Posterior Tibial Slope in Medial Opening-wedge High Tibial Osteotomy: 2-D Versus 3-D Navigation

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abstract

Although opening-wedge high tibial osteotomy (HTO) is used to correct deformities, it can simultaneously alter tibial slope in the sagittal plane because of the triangular configuration of the proximal tibia, and this undesired change in tibial slope can influence knee kinematics, stability, and joint contact pressure. Therefore, medial opening-wedge HTO is a technically demanding procedure despite the use of 2-dimensional (2-D) navigation.

The authors evaluated the posterior tibial slope pre- and postoperatively in patients who underwent navigation-assisted opening-wedge HTO and compared posterior slope changes for 2-D and 3-dimensional (3-D) navigation versions. Patients were randomly divided into 2 groups based on the navigation system used: group A (2-D guidance for coronal alignment; 17 patients) and group B (3-D guidance for coronal and sagittal alignments; 17 patients). Postoperatively, the mechanical axis was corrected to a mean valgus of 2.81° (range, 1°-5.4°) in group A and 3.15° (range, 1.5°-5.6°) in group B. A significant intergroup difference existed for the amount of posterior tibial slope change (Δ slope) pre- and postoperatively (P=.04).

Opening-wedge HTO using navigation offers accurate alignment of the lower limb. In particular, the use of 3-D navigation results in significantly less change in the posterior tibial slope postoperatively than does the use of 2-D navigation. Accordingly, the authors recommend the use of 3-D navigation systems because they provide real-time intraoperative information about coronal, sagittal, and transverse axes and guide the maintenance of the native posterior tibial slope.

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High tibial osteotomy (HTO) has become an established operative procedure for medial compartment osteoarthritis in varus knees of young and active patients. Furthermore, it can also be used to treat localized medial cartilage defects, such as osteochondritis dissecans and condylar osteonecrosis. Lateral closing-wedge HTO was initially preferred, but medial opening-wedge HTO is becoming popular because it is simpler and allows adjustment in the coronal and sagittal planes. In addition, medial opening-wedge HTO avoids possible damage to the lateral aspect of the knee (ie, the proximal tibiofibular joint and the peroneal nerve).

Although medial opening-wedge HTO is used to correct deformities in the coronal plane, it can simultaneously alter tibial slope in the sagittal plane because of the triangular configuration of the proximal tibia, and this undesired change in tibial slope can influence knee kinematics, stability, and joint contact pressure. Over the past few years, navigation systems have been adapted to assist with HTO, and it has been reported that these systems allow more precise evaluations of deformities and more precise intraoperative real-time control of the axes obtained by correction. However, early 2-dimensional (2-D) navigation systems were able to measure only coronal plane correction directly, but now an updated 3-dimensional (3-D) osteotomy module is available that allows for measurements in the sagittal plane with tibial slope control. The purpose of this study was to compare the results of deformity correction directly, but now an updated 3-dimensional (3-D) osteotomy module is available that allows for measurements in the sagittal plane with tibial slope control.

The purpose of this study was to compare deformity correction in patients undergoing opening-wedge HTO with navigation and to compare the 2 navigation systems with respect to posterior slope changes.

**Materials and Methods**

Between May 2009 and September 2010, thirty-four patients with unicompartmental osteoarthritis with genu varum deformity were treated by navigation-assisted opening-wedge HTO. Exclusion criteria were a history of previous knee surgery, a finding of ligament deficiency, systemic arthritis, and osteonecrosis. The OrthoPilot (B. Braun Aesculap, Tuttingen, Germany) kinematics-based image-free navigation system was used in all patients. Patients were randomly divided with a closed envelope technique into 2 groups according to thenavigation system used: group A (OrthoPilot version 1.3 [2-D]; 17 patients) and group B (OrthoPilot version 1.5 [3-D]; 17 patients). All HTOs were performed in a standardized medial valgus opening-wedge manner by a single surgeon (E.K.S.) with experience with more than 100 cases treated using a navigation system.

Full-length standing anteroposterior radiographs of the lower limbs and non-weight-bearing lateral radiographs of the knee were obtained preoperatively and at 3 months postoperatively. To assess the accuracy of correction, alignment of the lower limb, as determined by the femoral mechanical axis and the mid-diaphyseal tibial axis, was measured. The posterior slope of the proximal tibia was measured using the angle between the line of mid-diaphyseal tibial axis and the slope of the tibial plateau (Figure 1). All radiological evaluations were performed by a single independent, blinded orthopedic surgeon who was not involved in the surgery (J.K.S.).

This study was approved by the Ethical Committee of Chonnam National University Hwasun Hospital. All patients provided informed consent before enrollment in the study.

**Surgical Technique**

In all patients, OrthoPilot transmitters were fixed on the distal femur and tibial shaft with two 2.5-mm K-wires on the lateral side. For the 3-D system, an additional transmitter was fixed on the proximal tibia above the level of osteotomy with two 2.5-mm K-wires to monitor tibial slope (Figure 2). To determine the mechanical leg axis, kinematic data, including hip, ankle, and knee joints, were registered. The medial border of the patellar tendon was identified in advance.

