Journal of Orthopaedics 16 (2019) 25–30

Contents lists available at ScienceDirect

Journal of Orthopaedics

journal homepage: www.elsevier.com/locate/jor

The usefulness of planning using a preoperative lateral leg image to determine accurate posterior tibial slope in total knee arthroplasty

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ARTICLE INFO

Keywords:
Total knee arthroplasty
Posterior tibial slope
Sagittal alignment

ABSTRACT

Objective: Sagittal alignment of the tibia following total knee arthroplasty (TKA) can affect various factors, such as durability, range of motion, stability, and even kinematics. The aim of the present study was to investigate whether taking plain preoperative lateral leg X-ray images to plan the posterior tibial slope can give an insert placement with more accurate sagittal alignment.

Methods: A total of 100 patients who underwent total TKA with posterior-stabilized prostheses. were divided into a group of 50 cases in which the posterior tibial slope was determined intra-operatively with only the fibular axis as the landmark, and a group of 50 cases in which determination of the posterior tibial slope was planned preoperatively with reference to preoperative lateral leg images. For the posterior slope, tibial cutting was performed with the posterior slope built into the bone cutting guide of the insert as the target. The angle of the fibular axis and the posterior slope of the tibial insert were measured on the postoperative lateral leg X-ray image, and the difference from the target angle was examined in the two groups.

Results: In the group in which only the fibular axis was used for reference, the mean deviation from the target was 3.96°, while in the group in which planning was carried out preoperatively using lateral leg X-ray images, the mean deviation was 1.59° ($P < 0.05$).

Conclusion: Drawing up a preoperative plan using lateral leg X-ray images gives a useful landmark at low cost for accurate determination of TKA posterior tibial slope.

1. Introduction

Sagittal alignment of the tibia following total knee arthroplasty (TKA) can influence various factors, such as durability, range of motion, stability, and even kinematics.[1–5] Many surgeons use extramedullary or intramedullary tibial cutting guides to make the tibial cut.[6–8] In recent years, computer navigation or patient-matched instruments have been used to achieve a more accurate cut,[9–11] but such systems are not in use at all facilities because of the constraints of cost and available equipment.

With coronal alignment of the tibia following TKA, a so-called neutral alignment is recommended, and there are numerous reports of poor outcomes with alignment at ≥3°.[12] In recent years, Bellemans et al. proposed the concept of constitutional varus,[13] and TKA has also been performed using the kinematic alignment method,[14] with reports of long-term clinical outcomes pending. With rotational tibial alignment, internal rotation of the tibial component is reported to be a cause of patellofemoral complications, and excessive internal rotation is therefore to be avoided.[15] In addition, internal rotation of the tibial component is reported to reduce range of motion and increase the risk of revision.[16,17] With regard to sagittal alignment of the tibia, there is the problem of whether cruciate-retaining (CR) and posterior-stabilized (PS) TKA should have the same target. With CR, it has been reported that, if the posterior tibial slope differs from the slope before surgery, there will be a change in the strain on the posterior cruciate ligament (PCL), so it is therefore better to make the postoperative posterior slope about the same as that before surgery.[18] In the case of PS, there are reports that giving too great a posterior tibial slope risks anterior impingent of the tibial post,[19,20] and it is therefore better to ensure that there is not too much posterior slope. Including these reports, there is still considerable controversy concerning the appropriate sagittal plane alignment of the tibia following TKA, and, in addition, there are few

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https://doi.org/10.1016/j.jor.2018.11.005
Received 24 October 2018; Accepted 28 November 2018
Available online 06 December 2018

Table 1
In the pre-operative background of the patients, there were no significant differences between the FG group and the PG group in age, sex, BMI, or laterality of the affected leg.

	Fibula Group (FG group)	Planning Group (PG group)	P value
N (number of patients)	50	50	
Age (y)	77.6 (65.0–91.0)	77.2 (67.0–88.0)	n.s.
Sex (male/female)	8/42	9/41	n.s.
BMI (kg/m^2)	26.3	26.9	n.s.
Number of legs (right/left)	27/23	26/24	n.s.
Implant (Scorpio/PERSONA)	25/25	25/25	n.s.

reports of methods for determining the appropriate alignment.

