Relationship between the tibial anteroposterior axis and the surgical epicondylar axis in varus and valgus knees

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Abstract

Purpose Proper rotational alignment in total knee arthroplasty (TKA) is essential for successful outcomes. The surgical epicondylar axis (SEA) has been frequently used to determine the femoral rotational alignment, and the anteroposterior (AP) axis of the tibia described in previous study has been introduced as a line perpendicular to the SEA in healthy knees. However, the rotational relationship between the distal femur and the proximal tibia would vary between normal and osteoarthritic knees, and a question remains whether the rotational relationship between the SEA and the AP axis of the tibia would be the same between normal and osteoarthritic knees. This study aims to determine whether the AP axis of the tibia is actually perpendicular to the SEA and useful for the tibial rotational alignment also in osteoarthritic knees.

Methods Preoperative computed tomography scans on 25 varus and 25 valgus knees undergoing TKA were studied. The SEA and the AP axis of the tibia were identified using a three-dimensional software, and the angle between the line perpendicular to the projected SEA and the AP axis was measured.

Results The AP axis of the tibia was $1.7° \pm 4.3°$ and $2.0° \pm 4.0°$ internally rotated relative to the line perpendicular to the SEA in the varus and valgus groups, respectively.

Conclusions The AP axis of the tibia was, on average, perpendicular to the SEA in both varus and valgus knees.

The AP axis would be useful for setting the tibial component with minimal rotational mismatch.

Level of evidence IV.

Introduction

Reconstruction of the mechanical leg axis in the coronal and sagittal plane is a major requirement in total knee arthroplasty (TKA) and unicompartmental knee arthroplasty (UKA) [7, 10, 15]. However, proper femoral and tibial component rotational positioning is also essential for successful TKA. Positioning is key as the consequences of malrotation would produce patellofemoral problems [2, 6, 8, 19, 22], flexion instability [6], ultra-high molecular weight polyethylene or post-wear [16, 22, 27], stiffness [23], and abnormal gait patterns [26].

The surgical epicondylar axis (SEA), the line connecting the tip of the lateral epicondyle to the medial epicondylar sulcus, has been shown to be not only a useful anatomic reference axis but also a functional flexion–extension axis [9, 17, 20, 21, 29]. In contrast to the femoral side, several references are used to determine tibial rotational orientation. The anteroposterior (AP) axis connecting the middle of the posterior cruciate ligament (PCL) to the medial border of the patellar tendon at the attachment level described by Akagi et al. has been introduced as a reproducible and reliable line perpendicular to the SEA in healthy knees [3, 4]. However, the rotational relationship between the distal femur and the proximal tibia in knee extended position would vary between normal and

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Fig. 1 **a** The middle of the PCL at the tibial attachment (*white circle*) was identified. **b**. The AP axis of the tibia, the SEA and the line perpendicular to the SEA were drawn (two *solid line* and one *dotted line*, respectively), and the angle between the line perpendicular to the SEA and the AP axis was measured
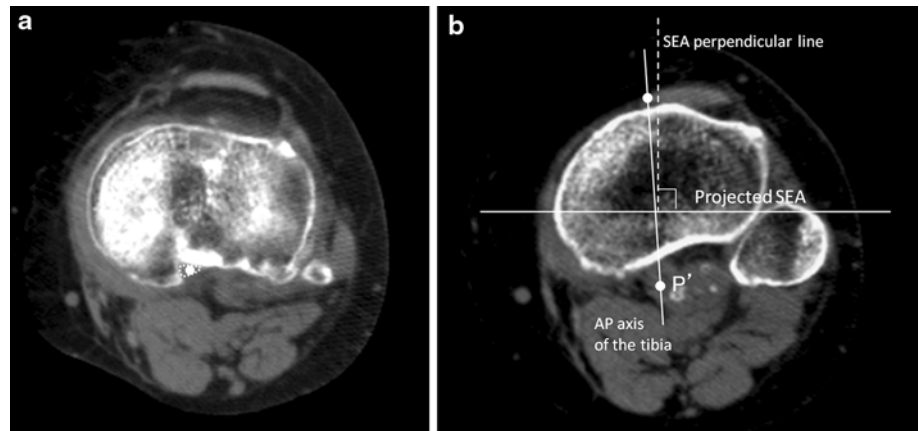
osteoarthritic knees [12]. Therefore, a question remains as to whether the AP axis of the tibia is actually perpendicular to the SEA in osteoarthritic knees. Moreover, it is well known that valgus knees have hypoplastic posterolateral condyle [18], and it is much more unclear in valgus knees whether the AP axis of the tibia is perpendicular to the SEA.

