg	83.9 ± 2.7	94.6 ± 3.2	**<.001**
Valgus stress JLCA, deg	–0.2 ± 2.2	0.3 ± 2.5	**.001**
Medial joint space width, mm	1.8 ± 1.2	1.9 ± 1.3	.318

[a]Data are shown as mean ± SD. Boldface *P* values indicate statistically significant difference between preoperative and final follow-up ($P < .05$). IKDC, International Knee Documentation Committee; JLCA, joint line convergence angle; KOOS, Knee injury and Osteoarthritis Outcome Score; MPTA, medial proximal tibial angle.

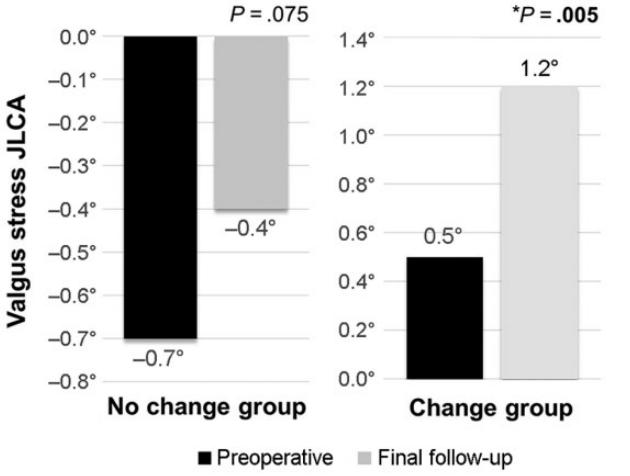

Figure 5. Comparison of preoperative and final follow-up valgus stress JLCA within each group. *Statistically significant difference between preoperative and final follow-up data ($P < .05$). JLCA, joint line convergence angle.

Similar to preoperative outcomes, greater postoperative valgus stress JLCA ($P < .001$) and less postoperative medial joint space width ($P < .001$) were demonstrated in the change group.

Two patients experienced postoperative infection at 6 weeks and 6 months after the surgery, respectively. Open debridement was performed, and they healed well. One patient experienced peroneal nerve palsy. After 6 months, all symptoms resolved except for a slight weakness of big toe extension strength.

DISCUSSION

The most important findings of the present study were the following: (1) 42% of cases (59 of 142 knees) of OWHTO showed a correction loss of >1° at a mean follow-up of 42 months, and (2) preoperative greater valgus stress JLCA and less medial joint space width were predictive factors for varus progression after OWHTO.

Time-dependent serial assessment of lower extremity alignment after OWHTO has been of interest. Lee et al[21] investigated serial changes in lower extremity alignment after OWHTO up to 2 years after surgery. They found that the WBL shifted medially and the HKA valgus angle decreased with time; the mean HKA angles at 1 month and 2 years postoperatively were valgus 3.9° and 2.9°, respectively. Song et al[40] observed serial changes in postoperative lower extremity alignment for 4 years and found that the WBL showed consistent progression toward the varus angles; WBL ratios were 63.8% and 58.1% at the immediate postoperative and final follow-ups, respectively. In previous studies, HKA angles or WBL ratios tended to proceed toward varus after OWHTO. In our study, the overall HKA angle changed from a valgus angle of 3.7° to 2.7°, which is consistent with previous studies. However, not all patients showed varus progression, and approximately 58% of all patients did not develop varus progression during a 42-month follow-up period. We believe that our results support the notion that the individualization of target points could be applied if surgeons expect a change in a patient's alignment after OWHTO.[15,40]

Knee joint osteoarthritis is a multifactorial disease initiated by biological, morphological, and biomechanical factors.[27] Previous research has shown that knee malalignment is a major factor for knee osteoarthritis characterized by disrupted biomechanics.[6,41] In particular, knee varus deformity has been found to be associated with a greater risk of medial compartment disease, including cartilage defects, meniscal tears, and medial collateral ligament tightness.[13,36] OWHTO transfers the mechanical axis from a medial to lateral position to decrease the medial contact force and subsequently delay the progression of medial compartment degeneration. It appears that a change in lower extremity alignment toward varus angles after osteotomy is an aspect in the progression to knee osteoarthritis.[40] In our study, preoperative medial

TABLE 5
Comparison of Descriptive Data and Preoperative and Intraoperative Outcomes Between Groups[a]

	No Change (n = 83 Knees)	Change (n = 59 Knees)	*P*
Age, y	52.4 ± 9.4	54.0 ± 7.8	.294
Sex, M:F	30:53	17:42	.373
Body mass index	26.9 ± 4.1	26.8 ± 3.7	.805
Follow-up period, mo	41.9 ± 14.4	42.0 ± 15.8	.964
Range of motion, deg	135.2 ± 11.8	136.6 ± 12.4	.503
IKDC subjective score	34.7 ± 18.0	39.2 ± 20.2	.187
KOOS			
Pain	50.3 ± 21.7	52.2 ± 19.1	.593
Symptoms	56.7 ± 21.2	55.9 ± 19.3	.834
Activities of Daily Living	56.3 ± 23.1	57.4 ± 21.6	.772
Sport and Recreation	24.3 ± 24.4	28.9 ± 25.4	.299
Quality of Life	35.8 ± 23.1	26.2 ± 21.9	.936
HKA angle, deg	8.1 ± 2.6	9.1 ± 3.1	.053
Tibial slope, deg	78.9 ± 3.5	79.6 ± 4.6	.331
MPTA, deg	83.9 ± 2.7	83.8 ± 2.7	.946
Valgus stress JLCA, deg	–0.7 ± 2.3	0.5 ± 1.8	**.001**
Medial joint space width, mm	2.1 ± 1.3	1.4 ± 0.8	**<.001**
ICRS grade of MFC, 1/2/3/4	0/3/42/38	0/3/15/41	**.009**
ICRS grade of MTP, 1/2/3/4	3/10/46/24	0/3/26/30	**.021**
Meniscal tear grade, 1/2/3	0/36/47	0/22/37	.493