In the present study, differences in radiological outcomes and surgery times were investigated between a group in which TKA was carried out intraoperatively with only the fibular axis as a landmark for the posterior tibial slope (Fibula Group, FG), and a group in which TKA was carried out with preoperative planning using a lateral X-ray image of the lower leg (Planning Group, PG).

2. Materials and methods

The subjects were 100 patients undergoing PS TKA who were randomly divided into the FG and the PG. All subjects were knee osteoarthritis patients undergoing TKA for the first time. Patients with prior knee surgeries including osteotomy, meniscectomy or suture, or anterior cruciate ligament reconstruction were excluded from the study. There were no significant differences between the two groups in age, sex, body mass index (BMI), or laterality of the operated side. The inserts used were the Scorpio NRG (Stryker, Mahwah, NJ, USA) and the PERSONA (Zimmer & Biomet, Warsaw, IN, USA) (Table 1). The inserts were assigned randomly. All operations were performed by the same surgeon. Bone resection was performed through the medial parapatellar approach with measured resection using an extramedullary guide. The insert was placed using cement. Extramedullary cutting guides may be spiked or spikeless,[21] and spikeless guides were used in the present study.

Prior to the procedure, a lateral view X-ray image of the whole leg was taken in the decubitus position with the knee at 90°, approximating the leg position for placement of the tibial insert during the procedure. Various points can be used as the landmark for posterior tibial slope, but, in the present study, the landmark was the fibular axis. A line P parallel to the fibular axis was drawn in front of the tibia (Fig. 1a), and the distances from line P to the skin surface at the midway point between the tibial tubercle and the tip of the medial malleolus (Fig. 1b, line A) and from line P to the forward surface of the lower leg skin concavity (Fig. 1b, line B) were measured. The ratio B/A was calculated from these measured values. During the procedure, draping was carried out in such a way that the front of the leg could be clearly understood (Fig. 2a). Tibial cutting was performed using an extramedullary guide, and the cutting guide was placed at 5° for the Scorpio and 3° for the PERSONA, with placement at the respective built-in posterior slope angle targeted in each case. The actual distance from the tibial tubercle to the tip of the medial malleolus was measured, and the distance from