The objective of the current study is to identify whether the AP axis of the tibia is perpendicular to the SEA and useful for the tibial rotational alignment also in osteoarthritic knees based on preoperative computed tomography (CT) scan data.

Materials and methods

This study was approved by the institutional review board (Kyushu University, 3-1-1 Maidashi, Higashi-ku, Fukuoka 812-8582, Japan, No. 21-8). Informed consent for participation was obtained from all patients. We obtained preoperative knee CT scans on 52 patients with primary varus osteoarthritis (varus angle: median 10.0°, range 0.5°–22.5°) and on 28 patients with primary valgus osteoarthritis (valgus angle: median 6.3°, range 0.3°–25.0°) undergoing TKA. Postoperative knees displaying intra-articular osteosynthesis, high tibial osteotomies and unicompartmental knee arthroplasties were excluded from the study. The patients were all Japanese.

The patients were placed in the supine position on the scanning table and the affected knee was naturally extended without any feeling of internal or external rotation. Transverse CT scans were taken at the levels ranging from the hip joint to the ankle joint at 2-mm intervals. CT images were acquired as DICOM data from the CT system server. A three-dimensional (3D) image of the lower extremity was reconstructed on the computer using the program 3D template (version 02.02.02, Japan Medical Matls. Corp., Osaka, Japan). An axial plane was defined

perpendicular to the tibial mechanical axis. The flexion angle of the knee was defined as the angle between the femoral mechanical axis and the tibial mechanical axis.

The tip of the lateral epicondyle and the medial epicondylar sulcus were identified, and the SEA was drawn. In eight varus knees and four valgus knees, the medial epicondylar sulcus could not be recognized on CT scans. In these subjects, the clinical epicondylar axis (CEA) connecting the most prominent point of the medial epicondyle and the lateral epicondyle was identified, and the SEA assumed as a line rotating the CEA internally by 3° [5, 28]. For the AP axis of the tibia, the middle of the PCL at the tibial attachment (Fig. 1a) and the medial border of the patellar tendon at the attachment level (Fig. 1b) were identified.

The SEA and the AP axis were projected onto a plane of the patellar tendon attachment at the tibia perpendicular to the tibial mechanical axis, and the angle between the line perpendicular to the projected SEA and the AP axis was measured (Fig. 1b). All the angles were measured in the computer program 3D template and the program allowed one decimal.

Statistical analysis

Seven patients in the varus group and three patients in the valgus group with a flexion contracture greater than 15° were excluded as this would have resulted in an altered reciprocal rotational position between the femur and tibia. Patients in the varus group were matched with the valgus group as often as possible based on knee extension angle, gender and the hip-knee-ankle angle (HKA, the angle between the femoral and tibial mechanical axis). Setting an order of priority described above, the matched 25 varus knees were extracted (Table 1).

All the measurement procedures were repeated three times at least a week apart by one examiner (SK) for all patients, and the average of three measurements was

Table 1 Comparisons of parameters between varus and valgus knees

	Varus knees	Valgus knees
Knee extension angle	$-6.6 \pm 4.0°$	$-6.3 \pm 3.9°$
Gender		
Male	5 knees	6 knees
Female	20 knees	19 knees
Hip-knee-ankle angle	$8.9 \pm 4.0°$ varus	$7.0 \pm 5.5°$ valgus

adopted as data. To evaluate the intra-observer and inter-observer reproducibility, the measurement was performed three times by one examiner (SK) and once by two examiners (HM, HN) on the 10 knees randomly selected from the study group. The intraclass correlation coefficient and the interclass correlation coefficient were 0.90 and 0.89 for measurement of the angle between the line perpendicular to the projected SEA and the AP axis of the tibia.

Results

The parameters of the varus and valgus groups were shown in Table 1 and all of them were not significantly different.

The AP axis of the tibia was 0.6° (median) internally rotated in the varus group and 2.6° (median) internally rotated in the valgus group relative to the line perpendicular to the SEA (Fig. 2).

Discussion

The most important finding of the present study was that the AP axis of the tibia was almost perpendicular to the SEA in both varus and valgus knees. Aglietti et al. [1] measured the angle between the line perpendicular to the SEA and the AP axis of the tibia (tibial rotation angle) in a manner similar to the current study in 100 osteoarthritic knees including varus and valgus knees. The tibial rotation angle was $0.1° \pm 3.3°$ in men and $0.0° \pm 3.9°$ in women, respectively. In that study, however, it was unclear whether the AP axis was actually perpendicular to the SEA in varus and valgus knees because their subjects were not divided into each group. Anatomical data of the knee should be evaluated separately in varus and valgus knees [24]. Because valgus knees have hypoplastic posterolateral condyle, it is much more unclear whether rotational relationship is the same in normal and valgus knees. The results of the current study suggested that the AP axis would be applicable as a tibial rotational reference in varus and valgus knees when performing TKA.

