ORIGINAL PAPER

Nagoya J. Med. Sci. **81**. 621–628, 2019
doi:10.18999/nagjms.81.4.621

Tibial rotational alignment after opening-wedge and closing-wedge high tibial osteotomy

Ryosuke Kawai[1], Takashi Tsukahara[1], Itaru Kawashima[1], and Harumoto Yamada[2]

[1]*Department of Orthopedic Surgery, Asahi University Hospital, Gifu, Japan*
[2]*Department of Orthopedic Surgery, Fujita Health University School of Medicine, Toyoake, Japan*

ABSTRACT

A lot of good outcomes have been reported after opening-wedge high tibial osteotomy (OWHTO) and closing-wedge high tibial osteotomy (CWHTO).The purpose of this study was to examine the rotational alignment after OWHTO and CWHTO performed by the same surgeon in one hospital.

The sample included 30 knees from 24 patients. In all cases, the same orthopaedic surgeon performed the osteotomy surgeries using the same method. The tibial external rotation angle (TERA) was measured using the CT images of proximal tibial plateau and distal tibial malleolus from the consecutive axial CT slices of tibia. In this study, two considerations were examined. The first was the change in rotation angle, which was defined by TERA noted before and after the operation. The second was the relationship between the correction angle of the osteotomy and the rotation angle change of the distal tibia. The first was evaluated using the paired-Student's *t*-test, while the second was analyzed with Pearson's correlation coefficient. In the OWHTO group, the mean TERA was 21.4± 7.0° preoperatively and 20.2 ± 8.0° postoperatively, but no significant difference was seen between pre- and post-operation measurements (p = 0.21). Significant TERA increasing (that is, external rotation of the distal tibia) was seen postoperatively in only three knees. In the CWHTO group, the mean TERA was 19.9 ± 10.5° preoperatively and 16.5 ± 9.5° postoperatively, and significant difference was seen between pre- and post-operative TERA ($p < 0.05$). No significant correlation was seen between the correction angle and the change of the rotation angle in either group ($r = 0.40$, $r = 0.12$) .

In the OWHTO group, both internal and external rotation of the distal tibia can occur after surgery. In the CWHTO group, the distal tibia rotated internally postoperatively. No significant correlation was seen between the correction angle and the change in the rotation angle in either group

Keywords: opening-wedge high tibial osteotomy (OWHTO), closing-wedge high tibial osteotomy (CWHTO), rotation

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BACKGROUND

A lot of good outcomes have been reported after opening-wedge high tibial osteotomy (OWHTO) and closing-wedge high tibial osteotomy (CWHTO). On the other hand, it is thought that the excessive external rotation of the distal tibia after osteotomy might increase the pressure on the patellofemoral joint and encourage the development of patellofemoral joint osteoarthritis.

Received: January 11, 2019; accepted: March 12, 2019
Corresponding Ryosuke Kawai, MD
Department of Orthopedic Surgery Asahi University Hospital, 3-23 Hashiotocho, Gifu, Gifu 500-8523 Japan
Tel: +81-58-253-8011, E-mail: jobryohoo_k@yahoo.co.jp

However, there are still few literatures about postoperative rotational alignment, and the content differs for each article. Therefore, there is been no unified view about the postoperative change of rotational alignment. We thought that one of the reasons why there is no unified view is to be multifactorial. Many factors such as osteotomy procedures and techniques performed during osteotomy surgery affect postoperative rotational alignment. Hence, it is necessary to evaluate the rotational alignment of tibia in the situation reducing the variation of affecting surgical factors. We hypothesized that it is possible to reduce surgical variance in procedures and techniques by performing the operation by the same surgeon.

PURPOSE

The purpose of this study was to examine the rotational alignment after OWHTO and CWHTO performed by the same surgeon in one hospital.

