



Investigation of the control of rotational alignment in the tibial component during total knee arthroplasty

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Abstract

Background In this study, rotational errors that occur in relation to the tibial component of total knee arthroplasty (TKA) were investigated intraoperatively using a CT-free navigation system and postoperative CT images to confirm the correctness of the rotation.

Methods Forty patients who underwent TKA using the navigation system were examined. These patients were split evenly into two groups, those whose rotational position was confirmed using a mark made manually on the tibia, and those whose rotation was confirmed using the navigation. All patients underwent postoperative CT scanning and were evaluated using the Knee Society Score.

Results With navigation, a significant difference was found between the rotational positions for which we made a keel hole and those for which the tibial component was inserted unguided. After cementing, the rotational position in the group for which a manual mark was used to confirm the rotation differed significantly from the position for the group for which navigation during cementing was used. Although there were four outliers that had rotational errors over 3° after cementing in the manual mark group, there were no outliers in the navigation group. While there was significant difference in the rotational errors of the tibial component on postoperative CT between two groups, the Knee Society Score did not differ between two groups.

Conclusion The exact rotation of a tibial component cannot be maintained by simply creating a keel hole. The use of a manual mark resulted in rotational errors of the tibial component and the creation of the outliers. Therefore, it is suggested that the use of a navigation system can reduce the occurrence of such errors.

Keywords Total knee arthroplasty · CT-free navigation · Tibial component · Rotational error

Introduction

Total knee arthroplasty (TKA) is a common surgery for treating severe knee osteoarthritis. In TKA, it is considered that malalignment of femoral and tibial components can cause several complications, including anterior knee pain, patellofemoral instability, and early loosening of implants. Furthermore, such complications lead to revision surgeries and result in patient dissatisfaction [1–6]. The correct rotational position of femoral and tibial components is important for TKAs to last for long periods. The rotational alignment

of the femoral component has been extensively studied [1, 2, 7–14], and there are major anatomical landmarks on the medial and lateral supracondyles that are used to confirm the rotational position of femoral components. However, there are few such landmarks on the tibia. Akagi et al. [15] reported that when the anteroposterior axis of the tibia was defined as a perpendicular line to the transepicondylar axis, it may be possible to use the line connecting the middle of the posterior cruciate ligament and the medial border of the tibial attachment of the patellar tendon as a reference axis to indicate the anteroposterior orientation of the tibia.

Although coronal alignment can be confirmed by the proximal axis of tibia, the tibial anatomical landmarks used for axial rotational alignment are lost during osteotomy. Therefore, the axial rotational position cannot be correctly checked because of the elimination of the posterior cruciate ligament, especially in posterior-stabilized (PS) TKA. Furthermore, the

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femoral component rarely deviates in fixation as osteotomy of the femoral site is performed on several planes, five for most prostheses. However, because the tibial site becomes planar after osteotomy of a single plane, the rotational position of the tibial component cannot be adequately confirmed. Therefore, malrotation of the tibial component easily occurs when a keel hole is bored and the tibial component is cemented. Although there are several reports that the use of navigation allows the correct alignment of the femoral component and helps to avoid errors in the rotation of the femoral component in axial alignment [16, 17], to our knowledge, there are few reports concerning the rotational position of the tibial component. Kuriyama et al. [18] demonstrated that rotational errors of tibial components could occur during cementing and that they could be confirmed using computed tomography (CT)-based navigation. Additionally, they also reported that the CT-free navigation system could not confirm the rotational position of the tibial component.

We also believe that rotational error of tibial components can occur anytime between making a keel hole, inserting the tibial component into the keel hole, and cementing the tibial component. The purpose of this study was to examine factors that cause rotational errors when using CT-free navigation system to insert the tibial component during TKA.

Subjects and Methods

Forty patients (40 knees), with an average age of 72 years (range 56–86 years) and who underwent TKA using a CT-free navigation system (Stryker Knee Navigation System,

Stryker Leibinger, Software vs 4.0), were examined in this study. In all surgeries, the Scorpio Non-Restrictive Geometry (NRG) PS knee system (Stryker Orthopedics, Mahwah, NJ, USA) was used as the TKA implant.