To avoid rotational mismatch, surgeons can make appropriate corrections of the tibial rotational alignment
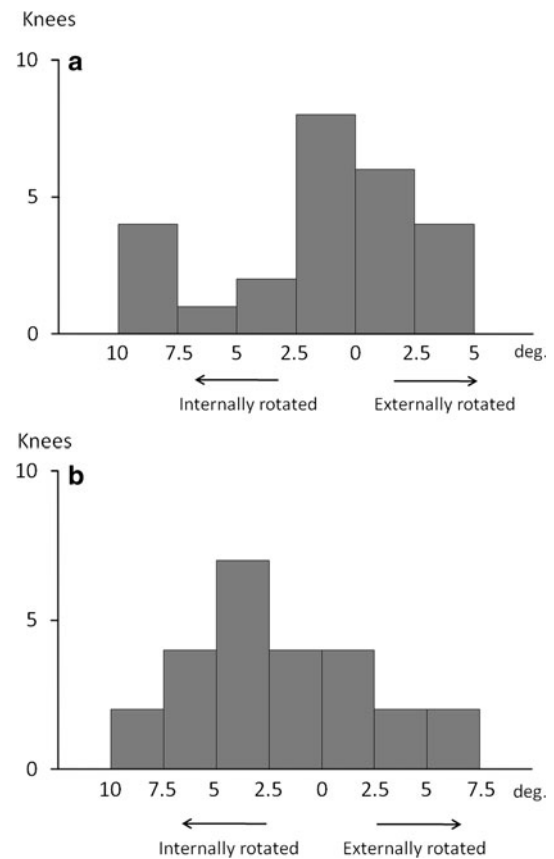
Fig. 2 Distribution histograms of varus and valgus knees were constructed to determine the amount of internal or external rotation of the AP axis of the tibia relative to the line perpendicular to the SEA. **a** varus knees, **b** valgus knees

with trial components. However, the proximal tibia should be cut in the same direction of the tibial component position when the tibia is prepared with some degree of posterior slope. If the rotational direction of the tibial cutting procedure is different from the rotational position of the tibial component, the component would be malaligned in varus or valgus due to its tibial posterior slope [14]. Therefore, the tibial rotational alignment should be determined before cutting the proximal tibia. In this respect, the AP axis is believed to be useful when deformities exist.

Whether the same rotational relationship exists before and after surgery is another important clinical question. Relative rotational position between the distal femur and the proximal tibia is determined by many factors such as the articular configuration [11], the ligamentous tension and the muscle traction. Tight soft tissue structures have been released during TKA, and the current prosthetic design does not have a constrained articulation. Therefore, tendon attachment location such as the tibial tuberosity is a major factor for determining the rotational relationship between the distal femur and the proximal tibia after TKA. Since the location of the tendon attachment does not

change by surgery, we believe the rotational position would not significantly change perioperatively.

There are several limitations to this study. First, we evaluated a limited number (25 knees) of valgus knees. Secondly, some knees evaluated in the study were not able to reach full extension in the CT scanner due to flexion contractures greater than 15° (seven varus knees and three valgus knees); therefore, they were excluded in the study. These slight flexion angles would have possibly affected the reciprocal rotational position between the femur and tibia. Thirdly, this study has been performed under the static knee condition. However, the rotational relationship between the femoral and tibial components is generally confirmed in knee extended position during surgery, and it is dependent principally on the articular configuration, the ligamentous tension and the muscle traction under the dynamic knee condition. Therefore, it is basically important that the rotational positions of each component are determined in knee extended position. Additionally, the study population was limited to Japanese subjects. The study described by Akagi et al. also included Japanese subjects, and our study is in agreement with their study in this respect. However, it is possible that the data included in the current study would be typical only for knees of Japanese subjects and therefore there would be anatomic differences from the Caucasian population [13, 25]. Therefore, one should interpret the results of this study cautiously.

Conclusion

We investigated that the AP axis of the tibia was, on average, almost perpendicular to the SEA in varus and valgus knees. The clinical relevance of the present study is that the AP axis can be used as a tibial rotational reference in varus as well as valgus knees to minimize the risk for rotational mismatch between the femoral and tibial components.

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