

# Disparity between Preoperative Target Correction Amount and Postoperative Correction Amount in Open Wedge High Tibial Osteotomy

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**Purpose:** The purpose of this study was to evaluate the disparity between the preoperative target correction amount and the postoperative correction amount in open wedge high tibial osteotomy (OWHTO) in patients divided according to the planned osteotomy gap.

**Materials and Methods:** Seventy-two patients were divided into two groups (group 1 with the planned opening gap larger than the mean opening gap length of total patients and group 2 with a smaller opening gap). The opening gap was determined according to the target weight bearing line (WBL) ratio on the preoperative whole leg radiograph. Absolute and relative values of the disparity between the target and postoperative WBL ratios were compared between groups in order to clarify whether the disparity was deviated toward over- or under-correction.

**Results:** The absolute value of disparity between the target and postoperative WBL ratios in group 1 was significantly larger than that in group 2 (6.01%±5.68% vs. 3.32%±3.38%;  $p=0.02$ ). However, there was no statistically significant difference in relative values between groups ( $p=0.54$ ).

**Conclusions:** The postoperative WBL ratio after OWHTO was different from the preoperative target WBL ratio if the planned osteotomy gap was large. This mismatch was not deviated toward one side, either over- or under-correction.

**Keywords:** Knee, Osteoarthritis, Varus deformity, Osteotomy

## Introduction

Medial open wedge high tibial osteotomy (OWHTO) is a good option for treatment of medial unicompartmental osteoarthritis<sup>1-3</sup>. For successful OWHTO, proper indication, analysis of the deformity, thorough planning, appropriate surgical technique, and postoperative management are mandatory<sup>4-6</sup>. Among them, thorough planning could be regarded as an essential factor be-

cause accurate correction could be obtained through precise planning and proper surgical technique. Several methods, such as those of Hernigou et al.<sup>7</sup>, Dugdale et al.<sup>8</sup>, and Miniaci et al.<sup>9</sup>, have been introduced for preoperative planning using a whole leg radiograph<sup>10,11</sup>. Recently, the navigation system and digital imaging methods have also been introduced for accurate assessment of the deformity and adjustment in preoperative planning for the real operation<sup>11-18</sup>. Additionally, the picture archiving and communication system (PACS) and Photoshop are used for direct measurement of the height of the osteotomy gap with high reliability and easy availability<sup>6</sup>.

Surgeons recommend that the osteotomy gap according to the planned correction amount should be adjusted intraoperatively based on the status of the medial compartment and the goal of the osteotomy in OWHTO<sup>19,20</sup>. Despite delicate preoperative planning and intraoperative adjustment, the postoperative correction amount could be different from that preoperatively planned<sup>21,22</sup>. It is because preoperative planning for OWHTO is mostly conducted in 2 dimensions, while correction of the varus

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deformity is a 3 dimensional task. We observed the tendency of mismatch between the preoperatively planned correction amount and the actual correction amount after OWHTO was more prominent when a large amount of correction was required. We suspected whether this may be due to the limitation of the 2 dimensional planning for the 3 dimensional procedure and associated with the surgical technique itself<sup>23)</sup>.

The purpose of this study was to evaluate the disparity between the preoperative target correction amount and postoperative correction amount in OWHTO of patients divided into two groups according to the planned osteotomy gap. The hypothesis of this study was that the actual correction amount after OWHTO would be different from the preoperatively planned target correction amount if the planned osteotomy gap was large.

## Materials and Methods

From March 2014 to January 2015, 72 biplanar OWHTO patients were enrolled in this retrospective analysis. This study was approved by our Institutional Ethics Committee, and the informed consents were obtained from all patients. The mean age of the patients was  $57.6 \pm 5.5$  years and there were 51 females and 21 males. All patients underwent OWHTO for treatment of medial unicompartmental osteoarthritis with a varus deformity. The status of the lateral compartment was checked on preoperative magnetic resonance imaging, physical examination, and intraoperative arthroscopic examination. Exclusion criteria were as follows: (1) secondary, such as post-traumatic arthritis, (2) OWHTO associated with ligament reconstruction, (3) bilateral OWHTO, (4) revision OWHTO, (5) double osteotomy including distal femoral osteotomy, and (6) absence of preoperative and postoperative standing radiograph taken in full extension because of the limitation of more than 5 degrees of extension in the knee joint.

