Original Article

Rotational Profile after Biplane Medial Opening Wedge High Tibial Osteotomy: A Preliminary Report

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Background: High tibial osteotomy [HTO] is a surgical procedure for treatment of medial compartmental osteoarthritis combined with varus deformities of the knee in middle-aged patients. The goal of this procedure is to shift the weight-bearing axis from the medial compartment to the lateral compartment of the knee joint, resulting in a change of knee alignment from varus to valgus. Although changing the coronal plane is the main purpose of high tibial osteotomy, changes in axial rotation after the procedure has been documented in previous studies. Unintentional change in the axial plane following HTO has been proposed as one of the factors that influence overall gait mechanics and patellofemoral kinematics.

Objective: This study aimed to measure changes in the degree of rotation in the axial plane resulting from biplane medial opening wedge high tibial osteotomy [MOWHTO].

Materials and Methods: Nine patients with medial compartmental osteoarthritis combined with varus deformity were enrolled in this study. Biplane MOWHTO with medial high tibia plate fixation was performed on all the patients by a single surgeon. The change in rotational profile of the tibia after surgery was determined by comparing the pre- and post-surgery angle between the proximal posterior tibial axis and the distal bimalleolar axis using CT scans. The data were analyzed using a paired t-test. Values of $p<0.05$ were considered statistically significant.

Results: A change in rotational profile after biplane MOWHTO was found in all patients. Eight patients showed external rotation and one patient showed internal rotation. However, the change in the degree of axial rotation was not significant.

Conclusion: Although not significant, minor changes in the degree of rotation were detected. Those changes suggest that an unintended rotation of the tibia could have occurred during biplane MOWHTO, especially changes in the external rotation patterns. Unintended rotation of the tibia is a factor that needs be considered during the opening of the osteotomy gap in high tibial osteotomy.

Keywords: HTO; Biplane; Medial opening wedge high tibial osteotomy; Rotation profile; External rotation

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The high tibial osteotomy [HTO] procedure is a surgical technique for treatment of medial compartmental osteoarthritis combined with varus deformities of the knee in middle-aged patients. The goal of the procedure is to reduce knee pain by shifting the weight-bearing axis from the medial compartment that has degenerative arthritis to the healthy lateral compartment of the knee joint, resulting in a change of knee alignment from a varus deformity to normal valgus alignment[1-4]. Intentional alteration of coronal plane is the main purpose of this procedure[3-6].

Because the tibia is a 3-dimensional structure with a triangular shape, osteotomy could be expected to have an effect in all 3 dimensions (coronal, sagittal, and axial planes). Many authors have previously demonstrated that in the sagittal plane, MOWHTO affects the posterior tibial slope [PTS]. They have also investigated the causes of and methods to prevent those sagittal changes[6-10]. However, only a few cadaveric and radiographic studies have addressed the

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rotation of the tibia in the axial plane after HTO[6,11-13]. From our preliminary clinical data, some post-operative patients have had a change in lower limb rotation after HTO. This study aimed to measure the degree of rotation that occurs after biplane MOWHTO.

Materials and Methods

All procedures were approved by the Ethics Committee, Lerdsin General Hospital. The prospective case series included 9 knees in 9 consecutive patients. These patients underwent the MOWHTO procedure during the period October 2016 through May 2017 in Lerdsin General Hospital, Bangkok. All patients consented to participate in this observational study and agreed to the study protocol including CT evaluation. Inclusion criterion was patients with medial compartment osteoarthritis combined with varus deformities of the knee joint who were scheduled to undergo an MOWHTO operation performed by one of the authors. All knees were radiographically assessed preoperatively and postoperatively (including conventional anteroposterior [AP] and lateral radiographs, weight-bearing scanograms, and CT scans). The exclusion criteria for this study (and for MOWHTO) were symptomatic lateral compartmental or patellofemoral osteoarthritis, flexion contracture more than 15°, range of motion less than 100°, BMI >35, lateral collateral ligament laxity more than grade 3, rheumatoid arthritis, gouty arthritis, and septic arthritis.