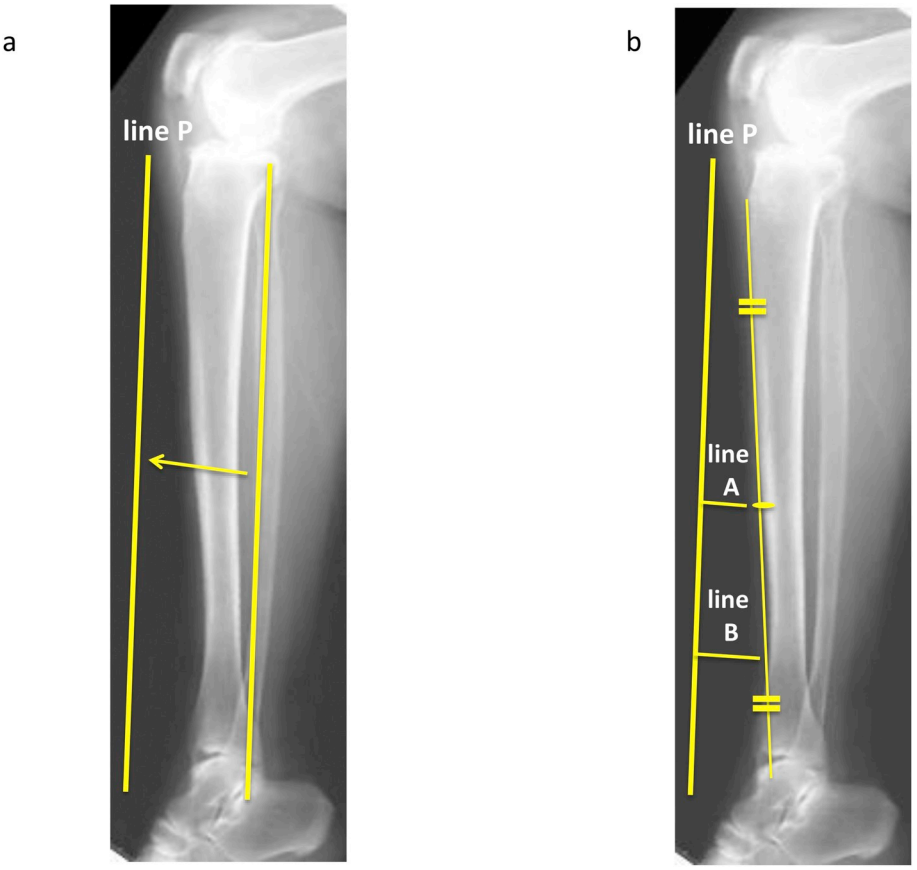

Fig. 1. Prior to the procedure, an X-ray was taken in the decubitus position with the knee bent at 90°, approximating the tibial insert placement position during the procedure, and line P was drawn parallel to the fibular axis in front of the tibia (Fig. 1a). The distances from line P to the surface of the skin of the leg at the midpoint between the tibial tubercle and the tip of the medial malleolus (line A), and from line P to the skin surface at the concavity of the lower leg (line B), were measured. The ratio B/A was then calculated (Fig. 1b).

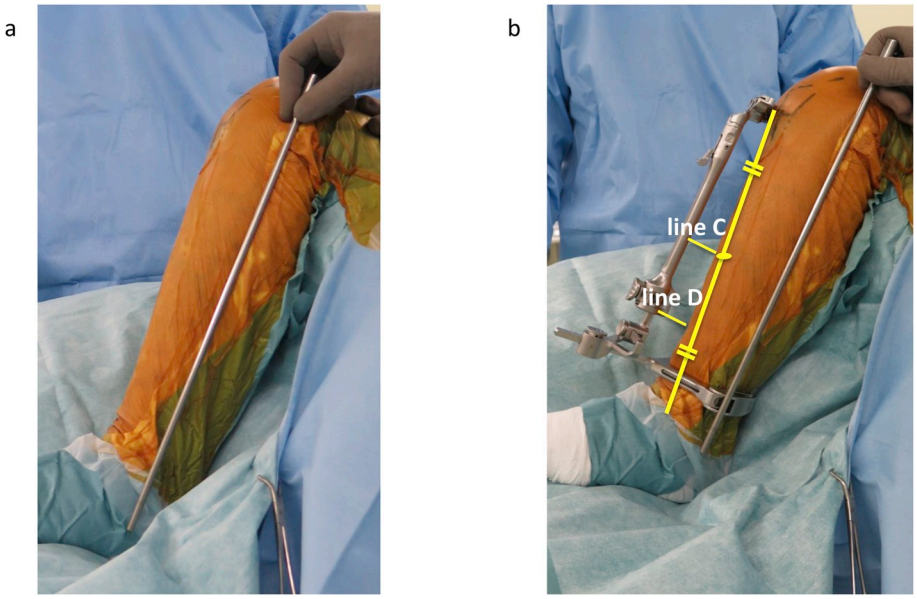

Fig. 2. During the procedure, draping was arranged so that the front surface of the leg could be clearly seen. As a reference for the fibular axis, an alignment rod was placed as shown in the figure by feeling the head of the fibula and the lateral malleolus (Fig. 2a). The actual distance from the tibial tubercle to the tip of the medial malleolus was measured during the procedure, and the distance from the midpoint to the extramedullary guide was measured (line C). The length of line C was multiplied by the above-mentioned ratio B/A, and the posterior slope of the guide was adjusted such that the distance from the forward surface of the lower leg skin concavity to the extramedullary guide matched this value (line D). Thus, in the PG group, the posterior slope was determined by using this ratio to position the extramedullary guide parallel to line P, which was drawn prior to the procedure (Fig. 1). In the FG group, the posterior slope was determined by positioning the extramedullary guide parallel to the alignment rod, which was placed as a reference for the fibular axis (Fig. 2).