### 1. Preoperative Planning and Intraoperative Adjustment of the Amount of Correction

The weight bearing line (WBL) ratio on the standing whole leg radiograph was used to determine the target amount of correction (postoperative 6 weeks)<sup>24)</sup>. The INFINITT ver. 5.0.9.2 (INFINITT®, Seoul, Korea), which could measure automatically to 2 decimal places, was used for radiological measurements of the WBL ratio. The WBL was drawn from the center of the femoral head to the center of the superior articular surface of the talus. For calculation of the WBL ratio, the denominator was the width of the tibia, as measured using a ruler, and the numerator was the

tibial intersection of the WBL (with medial tibial edge at 0% and the lateral tibial edge at 100%).

For the preoperative planning, the planned 55.0%, 57.5%, 60.0%, 62.5%, 65.0%, and 67.5% WBLs were drawn in the standing whole leg radiographs. First, a line extending from the center of the hip through the center of the knee and the ankle was drawn<sup>24)</sup>. The second line (osteotomy line) was drawn from the starting point of the osteotomy (4 cm below the joint line) to the tip of the fibular head. The third line connecting the hinge point and the center of the ankle joint was drawn. The fourth line with the same length of the third line was drawn from the hinge point to the first line. The angle between the third and fourth lines was determined as a correction angle. The image was saved as a Joint Photographic Experts Group file and then transferred to Adobe Photoshop ver. 12.0 (Adobe™, San Jose, CA, USA) and the distal portion of the osteotomy was rotated for correction and saved as a Digital Image Communication in Medicine file. The image was re-transferred to the measuring system and the height of the opening gap at the osteotomy site was measured at each target WBL ratio (Fig. 1).

During the surgery, the target WBL ratio was determined according to the status of the medial compartment of the knee joint based on the surgeon's subjective assessment between 55.0% and 67.5%. The amount of opening gap at the osteotomy site was determined based on the planned osteotomy gap for each WBL ratio (Fig. 1). Lesser amount of correction was performed if cartilage status of the lateral compartment was slightly bad or the osteotomy was performed for protection of the medial compartment after the procedure such as microfracture or meniscal root repair. Larger correction was usually performed if the medial compartment showed the kissing lesion of cartilage or obliteration of the medial joint space. Biplanar osteotomy was performed and distraction was performed at most posterior gap (Fig. 2)<sup>25)</sup>.

All patients were divided into 2 groups according to the correction amount (group 1 with an opening gap larger than the mean height of the opening gap of total patients and group 2 with an opening gap smaller than the mean height of the opening gap of total patients). The difference between the preoperative target WBL ratio and postoperative WBL ratio measured at 6 weeks after surgery was compared between groups (Fig. 3). For clarification of under- or over-correction, relative and absolute valued were used in the comparison. Correlation analysis was also performed to evaluate the inaccuracy according to the amount of correction.