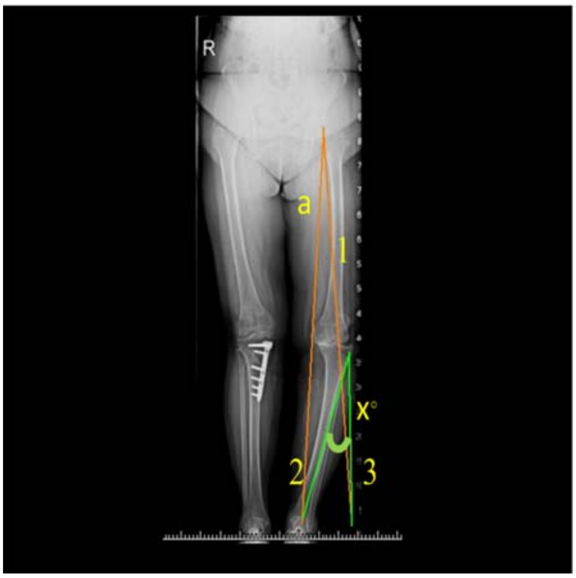

Figure 1. Miniaci's method was used to measure the level of osteotomy, degree of correction, and osteotomy wedge gap length. (Line a: weight bearing axis; Line 1: planned weight bearing line for the postoperative correction. Line 2: osteotomy hinge point to the center of the ankle. Line 3: osteotomy hinge point to the arc intersection of line 1. The lengths of Line 2 and 3 are equal and the angle formed by lines 2 and 3 is the planned correction angle (x).

Surgical techniques

A preoperative template was prepared using the weight-bearing scanogram method. The level of osteotomy, degree of correction, and osteotomy wedge gap length were measured using Miniaci's method[14] (Figure 1).

The patients were placed in a supine position. In all cases an arthroscopic examination was performed to assess the status of the cartilage, meniscus, and cruciate ligaments. Then the legs were positioned in full extension. A six to eight cm anteromedial longitudinal skin incision was made one cm below the joint line and extending to the pes anserinus tendons. The sartorial fascia was divided at the cranial border of the pes anserinus and the pes tendons were retracted distally[15]. At this time, the anterior border of the superficial layer of the medial collateral ligament [MCL] became visible[16]. Next, the periosteal elevator was passed under the MCL and the ligament was lifted from the tibia. The anterior portion of the superficial MCL was detached from the tibial insertion point down to the posterior ridge of the tibia. A blunt retractor was inserted behind the tibia. The insertion point of the patellar tendon at the tibial tuberosity was identified and exposed at the anterior edge of the incision.

To define the cross point and the transverse cut, a guide wire (2 mm Kirschner wire) was inserted from the osteotomy site to the tibiofibular joint along with the pre-operative template. Under fluoroscopic guidance, the transverse osteotomy was performed using an oscillating saw adjacent and distal to the guide wire to avoid proximal migration of the oscillating saw into the joint. The osteotomy cut was done on the hard posterolateral and posteromedial tibial cortex and the full depth of the osteotomy was approximately two thirds of the posterior tibial width. Then, the anterior ascending saw cut was made with a narrow saw blade at the posterior aspect of the tibial tuberosity. The ascending cut must be completed the medial and lateral aspects of the anterior cortex. The osteotomy wedge was inserted into the transverse osteotomy up to the lateral bony hinge using an osteotomy chisel. Light hammer blows were used to open the gap. The insertion depth of the wedge corresponded to the depth of the osteotomy. An additional chisel was then inserted slowly to a depth less than the first chisel to prevent lateral cortical breakage. After the desired osteotomy gap length was achieved(7), a spreader was inserted and positioned posteriorly as much deep as possible. Next, the osteotomy chisel was removed and the anterior gap length was maintained at half of the posterior gap length to prevent increasing the posterior tibial slope(17). The osteotomy site was stabilized with a medial high tibia plate (Tomofix plate, DePuy Synthes, Bettlach, Switzerland).