PATIENTS

The sample included 30 knees from 24 patients. In all cases, the same orthopaedic surgeon performed the osteotomy surgeries using the same method. The OWHTO group included six men and nine women (mean age = 60 years, range = 47–73 years). The mean body mass index (BMI) was 26.6 kg/m^2 (range = 22.8–32.6 kg/m^2). The mean correction angle was 8° (range = 5–10°). The osteotomy was fixed with Tomo-Fix plate® (DePuySynthes, Bettlach, Switzerland) for 10 knees and TriS Medial HTO Plate System® (Olympus Terumo Biomaterials, Japan) for 5 knees. Anterior cruciate ligament (ACL) reconstruction was performed simultaneously in two knees, and double level osteotomy (DLO) was performed in three knees. A Takeuchi[1] type 1 lateral hinge fracture complication was seen in one knee.

The CWHTO group included eight men and seven women (mean age = 57 years, range 42–73 years). The mean BMI was 23.9 kg/m^2 (range = 19.6–29.5 kg/m^2). The mean correction angle was 11° (range = 6–17°), which was significantly larger than that of the OWHTO Group ($p < 0.05$; Student's *t*-test). This group included nine Hybrid HTO,2 and all 15 surgeries were performed using the Lateral HTO plate® (Olympus Terumo Biomaterials, Japan). Posterior cruciate ligament (PCL) reconstruction was performed simultaneously in one case (Table 1).

Table 1 Patients in the present study

	OWHTO Group (*n* = 15)	**CWHTO Group (*n* = 15) (CWHTO = 6, Hybrid HTO = 9)**
age	60 (47–73)	57 (42–73)
men/women	6/9	8/7
BMI (kg/m^2)	26.6 (22.8–32.6)	23.9 (19.6–29.5)
Correction angle (deg)	8 (5–10)	11 (6–17)
Implants	Tomo Fix, 10; Tris, 5	Lateral HTO, 15
Additional operation	ACL reconstruction, 2 Double level osteotomy, 3	PCL reconstruction, 1
Complications	Type 1 hinge fracture, 1	None

SURGICAL TECHNIQUE

The same surgeon operated on all patients, performing both OWHTO and CWHTO by bi-plane osteotomy. The ascending cut was performed while maintaining the thickness of flange (thickness of tubercle) at one third of the tibia, with the cutting angle of the ascending plane being 100° to the oblique plane. In OWHTO, the superficial medial collateral ligament (sMCL) was completely released at the distal attachment. Pes was preserved, except for two cases which was performed simultaneous ACL reconstruction using the hamstrings. The oblique osteotomy was started at the medial cortex 4cm distal from the medial tibia plateau, and ended at the lateral hinge point (5mm medial from the lateral cortex and just the height of the proximal tibiofibular joint).The oblique osteotomy site was gradually opened using a bone spreader in knee extension position on the operating table. In CWHTO, fibula osteotomy was initially performed in the mid portion. The proximal oblique osteotomy was started at the lateral cortex 4cm distal from the lateral tibia plateau. The distal osteotomy line was decided using a goniometer under fluoroscopic control. After removing the closed wedge bone fragment, the oblique osteotomy site was carefully closed with additional axial force in the position of the knee extension. In only one case, PCL reconstruction using the hamstrings was performed simultaneously. The nine Hybrid HTO were performed according to the procedure of Takeuchi et al.[2]

METHODS

Computerized tomography (CT) of the tibia was performed just before the operation and within 1 week postoperatively. The tibial external rotation angle (TERA) was measured using the CT images of proximal tibial plateau and distal tibial malleolus (Fig. 1) from the consecutive axial CT slices of tibia. These two images were superimposed and the angle between the tangent line to the posterior condyles of the proximal tibia and the coronal bisector of distal tibia was measured by Advantage Workstation 4.6 version 5 (GE Healthcare, Illinois, USA).