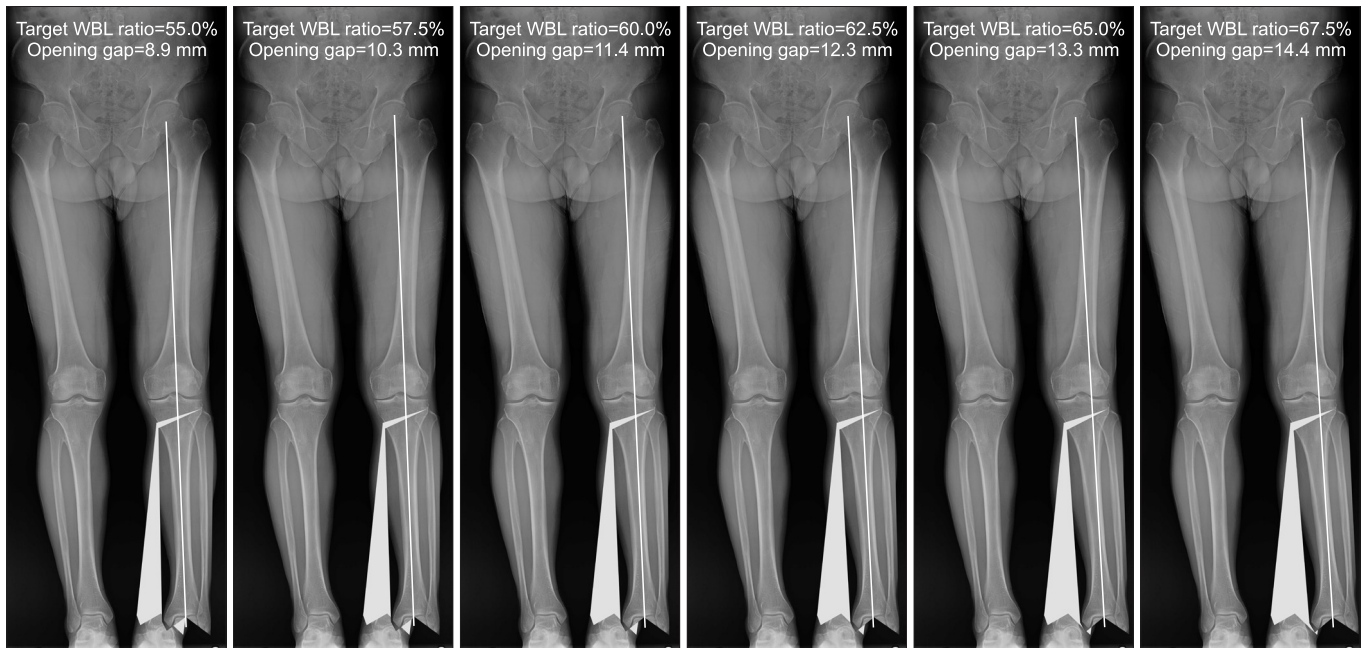


Fig. 1. Preoperative target weight bearing line (WBL) ratios (55.0%, 57.5%, 60.0%, 62.5%, 65.0%, and 67.5%) and the heights of opening gap at the osteotomy sites.



Fig. 2. The height of the opening gap was adjusted according to the preoperative plan and intraoperative status of the medial compartment.

## 2. Statistical Analysis

Statistical analysis was conducted using PASW Statistics ver. 18.0 (IBM Corp., Armonk, NY, USA). Student's *t*-test was used to compare between groups. Pearson's correlation analysis was performed to evaluate the accuracy of the preoperative planning according to the correction degree. The statistical significance was set at  $p < 0.05$ . Two orthopedic surgeons measured all parameters twice with a 2–3 week interval. The reliability of the measurements was assessed by examining the intra-rater and inter-rater reliability using the intra-class correlation coefficient.



Fig. 3. Radiographs of a 59-year-old male showing a difference of 5.3% between the preoperative target weight bearing line (WBL) ratio and postoperative WBL ratio (65.0%–59.7%).

## Results

The inter- and intra-observer reliabilities for the measurement of the WBL ratio were satisfactory and the mean values were 0.89 (range, 0.82 to 0.94) and 0.92 (range, 0.88 to 0.97), respectively.

The mean target WBL ratio was  $62.5\% \pm 1.8\%$  (range, 55.0% to 67.5%). The mean opening gap at the osteotomy site was  $10.8 \pm 3.2$

**Table 1.** Preoperative Demographics

	Group 1	Group 2	p-value
No. of patients	34	38	
Age (yr)	56.9±4.7	58.1±5.5	0.392 <sup>a)</sup>
BMI (kg/m <sup>2</sup> )	27.6±3.1	26.7±4.2	0.294 <sup>a)</sup>
Sex (male/female)	10/24	11/27	0.965 <sup>b)</sup>
Side (left/right)	16/18	18/20	0.979 <sup>b)</sup>
Varus alignment (°)	8.6±2.4	7.2±1.8	0.046 <sup>a)</sup>
MPTA (°)	85.1±2.7	85.9±2.4	0.387 <sup>a)</sup>
Posterior tibial slope (°)	9.2±1.2	10.1±2.7	0.247 <sup>a)</sup>

Values are presented as number only or mean±standard deviation. The statistical significance was set at  $p<0.05$ .

Group 1: opening gap larger than the mean height of the opening gap of total patients, Group 2: opening gap smaller than the mean height of the opening gap of total patients.

BMI: body mass index, MPTA: medial proximal tibial angle.

<sup>a)</sup>Derived from Student's *t*-test.

<sup>b)</sup>Derived from Pearson chi-square test.

mm (range, 6 to 18 mm). This mean opening gap of 10.8 mm divided all patients into two groups (34 patients in group 1 and 38 patients in group 2). Preoperative demographics of the two groups are shown in Table 1.

The difference of the absolute value between the target WBL ratio and postoperative WBL ratio was statistically significant between both groups ( $p=0.02$ ). However, there was no statistically significant difference in relative values between both groups ( $p=0.54$ ). Detailed differences between the target WBL ratio and postoperative WBL ratio are listed in Table 2.

In the correlation analysis of absolute values, the correlation coefficient was 0.35, showing statistical significance ( $p<0.01$ ). However, in the correlation analysis of relative values, the correlation coefficient was 0.11, showing no statistical significance ( $p=0.38$ ).