Firstly, we performed registration of several anatomical landmarks and set up the navigation system. Following this, the navigation was used in all cases during the osteotomy of the femur (distal, anterior, posterior, and chamfers) and tibial plateau. To confirm the rotational position when making a keel hole, we defined the anteroposterior axis of the tibia based on Akagi's line [15]. After the osteotomy, we used the navigation system to measure the rotational degree when the operator unintentionally inserted a tibial component, unguided, along a keel hole. Then, in order to determine errors after creating the keel hole, we evaluated the difference between the rotation when the operator bored a keel hole and the rotation after inserting the tibial component.

Next, we divided the patients into two groups (20 subjects in each group) reflecting the method that was used to confirm the rotational position during cementing of the tibial component. The first 20 consecutive knees concerned patients for whom rotational position was examined using a manual mark on the tibia created by monopolar cautery, and these were included in Group M. The following 20 knees concerned patients whose rotational position was confirmed using the navigation during cementing, and these were included in Group N. We developed an original custom guide linked with the navigation system to confirm the rotational position during cementing (Fig. 1). After cementing, we measured the final rotational position using the navigation in both Group M and Group N, and the difference

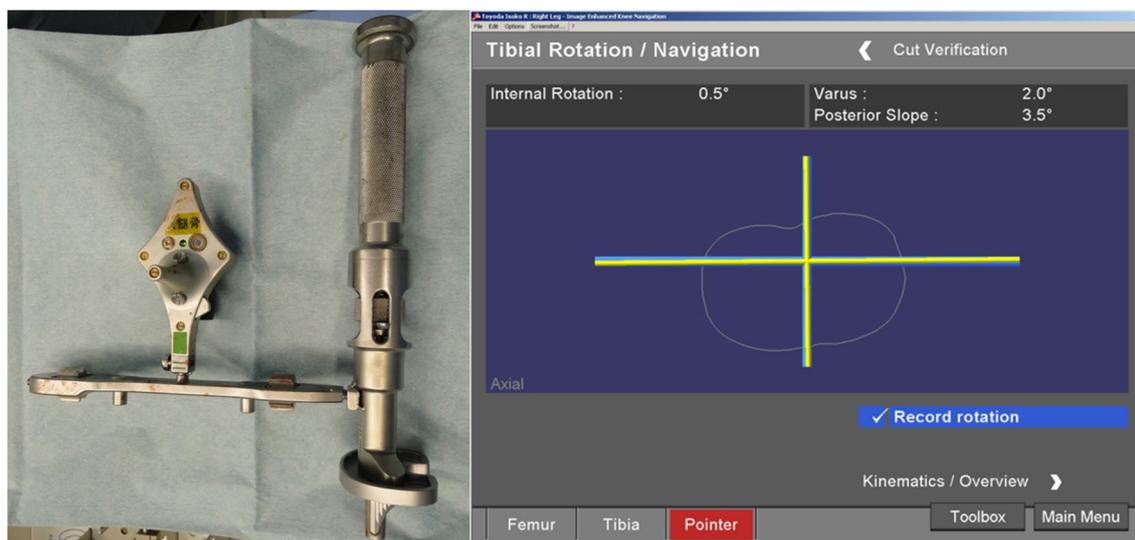


Fig. 1 An original custom guide linked with a navigation system to confirm the rotational position of the tibial component. This guide was designed such that a navigation tracker was exactly attached to

the front of the holder of the tibial component. The rotational position was displayed on the navigation monitor

between the rotation when the operator bored a keel hole and the rotation after cementing in Group M was compared to that in Group N. Finally, we evaluated the rotational errors of the tibial components by comparing postoperative CT images with preoperative CT images and intraoperative data with that of navigation. The Knee Society Score (KSS) for all patients was checked at 6 months after surgery.

In this paper, external rotation was represented with minus values, internal rotation with plus values, and the centre between external and internal rotation as zero.

Statistical analysis

For all patients, the difference between the rotational position when the operator bored a keel hole and that when the operator unintentionally inserted a tibial component unguided was statistically analyzed using a paired *t* test. Several factors concerning Group N and M were statistically analyzed using Welch's *t* test: specifically, the comparison between the final rotation of the tibial component, the difference between the rotational position when the operator bored a keel hole and that when the operator inserted a tibial component, the rotational errors in postoperative CT images, and the KSS at 6 months after surgery. The IBM SPSS statistics version 21 (IBM Corporation, New York, USA) was used for statistical analysis. A *p* value of 0.05 was considered statistically significant.