In this study, two considerations were examined. The first was the change in rotation angle,

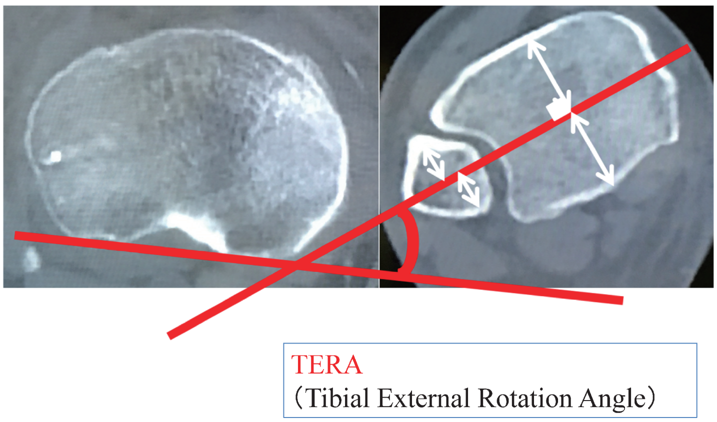

Fig. 1 Tibial external rotation angle (TERA)
The tibial external rotation angle (TERA) was measured using the CT images of the proximal tibial plateau and distal tibial malleolus. The angle between the tangent line to the posterior condyles of the proximal tibia and the coronal bisector of distal tibia was measured as TERA.

which was defined by TERA noted before and after the operation. The second was the relationship between the correction angle of the osteotomy and the rotation angle change of the distal tibia. The first was evaluated using the paired-Student's *t*-test, while the second was analyzed with Pearson's correlation coefficient.

RESULTS

In the OWHTO group, the mean TERA was 21.4± 7.0° preoperatively and 20.2 ± 8.0° postoperatively, but no significant difference was seen between pre- and post-operative measurements (p = 0.21). A significant TERA increase (that is, external rotation of the distal tibia) was seen postoperatively in only three knees. One knee had a type 1 lateral hinge fracture and two knees (bilateral knees of one patient) had severe varus deformities that required DLO. Complication was found in one case, which was a type 1 lateral hinge fracture.

In the CWHTO group, the mean TERA was 19.9 ± 10.5° preoperatively and 16.5 ± 9.5° postoperatively, a significant difference was seen between pre- and post-operative TERA ($p < 0.05$). This result demonstrates that the internal rotation of the distal tibia was decreased postoperatively (Fig. 2).

No significant correlation was seen between the correction angle and the change of the rotation angle in either group (OWHTO: r = 0.40, CWHTO: r = 0.12) (Fig. 3).

DISCUSSION

Various reports have been published regarding rotational alignment after OWHTO. Some papers[3-5] reported that rotational alignment of the distal tibia was changed to internal rotation, while others[6,7] described external rotation. We thought that one of reasons for various reports existing is that the changes in rotational alignment were affected by many factors, especially surgical procedures and techniques such as a coronal ascending osteotomy angle and knee position during operation. Therefore, in the present study, all operations were performed by the same surgeon in the same hospital, meaning that differences according to individual surgeon and surgical technique were eliminated.

In the OWHTO group, both internal and external rotation of the distal tibia occurred after the operation. The mean TERA was decreased, showing a slight internal rotation of the distal tibia postoperatively, but the difference was not significant. Although this result included all OWHTO cases, in case of type 1 lateral hinge fracture, we thought there was a possibility that irregular rotation might have been caused by collapse of the lateral hinge. For that reason, we excluded this one case from the analysis and evaluated the results again. As a result, the distal tibia tended to be internal rotation (p = 0.08). Reconfirming all OWHTO cases, a significant increase in postoperative TERA (that is, external rotation of the distal tibia) was seen in only three knees (one knee type 1 lateral hinge fracture and two knees from one patient with bilateral DLO) (Fig. 4). In the type 1 lateral hinge fracture case, the instability at the hinge site might have caused irregular rotation during the osteotomy. In the bilateral DLO case, the patient had a severely degenerated varus knee (Femorotibial angle of right knee 191°, left knee 190°). In cases of severe osteoarthritis of knee, there was a tendency for the lower limbs, including hip joints, to be external rotation (Fig. 5). Particularly under general anaesthesia, the tendency of external rotation of the distal tibia became prominent due to muscle relaxation, and a strong rotation force was applied to the osteotomy site. We speculated this rotation force might cause