the midpoint to the extramedullary guide was measured (Fig. 2b, line C). C was multiplied by the above-mentioned ratio B/A to give the value D, and the posterior slope of the guide was adjusted such that the distance from the forward surface of the lower leg skin concavity to the extramedullary guide matched D (Fig. 2b, line D). Thus, cutting in the PG was carried out with the extramedullary guide during the procedure set parallel to line P (Fig. 1a), which was drawn prior to the procedure.

At 3 months after surgery, the lateral view X-ray image of the whole leg was taken in the decubitus position with the knee at 90°, in the same way as before the procedure. The angle between the fibular axis and the insert was measured, and the difference between the measured angle and the preoperative target angle of 5° with the Scorpio and 3° with the PERSONA was determined. In addition, since postoperative posterior tibial slope was determined with reference to the fibular axis in this study, the angle of the posterior slope between the tibial insert and the fibular axis was measured (Fig. 3).

3. Statistical analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) ver. 23.0 (IBM Corp., Armonk, NY, USA). Significant differences between the two groups were investigated using paired *t*-tests, with $P < 0.05$ taken as significant.

4. Results

The mean difference between the posterior tibial slope angle predicted prior to the procedure and the actual posterior slope angle of the insert was 3.9° in the FG and 1.6° in the PG. A significant difference was found between the two groups (Fig. 4). Thus, carrying out bone cutting by using a lateral view of the lower leg to preoperatively plan the posterior tibial slope allowed bone cutting with a more accurate posterior tibial slope in comparison to using the fibular axis as a landmark during the procedure.

5. Discussion

There have been various reports regarding the posterior tibial slope angle, and there are a number of controversies. It has been reported that giving posterior slope to the tibia generally increases the joint range of motion and improves the efficiency of quadriceps muscle strength.[4,22] With CR TKA, it has been reported that a smaller posterior slope increases the strain of the PCL,[23] causes restricted range of motion, and leads to abrasion of the polyethylene post. It has also been reported that, with CR TKA, it is best to aim for about the same posterior slope as before the procedure, since this has no effect on kinematics.[18] However, in some patients, the natural tibial slope can exceed 10°,[24] and there are still a number of points to be clarified regarding how far the posterior slope should be set. It has been reported that, if the tibia is cut with a posterior slope of 0°, the mean proportion of the PCL attachment removed is 45% in men and 46% in women, while with a 7° posterior slope, the mean proportion is 69% in men and 67% in women.[25] Thus, if too great a posterior slope is given, the functioning of the PCL itself may be lost.

There are few reports regarding the posterior slope with PS TKA. There is a report that making the posterior slope too great can cause anterior translation of the tibia, or it can lead to wear on the posterior side of the insert.[20] In addition, there have also been reports of anterior impingement of the tibial post occurring with PS TKA because of the post-cam mechanism.[19,20] Okamoto et al.[26] carried out a study using KneeSIM, and they reported that, in PS TKA, maximum quadriceps force and patellofemoral contact force decreased with tibial posterior slope, and that anterior sliding of the tibial component occurred at tibial posterior slopes of at least 5°, and anterior impingement occurred at slopes of at least 10°. Therefore, they recommend posterior slopes of less than 5° with PS TKA. It therefore appears that excessive posterior slope is to be avoided in PS TKA.