Radiographic evaluation

Radiographic evaluation of the tibia was performed using a combination of conventional AP and lateral radiographs, weight-bearing scanograms, and CT scans. A pre-operative radiograph was obtained within one week before each operation. Post-operative conventional AP and lateral radiographs and CT scans were taken one week after the operation, and post-operative weight-bearing scanograms were taken two months after the operation.

The hip-knee-ankle angle [HKAA], PTS, and distal tibial rotation [DTR] were measured and analyzed using a picture archiving and communication system (PACSTM UniWeb Viewer, EBM Technologies, Taipei, Taiwan). The HKAA is defined as the medial angle formed by the mechanical axis of the femur and the mechanical axis of the tibia in a weight-bearing scanogram(18). The PTS is defined as the angle formed by the medial tibial plateau line and a line perpendicular to the posterior tibial cortex in lateral view(19). Finally, the DTR, defined as the angle formed by the proximal posterior tibial axis (a line that passes through the two most posterior joints on the tibial plateau) and the bimalleolar axis (a line that passes though the centers of the dense surfaces of the malleoli, just below the tibial plafond articular surface) were measured with CT scans (Figure 2)(20).

Statistical analysis

The data were recorded using Microsoft Excel 2016 version (Microsoft Corp, Redmond, WA, USA). Data are shown as mean $\pm$ SD. Statistical analysis was done using GraphPad Prism version 7.02 software. Analysis of pre-operative and post-operative radiograph parameters was performed using the paired t-test. Values of $p<0.05$ were considered statistically significant.

Results

Demographic and clinical data of patients included in this study are shown in Table 1. A change in rotation profile after the medial opening wedge high tibial osteotomy was found in all patients. Eight patients showed external rotation and one patient showed internal rotation. The mean and range of preoperative and postoperative DTR were external rotation of 25.86° (18 to 40.1°) and 27.72° (18.4 to 42.7°), respectively. The distal tibiae were more externally rotated by 1.45° after MOWHTO. The mean and range

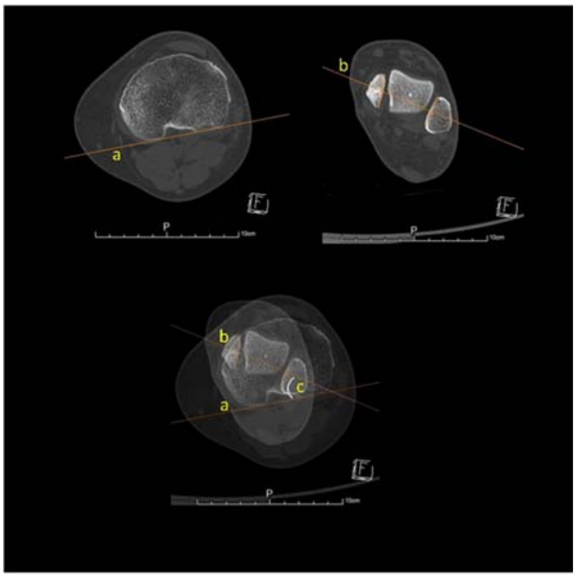

Figure 2. Measurement of DTR by PACS. CT scans were used to evaluate the angle between the proximal posterior tibial axis (a) and the bimalleolar axis (b). The angle (c) is the distal tibial rotation angle (DTR).

Table 1. Demographic and clinical data

Variable	Patients (n = 9)
Age mean (range)	58 (50 to 67)
Gender	
Male	5 (55.6%)
Female	4 (44.4%)
Height (cm) mean (range)	161.4 (149 to 169)
Weight (kg) mean (range)	67.6 (56 to 74)
Body mass index (kg/m^2) mean (range)	26.2 (23.3 to 28.0)
Lower extremity varus deformity (degrees) mean (range)	9.9 (3.3 to 17.1)

of preoperative and postoperative HKAA were varus 9.9° (3.3 to 17.1°) and valgus 1.25° (-6.5 to 2.5°). The mean difference between pre-operative and post-operative HKAA was 14.56° (6.4 to 20.8°) and the PTS was increased from 9.99° (8.4 to 11.7°) pre-operatively to 11.36° (9 to 15°) post-operatively. None of the differences between preoperative and postoperative radiographic measurements of DTR and PTS were statistically significant (Table 2).