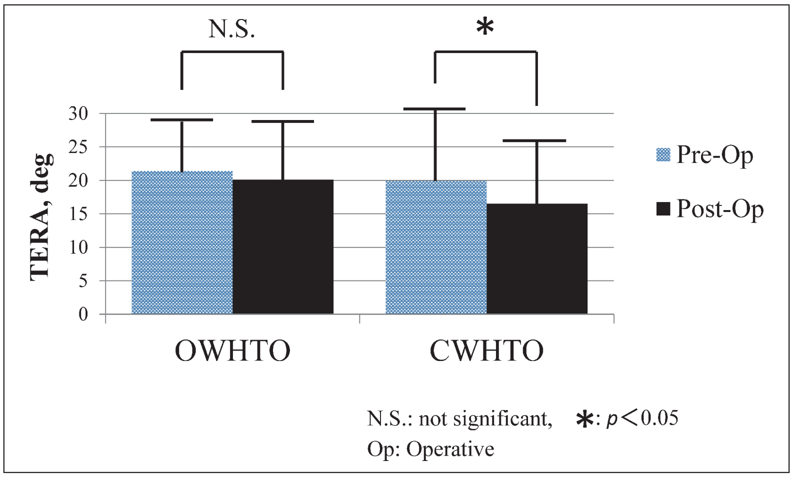

Fig. 2 TERA change
In the OWHTO group, the mean TERA was 21.4± 7.0° preoperatively and 20.2 ± 8.0° postoperatively, with no significant difference (p = 0.21).
In the CWHTO group, the mean TERA was 19.9 ± 10.5° preoperatively and 16.5 ± 9.5° postoperatively, a significant difference was seen between pre- and post-operative TERA (p < 0.05).

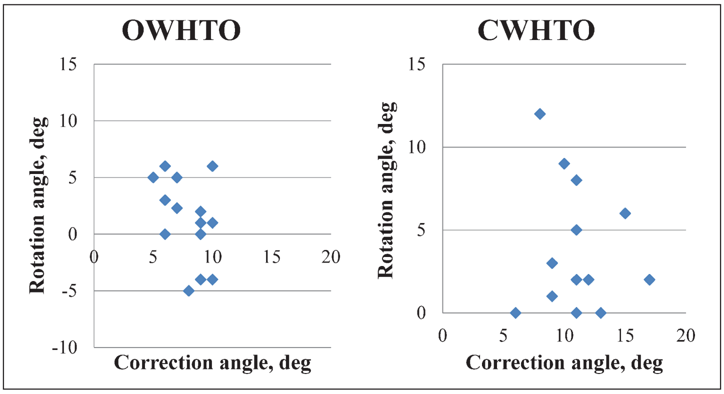

Fig. 3 Relationship between the rotation angle and the correction angle
No significant relationship is seen using Pearson's correlation coefficient in either OWHTO and CWHTO (r = 0.40, r = 0.12).

external rotation of the distal tibia after OWHTO. From these cases, not only surgical factors such as osteotomy procedures and techniques, but also factors concerning patients might affect rotational alignment after OWHTO.