## Discussion

The principal finding of this study was that the difference between the target and postoperative WBL ratios showed statistical significance only in the absolute values, not in the relative values. Moreover, the differences in absolute values between the target and postoperative WBL ratios in group 1 were significantly larger than those in group 2. It could imply that disparity between the preoperative target WBL ratio and the postoperative WBL ratio could occur if the amount of correction was large. However, it was not deviated toward the side of either over- or under-correction.

Preoperative planning of OWHTO is performed for determina-

**Table 2.** Difference between Preoperative Target WBL Ratio and Postoperative WBL Ratio

	Group	Difference (%)	p-value
Absolute value of difference in WBL ratio	1	6.01±5.68	0.02
	2	3.32±3.38	
Relative value of difference in WBL ratio	1	2.13±8.10	0.54
	2	1.19±4.62	

Values are presented as mean±standard deviation. The statistical significance was set at  $p<0.05$ .

Group 1: opening gap larger than the mean height of the opening gap of total patients, Group 2: opening gap smaller than the mean height of the opening gap of total patients.

WBL: weight bearing line.

tion of the length of the opening gap for acquisition of the target valgus angle. Pape and Rupp<sup>11)</sup> reported that the difference of 10 mm in height of the osteotomy gap corresponds to the change of 8°–10° angulation in the alignment. The Fujisawa point<sup>26)</sup> is most commonly used and 62% point of the WBL ratio corresponds to the valgus angulation of 1°–3°. However, the target point should differ according to the status of the medial compartment. Our intraoperative target WBL ratio was variable according to the status of the medial compartment, but the mean target WBL ratio was similar to the Fujisawa point<sup>26)</sup>.

Medial contracture and lateral laxity are usually encountered in the knee joint during OWHTO. Lateral subluxation of the proximal tibia is also commonly observed in the knee joint. Therefore, the medial collateral ligament is released or resected for prevention of high pressure on the medial compartment<sup>27)</sup>. Based on our experience, it was assumed that the different ligament tension between the medial and lateral sides and tibial subluxation would be possible causes of the mismatch between the preoperatively planned and postoperative WBL ratios because the tendency was more prominent if the deformity was severer requiring a greater correction.

Postoperative limb alignment can be planned based on the anatomical alignment, mechanical alignment, or WBL ratio prior to OWHTO. Additionally, many surgeons still use an intraoperative radiopaque line such as the Bovie cable under the fluoroscopic guidance. However, previous studies reported significant differences among the methods. In a recent study, the cable-based method resulted in more unacceptable corrections than did the PACS image-based preoperative planning. It would be due to differences in the mechanical axis between radiographs taken in preoperative standing position and those obtained in supine position, which have been reported to be over 3 degrees. In this study, axial pressure was applied to the foot sole during intraop-



erative adjustment of the target axis, in which weight bearing was simulated in the supine position. Despite the effort, postoperative activity of muscles around the knee joint may have caused the difference between the intraoperative target alignment and the postoperative alignment.

Recently introduced digital planning software, such as med-iCAD (Hectec GmbH, Landshut, Germany) and PreOPlan (Synthes, Zuchwil, Switzerland), has improved inter-rater reliability and correctness in preoperative planning and measurement of the limb alignment<sup>10</sup>. In this study, we did not use any planning program for preoperative planning, but PACS and Adobe Photoshop ver. 12.0 were used. PACS software was reported to have higher inter- and intra-observer reliability for evaluation of the lower extremity alignment<sup>28</sup>. However, the difference between the preoperative target amount of correction and postoperative amount of correction was noted in this study. This difference may have been caused by the fact that the planning was only performed based on the 2 dimensional evaluation of the WBL ratio, whereas correction of deformities involved 3 dimensional procedures based on the coronal and sagittal planes<sup>23,29</sup>. In the future, a 3 dimensional planning method would be required because the deformity of lower extremity is 3 dimensional.

There are some limitations that should be considered. First, this study was a retrospective study with a small number of patients; hence, a selection bias could have occurred. Second, only one planning method was used to assess the accuracy of planning; however, the reliability of the planning method was verified in previous research<sup>6</sup>. Third, the WBL ratio was examined only at the postoperative 6 weeks and serial change was not assessed. Serial assessment of the WBL ratio after OWHTO may have altered the distribution of two groups. Finally, the degree of preoperative varus deformity might have critically impacted the amount of opening gap at the osteotomy site. However, the difference in preoperative varus deformity was not considered in the classification of patient groups.

## Conclusions

The postoperative WBL ratio after OWHTO was different from the preoperative target WBL ratio if the planned osteotomy gap was large. This mismatch was not deviated toward one side of either over- or under-correction.

## Conflict of Interest

No potential conflict of interest relevant to this article was re-

ported.

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