Results

For all subjects, the rotational position of the keel holes made by the operator using the navigation system ranged from -1.5° to $+4.5^\circ$, and the mean rotation (standard deviation: (SD)) was $+0.1^\circ$ (1.2°). The rotational position of the tibial component when the operator inserted it unguided along the keel hole ranged from -5.5° to $+5.5^\circ$, and the mean rotation (SD) was $+2.3^\circ$ (3.4°). There was a significant difference between the rotational position of the keel holes bored by the operator using navigation and those when the operator inserted a tibia component along a keel hole unguided ($p=0.00059$).

There were 20 patients in group N, with an average age of 73 (range 60–86) years, and there were 20 patients in group M, with an average age of 72 (range 56–85) years. In Group N, the final rotational position after cementing ranged from -2.0° to $+2.0^\circ$, and the mean rotation (SD) was -0.1° (1.0°). In Group M, the final rotational position ranged from -2.0° to $+5.5^\circ$, and the mean rotation (SD) was $+1.1^\circ$ (2.1°). There was a significant difference between the final rotational position after cementing for Group M and that of Group N ($p=0.038$). In particular, Group M had four outliers (20%) that had an error of over 3° in internal or

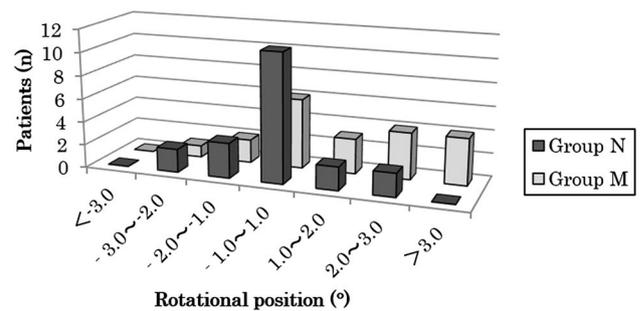


Fig. 2 The final rotational position after cementing. In Group M, there were four outliers (20%) that had an error of over 3° in the internal rotation after cementing, whereas there was no outlier in Group N. Minus values: external rotation, plus values: internal rotation

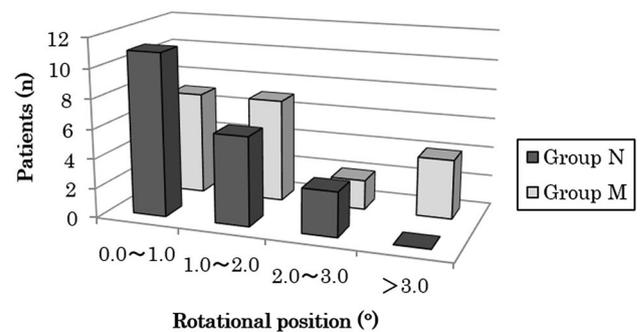


Fig. 3 The error between the rotational position when the operator made a keel hole and after cementing. Errors of over 3° occurred in four cases (20%) in Group M, whereas there was no outlier in Group N

external rotation after cementing, while there was no outlier in Group N (Fig. 2).

For Group N, the error between the rotational position when the operator made the keel hole and the position after cementing ranged from 0.0° to 2.0° , and the mean value (SD) was 0.7° (0.5°). In Group M, the error between the rotational position when the operator bored a keel hole and the position after cementing ranged from 0.0° to 5.0° , and the mean value (SD) was 1.5° (1.5°). There was no significant difference between the errors in Group M and in Group N ($p=0.051$). However, errors of over 3° occurred in four cases (20%) in Group M, whereas there was no outlier in Group N (Fig. 3).

In Group N, the rotational position of the tibial component in postoperative CT ranged from -8.0° to $+8.0^\circ$, and the mean rotation (SD) was $+0.4^\circ$ (4.4°). In Group M, the rotational position of the tibial component in postoperative CT ranged from -10.0° to $+11.0^\circ$, and the mean rotation (SD) was $+1.5^\circ$ (7.8°). In postoperative CT, the rotational error of the tibial component from Akagi's line [15], which was measured by comparing it with preoperative

CT images in Group M (mean 7.1° , SD 3.0°), was greater than that in Group N (mean 3.2° , SD 3.0°) ($p=0.0012$). Although outliers which had over 3° errors in Group N were 5 knees (25%), there were 15 knees (75%) in Group M as outliers.