Regarding factors related to rotational alignment changes after OWHTO, Hintewimmer et al[3] reported that medial soft tissue such as hamstrings cause internal rotation of distal tibia. Same as this report, in the present study, most of the cases in the OWHTO group show internal rotation of the distal tibia. We performed ACL reconstruction using the hamstrings simultaneously for cases 10 and 11. Although the hamstrings had been harvested before the osteotomy, a 2° internal rotation of the distal tibia was observed postoperatively in case 10, while there was no change

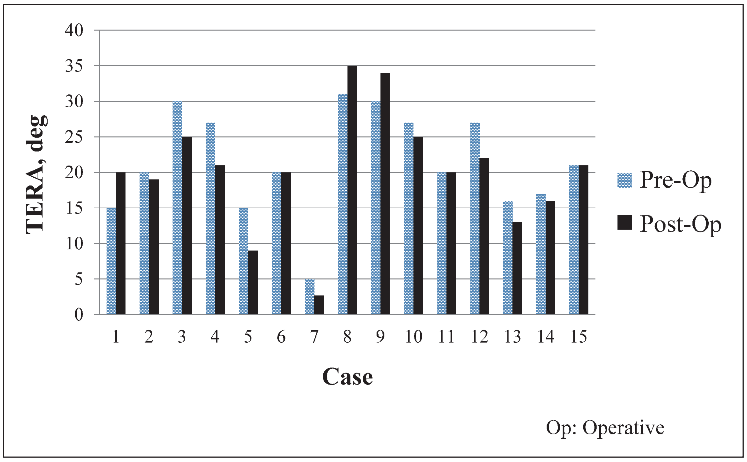

Fig. 4 All cases of OWHTO
In only three cases (cases 1, 8 and 9), TERA was significantly increased after OWHTO. Case 1 had a type 1 lateral hinge fracture and case 8 and 9 include one patient with severe osteoarthritis who underwent bilateral DLO.

Fig. 5 Case of severe osteoarthritis with bilateral DLO (case 8, 9)
Before the operation, the patient had a severely degenerated varus knee (FTA : right 191°, left 190°) . There was a tendency for the lower limbs, including hip joints, to be externally rotated. As can be seen, bilateral feet face out while walking.

in case 11. Hamstrings might not have a great effect on rotation alignment of the distal tibia after OWHTO. Certainly, it is inadequate to discuss this point using these two cases. More cases in which hamstrings were harvested are needed and other medial soft tissue besides hamstrings should also be evaluated.

Notably, in the three cases which showed external rotation of the distal tibia after OWHTO, the ascending plane of osteotomy did not contact completely in a postoperative CT image. Especially in case1 (case of type 1 lateral hinge fracture), gap space was seen between the flange and proximal tibia. This gap formation might be related to the external rotation of the distal tibia. There is a possibility that excessive external rotation of the distal tibia could create a gap at the ascending osteotomy site, which could cause delayed gap filling. Schroter et al[8] stated that lateral hinge fractures cause instability and delayed gap filling at the osteotomy site. Also in the present case 1, gap filling was delayed. We consider that both instability around the hinge point and the gap space at the ascending osteotomy site caused the delayed gap filling. Therefore, when opening the oblique osteotomy site, surgeons should be careful of not only the anterior-posterior alignment, but also the rotational alignment confirming the complete contact between the flange and proximal tibia.

Recently, patellofemoral joint problems after OWHTO have been reported.[9] Excessive external rotation of the distal tibia might also increase the pressure on the patellofemoral joint and encourage the development of patellofemoral joint osteoarthritis. Even considering this patellofemoral joint problem, excessive external rotation of the distal tibia should be avoided. Keeping the distal tibia in the correct position or slightly internal rotation can be one solution to avoid excessive external rotation and gap formation at the ascending osteotomy site.

Regarding other factors concerning rotational alignment changes after OWHTO, Lee et al[10] reported that the hinge axis angle significantly affects rotational alignment change after OWHTO. However, in the present study, we did not consider the hinge axis angle. Besides this, there might be other surgical and procedural factors affecting the rotational alignment of the distal tibia after OWHTO. More cases and studies are needed to further elaborate on these points.