To retract the patellar tendon laterally, a short longitudinal incision was made to allow a retractor to be placed deep to the patellar tendon just proximal to the tuberosity. A short-oblique minor osteotomy of the tibial tuberosity was made using an...
osteotomy to protect the patellar tendon insertion and facilitate HTO. Main osteotomy was started 3 cm distal to the medial joint line at the medial cortex of the proximal tibia. This osteotomy was directed to the mid-level of the tibiofibular joint, leaving 5 to 10 mm of the lateral tibial cortex intact. Careful valgization by stepwise insertion of 3 coupled osteotomies was performed to avoid intra-articular fracture.

The mechanical axis was visualized continuously throughout the procedure, and the aim of the correction was to achieve 3° of valgus. When the required correction was achieved, the osteotomy was stabilized with 2 Aescular plates (Medyssey, Dongducheon, Korea): one for anterior and one for posterior tibial fixation. At that time, the posterior plate was placed as posteriorly as possible at the posteromedial corner of the proximal tibia, and the anterior plate was placed below the short-oblique osteotomy of the tibial tuberosity. In group A, the size of the anterior plate was approximately 70% of the size of the posterior plate to avoid increasing the posterior slope, as determined in a previous study, but in group B, coronal alignment was corrected using navigational data to determine the size of the posterior plate, and the size of the anterior plate was then selected to maintain the inherent tibial slope based on navigational sagittal data.

Student’s t test was used to analyze patient data. A 2.2° difference in tibial slope was considered a meaningful intergroup difference, and the SD was set at 2.3° (determined by a preliminary trial with 5 patients per group). These values yielded an estimated sample size of 17 patients per group. The power calculation was performed with a confidence level of 95% (α=0.05) and a power (1-β) of 80%. Statistical analysis was performed using SPSS version 18.0 statistical software (SPSS, Inc, Chicago, Illinois).

**RESULTS**

Postoperatively, alignment of the lower limb was corrected adequately in groups A and B to a mean valgus of 2.81° (range, 1° to 5.4°) and 3.15° (range, 1.5° to 5.6°), respectively (P=.442), and posterior slope was well maintained, from 7.9° (range, 4° to 17.9°) and 9.3° (range, 7° to 18°) preoperatively to 9.0° (range, 4.7° to 17.4°) and 9.1° (range, 6.7° to 15.2°) postoperatively, respectively. No significant intergroup differences existed between the mean values of posterior tibial slope pre- and postoperatively; however, in group A, a significant difference in the amount of posterior slope change (Δ slope; preoperatively to 3 months postoperatively) of the tibia with a mean increase in posterior slope of 1.1° (range, −3.1° to 3.2°) was observed, whereas in group B, this mean increase in posterior slope was −0.2° (range, −2.8° to 1.8°) (Table). No specific complications related to the use of the navigation systems occurred in either group.

**DISCUSSION**

Opening-wedge HTO is a technically demanding procedure despite the use of navigation because it can result in changes to axes in the coronal and sagittal planes. Several studies have reported that the posterior slope of the proximal tibia tends to increase after opening-wedge HTO. It is likely that changes in the tibial slope after opening-wedge HTO are due to the anatomic characteristics of the proximal tibia, which is a triangularly shaped 3-D structure.

Navigation systems are becoming increasingly important in orthopedic surgery. In terms of corrective osteotomy of the knee, many studies have concluded that navigated HTO significantly improves the accuracy and decreases the variability of corrections. However, to the current authors’ knowledge, no report has been published on tibial slope changes in the sagittal plane for navigation systems. Therefore, the current study examined whether navigated opening-wedge HTO offers improved accuracy for corrections of coronal alignment and...
sought to determine whether posterior slope change for 3-D navigated HTO is significantly less than that for 2-D navigated HTO and whether this is achieved with a smaller SD.

The tibial slope can be influenced by several surgical factors; thus, the observed reductions in Δ slope in the current study cannot be wholly ascribed to the updated 3-D navigated osteotomy. However, the 2-D navigated HTO in this study was similar to those reported previously, and the same techniques were used, except for placing an additional transmitter on the proximal tibia, for both modalities and an effort made to maintain a posterior slope. More specifically, the osteotomy was made parallel to the joint line in the sagittal plane, posterior corticotomy was complete, posteromedial soft tissue of the proximal tibia was adequately released, and the plate was placed as posteriorly as possible. Accordingly, the current comparison of 2-D and 3-D navigated HTO is justifiable.

**Conclusion**

Opening-wedge HTO using navigation offers the accuracy of lower-limb coronal alignment, and, in the current study, the use of a 3-D navigation system resulted in significantly less Δ slope postoperatively than did the use of a 2-D navigation system. Accordingly, the authors recommend the use of 3-D navigation systems because they provide real-time intraoperative information about coronal, sagittal, and transverse axes and guide the maintenance of the native posterior tibial slope.

**References**