[a]Data are shown as mean ± SD (range) or No. of knees. Boldface *P* values indicate statistically significant difference between groups ($P < .05$). F, female; HKA, hip-knee-ankle; ICRS, International Cartilage Regeneration & Joint Preservation Society; IKDC, International Knee Documentation Committee; JLCA, joint line convergence angle; KOOS, Knee injury and Osteoarthritis Outcome Score; M, male; MFC, medial femoral condyle; MPTA, medial proximal tibial angle; MTP, medial tibial plateau.

TABLE 6
Comparison of Postoperative Outcomes Between Both Groups[a]

	No Change (n = 83 Knees)	Change (n = 59 Knees)	*P*
Range of motion, deg	136.6 ± 8.5	135.0 ± 8.6	.275
IKDC subjective score	58.7 ± 19.4	53.4 ± 18.5	.118
KOOS			
Pain	72.4 ± 23.3	65.5 ± 20.0	.086
Symptoms	51.8 ± 26.3	38.9 ± 24.6	**.046**
Activities of Daily Living	80.0 ± 19.6	72.6 ± 19.0	**.035**
Sport and Recreation	51.8 ± 26.3	38.9 ± 24.6	**.006**
Quality of Life	61.2 ± 26.2	55.1 ± 20.9	.169
HKA angle (3 mo), deg	–3.3 ± 2.4	–4.3 ± 2.7	**.026**
HKA angle (final follow-up), deg	–3.7 ± 2.6	–1.4 ± 3.1	**<.001**
Tibial slope, deg	77.4 ± 12.7	79.4 ± 5.2	.261
MPTA, deg	94.2 ± 3.2	94.9 ± 3.2	.56
Valgus stress JLCA, deg	–0.4 ± 2.4	1.2 ± 2.3	**<.001**
Medial joint space width, mm	2.3 ± 1.3	1.3 ± 0.9	**<.001**

Data are shown as mean ± SD. Boldface *P* values indicate statistically significant difference between groups ($P < .05$). HKA, hip-knee-ankle; IKDC, International Knee Documentation Committee; JLCA, joint line convergence angle; KOOS, Knee injury and Osteoarthritis Outcome Score; MPTA, medial proximal tibial angle.

joint narrowing and medial collateral ligament tightness were associated with a greater change in the lower extremity alignment toward varus angles; the reason is not yet fully understood. We believe that knee osteoarthritis could still progress owing to other issues, even if mechanical problems were addressed. For example, proprioceptive function is significantly impaired in an osteoarthritic knee joint.[38] Previous studies have insisted that proprioceptive deficits could be both a cause and a result of knee osteoarthritis.[18,38] In our study, the HKA angle at 3 months postoperatively was significantly overcorrected in the change group considering the knee degeneration. However, it was observed that the results between both groups were reversed at final follow-up. We believe that the progression of osteoarthritis in the change group might have been worse than that in the no-change group, even though more alignment corrections were achieved.

Several studies have reported excellent clinical outcomes after OWHTO.[4,7,28] Patient satisfaction after osteotomy surgery was reported to be in the range of 75% to 85%; conversely, a significant number of patients were dissatisfied after OWHTO.[8,25] One reason for dissatisfaction was the presence of severe knee-articular cartilage damage.[26,37] A previous study demonstrated that patients with varus recurrence after OWHTO do not experience poor clinical outcomes compared to patients with no varus recurrence.[40] In our study, 3 of the KOOS subscale scores in the change group were significantly inferior. We believe that the preoperative medial joint space was different between both groups, which was a major confounding factor, thus inducing significant differences in the KOOS subscale scores. It is difficult to say, based on our results alone, that subpar clinical outcomes were associated with an alignment change toward varus. To accurately analyze the relationship between alignment change and clinical outcomes, confounding variables should be eliminated.

Limitations

There were some limitations to our study. First, the patients were divided into the change and no-change groups according to change in HKA angle (either $>1^\circ$ or $\leq 1^\circ$) between the 3-month and final follow-up; if the follow-up period was longer, the number of patients in each group would have varied. Therefore, the causal relationship may not be strong. Second, this study evaluated midterm results; hence, osteoarthritic progression could not be fully assessed. Third, patellofemoral joint pathology could be a confounding factor in the analysis of clinical outcomes. Fourth, as patients without all serial whole-leg standing radiographs were excluded in this study, selection bias may have existed. Fifth, our study included only Asian patients; therefore, studies involving other races are needed in the future to apply to all races. Sixth, the superficial MCL was completely cut, the opening gap was filled with allogenous bone, and partial weightbearing was performed. It is possible that different surgical techniques or rehabilitation protocols might affect the results.

CONCLUSION

The study findings indicated that 42% (59 of 142 knees) of patients with OWHTO showed a correction loss of $>1^\circ$ at a mean follow-up of 42 months. The overall postoperative HKA angles progressed serially toward varus angles. Preoperative greater valgus stress JLCA and less medial joint space width were predictive factors for greater alignment change toward varus angles after OWHTO.

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