There was no significant difference in KSS at 6 months after surgery between Group N (mean 101.4, SD 28.5) and M (mean 100.4, SD 39.7) ($p=0.94$).

Discussion

There are several methods of determining the rotation of the tibial component, including the technique of coupling the tibial component to the femoral component in range of motion [19–21], using the medial and lateral malleolar of the ankle and the second metatarsal axis [22, 23], and using the line connecting the middle of the posterior cruciate ligament and the medial border of the tibial attachment of the patellar tendon [15]. We used Akagi's line [15] regarding the anteroposterior axis of the tibia, and, using navigation, we could precisely create a keel hole in the registration alignment. Furthermore, the standard deviation of the rotation of the tibial component had a low range. However, the exact rotational position could not be maintained when the tibial component was simply inserted along the keel hole. We consider that this is a result of cancellous bone fragility around the keel hole of the proximal tibia and of the fact that, after osteotomy, the tibial side has a single plane, whereas the femoral side provides multiple planes after osteotomy of the chamfer. Therefore, landmarks related to the rotational position are required when inserting the tibial component. When using a manual mark created by monopolar cautery, the final rotational position tended to be more internal than when navigation was used and there were also four outliers when monopolar cautery was used. Barrack et al. [1] reported that as little as 6.2° internal rotation of the tibial component was associated with postoperative anterior knee pain, and Berger et al. [2] demonstrated that combined internal rotation of the tibial and femoral components of 3° – 8° was correlated with patellar subluxation and a combined internal rotation of 7° – 17° was associated with observed patellar dislocation or patellar prosthesis failure. Eisenhuth et al. [24] reported that a tibial component was commonly set in the internal rotation because tibial posterolateral confirmation was insufficient in properly reveal the operation field, and rotational position was easily mistaken as the medial posterior condyle was larger than the lateral posterior condyle. We believe that a tibial component may be set in the internal rotation because a tibial component can interfere with the femoral lateral condyle during insertion. In the current study, the difference between the rotational position

when we made the keel hole and that after cementing was more significant in Group M than the difference in Group N. Furthermore, only Group M featured outliers with an error higher than 3° . Therefore, we consider that it is easy to cause errors in the rotation of the tibial components during cementing, even if we use a monopolar cautery mark, and the use of navigation allowed appropriate setting of the tibial component without internal rotation. Use of a navigation system has many advantages, for example, we can confirm rotational deviation easily and correct the rotation immediately, and there is a lower chance of errors in rotational position because not only the operator, but also the assistant can confirm rotational position during cementing using the navigation monitor. Recently, there have been several reports concerning TKAs using a patient-specific guide. Parratte et al. [25] performed a prospective comparative randomized study and reported that the coronal, sagittal, and rotational alignments of a group using a patient-specific guide were comparable to those of a group that underwent a conventional manual technique. In relation to the setting of implants, although use of the patient-specific guide may provide exact osteotomy, it may be that there is no difference in accuracy between TKA with a patient-specific guide and TKA using a conventional technique as errors can occur during cementing. Therefore, although we believe that navigation presents a more exact alignment than a patient-specific guide, CT-free navigation has problems in the alignment of a TKA implant. In this study, a discrepancy was found between the rotation of the tibial component during intraoperative navigation and that of postoperative CT. Davis et al. [26] showed, in a cadaver study, that errors during the manual registration of landmarks were observed and that such registration errors could have a significant effect on the alignment of the implant. The reason for no difference in the KSS between Group N and M may depend on the uncertainty of manual registration. Although rotational dispersion in the Group M was greater than that in Group N, the SD in Group N resembled that in Group M in a postoperative CT images. Therefore, the correct confirmation of anatomical landmarks is important even when using CT-free navigation.

Conclusion

As a result of the examination conducted in this study, it was found that, in TKA, the correct rotational position cannot be maintained by simply inserting a tibial component along a keel hole alone. The use of a monopolar cautery mark as a landmark for the rotational position resulted in internal rotation of the tibial component and caused outliers.

Adequate attention is required throughout the process of making a keel hole, inserting a tibial component, and cementing. The use of CT-free navigation can help to set the tibial components in the correct rotational position for registration. The accuracy of the registration is a task that arises with the CT-free navigator system.

Compliance with ethical standards

Conflict of interest No author has received any financial support from any company.

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