The conventional method for determining posterior tibial slope has been to use an extramedullary or intramedullary guide. In recent years, computer-assisted surgery, such as computer navigation, or patient-matched instruments have been used, and their usefulness has been

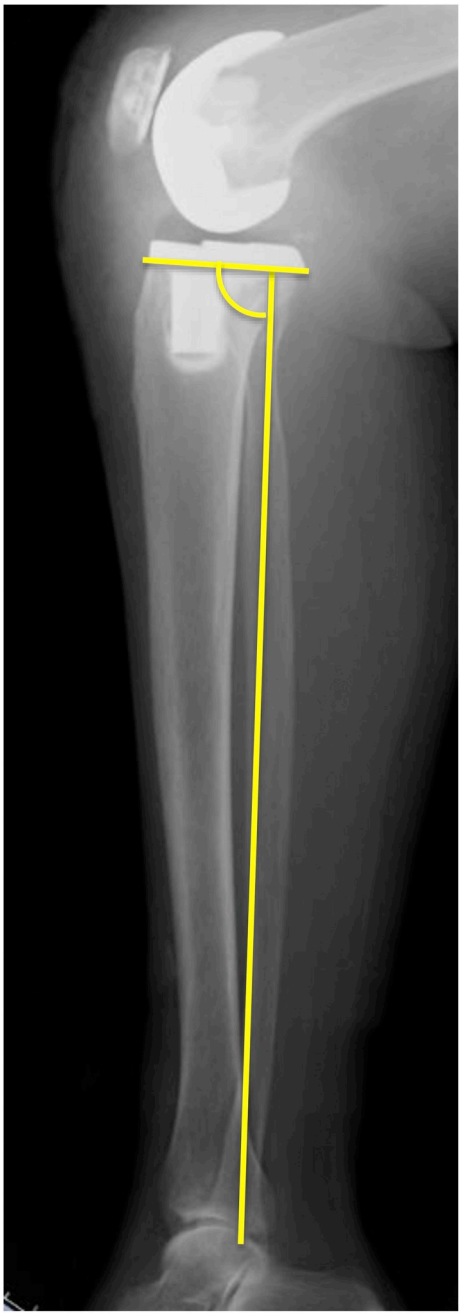

Fig. 3. After the procedure, a lateral-view image of the whole leg was taken in the decubitus position with the knee bent at 90°, in the same way as before the procedure. The angle between the fibular axis and the insert was measured, and the difference between the measured angle and the preoperative target angle of 5° with the Scorpio and 3° with the PERSONA was determined. In this study, as the posterior tibial slope was determined with reference to the fibular axis, the posterior slope angle was measured as the angle between the implant and the fibular axis.

reported.[9–11] While computer-assisted surgery is useful, it is very expensive and requires intricate systems and, therefore, has the limitation that it cannot be used in all facilities. Jones et al.[27] point to the need for a low-cost, handheld system in future. In the present study, the conventional method of an extramedullary guide was used, and the extent to which it can give accurate insert placement was investigated. Intramedullary and extramedullary guides both have their respective advantages and disadvantages, but the disadvantages of the intramedullary guide are that there is instability of the rod, the entry point can vary if there is deformation of the tibia,[6] and the increase in intrathecal pressure can cause embolization.[28,29] It has also been reported that the use of a navigation system to determine posterior tibial slope does not offer any great advantages over the use of an extramedullary guide,[9,10,30] and, therefore, an extramedullary guide was used in the present study.

There are various reports concerning the landmark for determining the actual posterior tibial slope. There are reports that the fibular axis from the body surface is useful,[31,32] but Seo et al.[33] reported the possibility of an increased risk of postoperative malalignment in patients with a BMI greater than 33.7 kg/m^2. At the same time, Kuroda et al.[34] reported that, while the fibular axis may perhaps be effective in general as an intra-operative index for posterior tibial slope, there is large variation between surgeons with the fibular axis, and it is not a reliable intra-operative index. The present method uses the preoperative bone configuration and distance from the entire surface of the fibula as an index, so that placement with minimal error is possible even in obese patients. In addition, the fibular axis was used as a preoperative landmark in the present study, but if, for example, the tibial axis were established as per the preoperative plan, placement could be made corresponding to the tibial axis. The present method is therefore useful because it can be used flexibly with various different landmarks.