In the CWHTO, the mean TERA decreased significantly in postoperative CT images; that is, internal rotation of the distal tibia and anterior translation of the tibia tubercle. Due to these changes, the pressure on the patellofemoral joint was decreased. CWHTO can be an appropriate method for medial compartment osteoarthritis, especially with patellofemoral joint osteoarthritis, compared with OWHTO. No significant correlation was seen between the correction angle of osteotomy and the change in the rotation angle. It seems unnecessary to be concerned about excessive internal rotation of the distal tibia after CWHTO, even in cases of major correction CWHTO for patients with severe varus knee. In the present study, the nine cases of Hybrid HTO were included in the CWHTO Group. Although there are some differences in the operation of both, there was no significant difference in the changes in postoperative rotational angles between CWHTO and Hybrid HTO (p =0.5; Student's t-test). There was also no significant difference in the results, regardless of whether CWHTO and Hybrid HTO were handled together or separately. Therefore, we evaluated them as identical in this study. However, because of the small number of cases, further investigation may be necessary.

CONCLUSIONS

In the present study, we evaluated the tibial rotational alignment after OWHTO and CWHTO eliminating the differences due to individual surgeons and surgical technique as much as possible. In the OWHTO group, both internal and external rotation of the distal tibia can occur after surgery. Especially in the case of a lateral hinge fracture and severe osteoarthritis with extreme external rotation of the lower extremity, the surgeon should confirm not only the anterior-posterior alignment, but also the rotational alignment during the operation. In the CWHTO group, the distal tibia rotated internally postoperatively. No significant correlation was seen between the correction angle and the change in the rotation angle in either group.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

FUNDING

There was no funding source.

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

REFERENCES

1) Takeuchi R, Ishikawa H, Kumagai K, et al. Fractures around the lateral cortical hinge after a medial opening-wedge high tibial osteotomy: a new classification of lateral hinge fracture. *Arthroscopy*. 2012;28(1):85–94.
2) Takeuchi R, Ishikawa H, Miyasaka Y, Sasaki Y, Kuniya T, Tsukahara S. A novel closed-wedge high tibial osteotomy procedure to treat osteoarthritis of the knee: hybrid technique and rehabilitation measures. *Arthrosc Tech*. 2014;3(4):e431–437.
3) Hinterwimmer S, Feucht MJ, Paul J, et al. Analysis of the effects of high tibial osteotomy on tibial rotation. *Int Orthop*. 2016;40(9):1849–1854.
4) Jacobi M, Villa V, Reischl N, et al. Factors influencing posterior tibial slope and tibial rotation in opening wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(9):2762–2768.
5) Jang KM, Lee JH, Park HJ, Kim JL, Han SB. Unintended rotational changes of the distal tibia after biplane medial open-wedge high tibial osteotomy. *J Arthroplasty*. 2016;31(1):59–63.
6) Kendoff D, Lo D, Goleski P, Warkentine B, O'Loughlin PF, Pearle AD. Open wedge tibial osteotomies influence on axial rotation and tibial slope. *Knee Surg Sports Traumatol Arthrosc*. 2008;16(10):904–910.
7) Duparc F, Thomine JM, Simonet J, Biga N. Femoral and tibial bone torsions associated with medial femoro-tibial osteoarthritis. Index of cumulative torsions. *Orthop Traumatol Surg Res*. 2014;100(1):69–74.
8) Schroter S, Freude T, Kopp MM, et al. Smoking and unstable hinge fractures cause delayed gap filling irrespective of early weight bearing after open wedge osteotomy. *Arthroscopy*. 2015;31(2):254–265.
9) Amzallag J, Pujol N, Maqdes A, Beaufils P, Judet T, Catonne Y. Patellar height modification after high tibial osteotomy by either medial opening-wedge or lateral closing-wedge osteotomies. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(1):255–259.
10) Lee BH, Ha CW, Moon SW, et al. Three-dimensional relationships between secondary changes and selective osteotomy parameters for biplane medial open-wedge high tibial osteotomy. *Knee*. 2017;24(2):362–371.