Discussion

Rotation of the tibia has been proposed as one of the factors that influences overall gait mechanics and patellofemoral kinematics. An increase in tibial external rotation leads to lateral patellofemoral impingement[21]. The study by Jacobi et al reported that a rotational change greater than 5° was considered clinically relevant, affecting the clinical outcome. Resent studies have addressed the axial change after HTO. The first description was in 1999, where Magyar et al[13] found a small change in axial tibial rotation in 33 patients after closed wedge HTO. In 2007, a study by Baumgarten et al[13], which was performed on eight cadaveric specimens, demonstrated external tibial rotation (range 16.0° to 23.0°) after OWHTO. In 2008, a study by Kendoff et al[6] reported external rotation in 13 cadaveric limbs after OWHTO. Taken together, these studies demonstrate an influence of OWHTO on the rotation of total tibial planes, both in external and internal forms.

The present study, in contrast, found no statistically significant difference in the changes in degrees of rotation after biplane MOWHTO. Only minor changes in the axial plane were detected. Strict control of the coronal axis [HKAA] and sagittal axis [PTS] might be an important factor that could help reduce the degree of rotation occurring in the axial plane. The mean rotational change found in this study was 1.45 degrees. These axial rotations occurred mostly in the external form. These data are in agreement with a study by Jacobi et al which found a rotation of the distal tibia of 1.5±2.9 degrees after OWHTO[11], most of which were internal rotations.

Although our study found no significant differences in the degrees of rotation, minor changes were detected. These minor changes suggest that unintended rotation of the tibia can occur after biplane MOWHTO, especially with external rotation patterns. This indicates that unintended rotation of the tibia should be an area of concern during the opening of the osteotomy gap in high tibial osteotomy.

There were some limitations in the current study. First is that the number of enrolled patients was relatively small, although a normal distribution was found in all measurements. Second, only radiological outcomes were measured and analyzed. No clinical outcomes were assessed because most of the patients had only short-term follow-up periods. Thus, clinical significance was hard to evaluate and the correlation between rotational change and clinical outcomes could not be throughly analyzed. More clinical studies are required to assess clinical outcomes in detail. The last limitation is that only MOWHTO was evaluated in this study. To further clarify rotational change, studies which include closed-wedge HTOs as well as MOWHTO should be conducted.

Conclusion

This study found no significant difference in the degree of axial plane rotation after MOWHTO, although minor rotations with a mean of 1.45 degrees were detected. These changes suggest that unintended rotation of the tibia can occur after biplane MOWHTO, especially changes in external rotation patterns. Concern should be given to unintended rotation of the tibia during the opening of the osteotomy gap in high tibial osteotomy.

What is already known on this topic?

The tibia is a 3-dimensional bone structure with a triangular shape. Osteotomy has an affect in all 3 dimensions (coronal, sagittal, and axial planes). Many

Table 2. Preoperative and postoperative radiographic measurements (degrees)

	Pre-operative	Post-operative	Difference
HKAA	9.9 (3.3 to 17.1)	-1.25 (-6.5) to 2.5)	14.56 (6.4 to 20.8)*
DTR	25.86 (18 to 40.1)	27.72 (18.4 to 42.7)	1.45 (-1.1) to 3.3)
PTS	9.99 (8.4 to 11.7)	11.36 (9 to 15)	1.17 (-1.1) to 1.3)

* Statistically significant difference (p<0.05)

researchers have demonstrated that MOWHTO affects the posterior tibial slope [PTS] in the sagittal plane and have investigated the causes of and methods to prevent these sagittal changes. However, only a few cadaveric and radiographic studies have addressed the rotation of the tibia in the axial plane after HTO.

What this study adds?

This study found that there is no significant difference in degree of axial plane rotation after MOWHTO. Nevertheless, this study showed that unintended rotation of the tibia should be a concern during the opening of the osteotomy gap in high tibial osteotomy.

Potential conflicts of interest

The authors declare no conflict of interest.

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