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A computed-tomography-scan-based template to place the femoral component in accurate rotation with respect to the surgical epicondylar axis in total knee arthroplasty

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ABSTRACT

Background: Femoral rotational alignment is considered an essential factor for total knee arthroplasty because malrotation of femoral components results in poor outcomes. To obtain proper alignment, we developed a superimposable computed tomography (CT) scan-based template to intraoperatively determine the accurate surgical epicondylar axis (SEA), and evaluated the effectiveness of this CT template.
Methods: In the experimental group (n = 55), three serial slices of CT images, including medial and lateral epicondyles, were merged into a single image, and SEA was overlaid. SEA was traced onto an image of an assumed distal femoral resection level; this combined image was then printed out onto a transparent film as a CT template. Following a distal femoral resection in TKA, SEA was duplicated onto the femoral surface. Thereafter, the posterior condyle was resected parallel to this SEA. In the control group (n = 53), posterior condyles were resected at three degrees of the external rotation from the posterior condylar line (PCL).
A posterior condylar angle (PCA) between PCL of the femoral component and SEA was postoperatively evaluated. Positive values indicated external rotation of the femoral component from the SEA.
Results: In the experimental group, PCA was 0.01° ± 1.61°, and three cases were considered as outliers (more than three degrees of less than −3 degrees). Conversely, in the control group, PCA was 0.10° ± 2.4°, and 12 cases were considered as outliers. Consequently, dispersion of PCA data was significantly smaller in the experimental group ($P = 0.004$).
Conclusions: The CT template accurately determined intraoperative SEA.

1. Introduction

Total knee arthroplasty (TKA), a successful operation used for the treatment of advanced osteoarthritis (OA) of the knee, has been shown to reduce pain with survival rates greater than 90% after 15 years [1]. However, up to 20% of the patients are not satisfied with the clinical outcome [2,3], resulting in more than 35% of revision cases within two years of the primary TKA [4,5]. Reduced success rates have been attributed to several causes, including aseptic loosening, polyethylene wear, joint instability, infection, arthrofibrosis, malalignment, malposition, deficient extensor mechanisms, periprosthetic fracture, and patellar complications.

A femoral rotational alignment in the transverse plane is a primary factor affecting postoperative flexion stability, tibiofemoral and patellofemoral kinematics, and alignment in flexion [6–8]. Both excessive internal and external rotations have been demonstrated to yield poor clinical outcomes; therefore, appropriate bone resections are crucial for a successful TKA.

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Gap-balancing and measured resections are the two most commonly utilized procedures for a bone resection involving the determination of femoral rotational alignment. In the gap-balancing technique, following a proximal tibial resection, soft tissues are balanced; subsequently, the femur is resected in a manner parallel to the tibia [9,10]. Conversely, in the measured resection technique, the distal femur is cut first, followed by proximal tibia resection. The center of knee rotation is often considered the surgical epicondylar axis (SEA), which is the line connecting the sulcus of the medial epicondyle with the prominence of the lateral epicondyle. The femoral component is assumed to be implanted parallel to the SEA based on bony anatomical landmarks [11]. The soft tissue is then released to ensure equalization of the flexion and extension gaps independently.

For the accurate determination of the SEA and the proper alignment of femoral components, the surface-derived bony landmarks, as well as the posterior condyle line (PCL), and the anteroposterior trochlea axis (the so-called Whiteside's line) have been utilized [12]. However, the sulcus of the medial epicondyle is difficult to recognize by intraoperative palpation or even via computed tomography (CT) scans due to flattening of the medial condyle or bone formation. Consequently, more than 25% of OA knees were reportedly classified as type 3, which means the sulcus is not recognizable on CT scans [13]. Moreover, the sulcus of the medial epicondyle was detected in only 33 knees of 96 OA cases on CT scans [14], whereas visualization of the PCL also varied based on the progression of the articular cartilage degeneration as the PCL is detected on the surface of the remnant cartilage of the medial and lateral posterior condyles [15]. Furthermore, the anteroposterior axis is not perpendicular to the SEA with the osteophyte in instances of varus knee deformities [16]. For these reasons, the bony landmark technique is not always precise for determining the femoral rotational alignment.

Recently, computer-assisted surgery (CAS) has been developed to reduce the alignment errors in TKA. Results from CAS demonstrated the improvement of the components' alignment in the coronal and sagittal planes. However, the benefit of femoral rotational alignment is still controversial [2,17,18]. CAS has also demonstrated no improvement in the femoral rotational alignment in advanced genu varum deformity compared with that in advanced genu valgum deformity [19]. Patient-specific instrumentation has also been utilized [20]; however, a consensus on the efficacy of the rotational alignment has not yet been formed [21,22]. Additionally, these technologies are expensive and require substantial time allotments for surgical procedures, which may increase operative invasiveness and surgical complications.

To appropriately implant the femoral component, with regard to the rotational alignment, we developed a superimposable CT-scan-based template in which the SEA is drawn on a distal femoral cross-section of the CT image at the assumed bone resection level to enable precise determination of the SEA. The objective of the current investigation was to evaluate the accuracy of the rotational alignment of the femoral component positioned using this CT template technique intraoperatively in TKA.

2. Patients & methods

This investigation was approved by the Institutional Review Board, and all patients provided informed consent for participation in the study.

Patients with a clinical and radiological diagnosis of OA knees, who had been scheduled to receive primary TKA between October 2015 and September 2016, were enrolled as the experimental group. Patients were excluded from the investigation if they had previous knee surgery, post-traumatic arthritis, or rheumatoid arthritis. Ultimately, 55 knees in 49 patients (six males and 43 females), including four females with simultaneous bilateral TKA and two females with staged TKA, were enrolled.

Patients who had previously received the primary TKA due to OA knees within two years and visited the institution between 1 April and 30 September 2016 served as the control group. The exclusion criteria consisted of previous knee surgery, post-traumatic arthritis, and rheumatoid and inflammatory arthritis. Moreover, patients who received primary TKA with navigation systems and revised TKA were excluded. Consequently, the data included 12 knees in nine males and 41 knees in 33 females. Three males and eight females received bilateral TKA. All bilateral cases were evaluated separately.

The preoperative lateral femorotibial angle (FTA) by the standing anteroposterior radiographs was also measured to evaluate the knee deformity, in which the valgus deformity was defined as occurring when the angle was smaller than 175°.

3. Preoperative preparation

The patients in the experimental group received preoperative 2.5-mm slice thickness CT scans of the affected knee and the CT images were imported into a DICOM viewer (OsiriX, Pixmeo SARL, Bernex, Switzerland). Three serial slices of the images in which the medial epicondyle and/or the lateral epicondyle were visible were selected to detect the SEA. Following identification of the distal femoral outline by the computer software (Photoshop, Adobe Systems Inc., San Jose, CA, USA), these three images were merged into a single image and the SEA was subsequently overlaid (Figure 1).

Thereafter, another two serial images indicating the assumed level of the distal femoral resection were extracted. This level was approximately nine millimeters proximal from the distal end of the femoral condyles, which is used to indicate the thickness of the general femoral implant. The resection level was decided by referencing the top of the intercondylar notch. However, this varied for each case. Moreover, the planes of the CT slices and the bone resection surface do not match perfectly, and thus, two images were prepared to increase the accuracy of this approach. The outline of the distal femur was then reselected, and the SEA drawn earlier was traced onto these two images separately. The images with the SEA were calibrated using the magnification rate, and then printed onto transparent films (Kokuyo, Osaka, Japan) at the original magnification. Finally, the films were sterilized at 55 °C for 45 min before their use as potential CT templates (Figure 2).

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