There are a number of limitations to the present study. The first is that lateral X-ray images of the lower leg were used to assess posterior tibial slope, but compared to lateral views of the knee, there may be additional inaccuracies relating to the position of the lower leg and the projection. With regard to lower leg position, all X-ray images were taken in the same way in the decubitus position with the knee at 90°, but it is impossible to take into account minute internal or external rotation of the leg, or varus or valgus of the tibial insert. In addition, there are differences in the projection angle with lateral images of the knee and leg, and while there were no problems in most cases, there were a few cases in which posterior tibial slope could not be measured accurately because a clear image of the tibial insert had not been taken, and the images had to be retaken with a slight adjustment of leg position. Next, the present study was not performed on the basis of a randomized, controlled trial. Nonetheless, the insert that was used was selected at random to ensure there were no particular differences between patients, and there were no significant differences in the preoperative baseline characteristics of patients.

6. Conclusion

Planning the posterior tibial slope preoperatively using lateral images of the leg is a low-cost, useful method for ensuring more accurate placement of the tibial insert. In addition, the present method can be used flexibly with various landmarks for determining posterior tibial slope, allowing placement of the insert to give the postoperative posterior tibial slope angle desired by the surgeon.

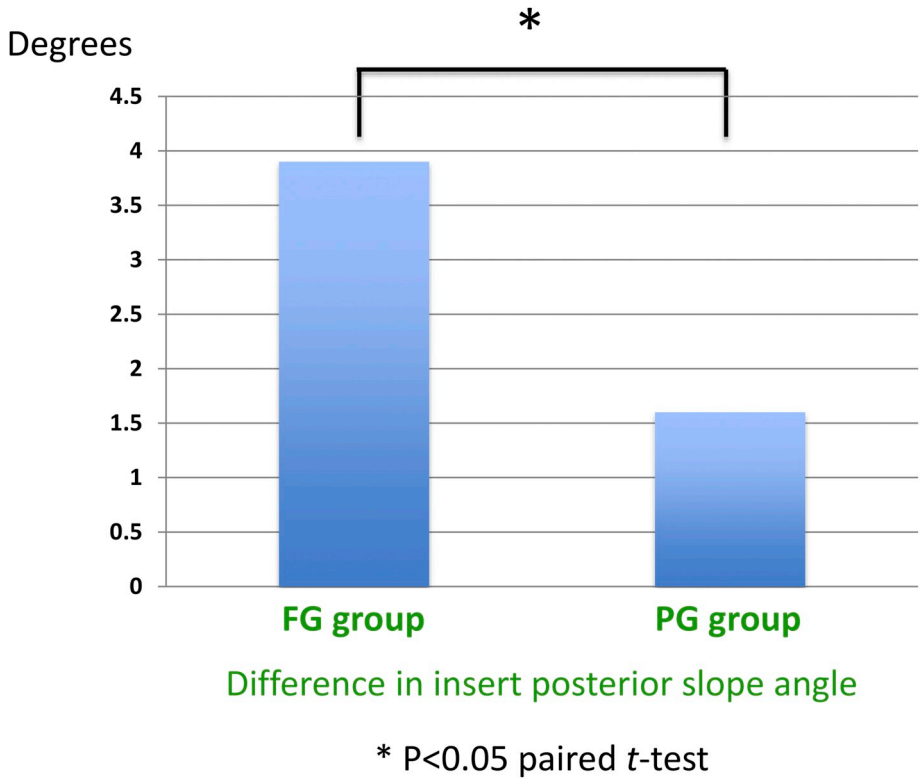

Fig. 4. The difference between the insert posterior slope angle and the target posterior tibial slope angle was significantly smaller in the PG group than the FG group. The results show that more accurate posterior tibial slope placement was possible in the PG group than the FG group.

Declaration of interest

None.

Consent

The authors state that informed consent was obtained from all patients.

Ethical approval

The study was approved by the local ethics committee Akita Red Cross Hospital (2018/total number 376).

Acknowledgment

The authors declare that they have not received financial support and they have no proprietary interests in the materials described in the article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jor.2018.11.005.

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