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Original article

Inaccurate rotational component position in image-free navigated unicompartmental knee arthroplasty

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Abstract

Background/Objective: The success of unicompartmental knee arthroplasty (UKA) is highly dependent on the accuracy of component and leg alignment. Computer-assisted surgery is gaining popularity in total knee arthroplasty with numerous studies reporting improved accuracy and decreased variability in implant position and postoperative limb alignment compared with conventional techniques. However, literature evaluating the accuracy of computer-navigated UKA is limited. Therefore, this study aimed to investigate the accuracy of component positions in navigated UKA using a three-dimensional (3D) image-matching system. To the best of our knowledge, this study is the first to evaluate the accuracy of implant-placement position in UKA using 3D image-matching systems.
Methods: Twenty-three knees in 22 patients (9 men, 13 women) underwent computer-assisted UKA performed by a senior surgeon from 2011 to 2013. All surgeries were performed with measured resection techniques using an image-free-navigation system. We recorded the coronal, sagittal, and rotational bone-resection angles towards the mechanical axis in the distal femur and proximal tibia using image-free navigation intraoperatively. The coronal, sagittal, and rotational alignments of the femoral and tibial components were also measured using the 3D image-matching system, and the accuracy of the navigated UKA was evaluated. The rotational alignment of the femur and tibia was defined as surgical epicondylar axis and Akagi's line, and a deviation over 3° from the AA was defined as an outlier.
Results: We observed coronal outliers for the femoral component in four of the 23 patients, and for the tibial component in three of the 23 patients. We also observed sagittal outliers for the femoral component in five of 23 patients, and for the tibial component in three of the 23 patients. Twenty-two tibial components were placed in external rotation relative to the rotational reference line.
Conclusion: In both coronal and sagittal alignments, there were a definite proportion of outliers. The ratio of outliers in rotational alignment was especially higher than that in coronal and sagittal alignments. In UKA, the identification of bony landmarks is difficult because of the small operation field. Therefore, careful surface mapping of particular bony landmarks is necessary, and it is not enough to use image-free navigation system in UKA.

Keywords: navigation accuracy; rotational mismatch; three-dimensional evaluation; unicompartmental knee arthroplasty

Introduction

Unicompartmental knee arthroplasty (UKA) has been performed for the treatment of isolated unicompartmental knee disease for more than three decades. The long-term outcomes of UKA depend on patient selection, age, sex, and level of

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activity.[1,2] In order to obtain a satisfactory outcome after UKA, proper surgical technique and optimal implant positioning are essential.[3,4] Since an inaccurate implantation is considered a factor for early failure, it is generally agreed that accuracy of implant positioning and reconstruction of the mechanical leg axis are major requirements for achieving good long-term results after UKA.[5–7] Recently, computer-assisted surgery has been gaining popularity for UKA, with several studies reporting improved accuracy and decreased variability in implant positioning and postoperative limb alignment.[2,7–9] However, most studies have evaluated implant position and limb alignment using radiography, which cannot assess component rotation. Furthermore, it is difficult to evaluate coronal and sagittal implant positions due to features of the component. Few studies have assessed three-dimensional (3D) implant position using computed tomography (CT) or magnetic resonance imaging,[10–12] and none has used a 3D digital templating system. The aim of this study was to investigate the accuracy of component positioning in navigated UKA using a 3D image-matching system. This study also discusses the difficulties associated with navigated UKA.

Materials and methods

This study included 23 consecutive UKAs in 22 patients (9 men, 13 women; average age, 72.6 years ± 5.99 years; age range, 61–80 years). Two types of UKA prosthesis [Unicompartmental High-Flex Knee System; Zimmer, Warsaw, IN, USA ($n = 10$); Triathlon Partial Knee Resurfacing System; Stryker Orthopaedics, Mahwah, NJ, USA ($n = 13$)] were implanted with measured resection techniques using an image-free navigation system (Stryker 4.0 image-free computer navigation system; Stryker Orthopaedics). After medial parapatellar arthrotomy and placement of the tracker pin, anatomical landmarks were digitised to determine the leg axis. The landmarks were as follows: (1) femur: hip-joint centre, centre of the distal femur, Whiteside's line,[13] articular femorotibial joint surface, and anterior surface of the femur; and (2) tibia: centre of the proximal femur, articular femorotibial joint surface, Akagi's line,[14] and medial and lateral malleoli. The hip-joint centre was calculated kinematically by tracking the position of the femoral reference frame during hip motion. The rotational axes of the femur and tibia were determined using Whiteside's line and Akagi's line, respectively. After registration, the tibial extramedullary cutting guides were attached and adjusted to match the coronal and sagittal alignments. Then, a sagittal cut of the tibia was performed along a line parallel to Akagi's line, in the most lateral rim of the medial plateau. The femoral distal cutting block was also adjusted to match the coronal and sagittal alignments by using navigation. When the femoral posterior bone cut was performed, the femoral rotational angle was aligned. We recorded the femoral and tibial bone-resection angles with respect to the mechanical axis intraoperatively by using the navigation system.

The tibial component is implanted perpendicular to the tibial mechanical axis in the coronal plane, at a 5° posterior slope to the sagittal mechanical axis, and parallel to Akagi's line in rotation. The femoral component is implanted perpendicular to the femoral mechanical axis in the coronal plane, at a few degrees of sagittal flexion, according to the surgeon's preoperative planning to match the implant with the curvature of the condyle and fully cover the posterior condyle with the implant, and parallel to the surgical epicondylar axis in rotation.

Evaluation of implant positioning

Four weeks postoperatively, anteroposterior and lateral radiographs were obtained and evaluated using Athena Knee 3D image-matching software (Soft Cube, Osaka, Japan).[15,16] Briefly, a 3D marker was attached on the surface of the patient's lower leg, and the silhouettes of the marker were used to couple the two radiographic images three-dimensionally (Figure 1A). Next, the implanted components were matched to the images using a computer-aided design program (Figure 1B). In addition, preoperative CT images were matched to the coupled radiographic images (Figure 1C). In this process, continuous CT data could be divided into femur and tibia. In the matched image, we measured the 3D alignment of the femoral and tibial components (Figure 1D). Lines to determine the component alignment are shown in Table 1.

We compared the bone-resection angles measured intraoperatively using the navigation system with component alignment angles measured postoperatively using Athena Knee. NA with a deviation of > 3° from AA was defined as outliers. Evaluations were performed three times by two authors (Akihiko Toda and Kazunari Ishida) who were blinded to the patients' clinical information, and the averages were used for analysis. The intra- and interobserver reliability showed favourable results for almost all items (Table 2). This study was approved by the Institutional Review Board at Kobe Kaisei Hospital, Kobe, Japan (identification number: 0049).

Statistical analysis

The results were analysed statistically using a statistical software package (Stat Mate III; ATMS Co., Ltd., Tokyo, Japan). Comparisons of the incidence of outliers amongst the coronal, sagittal, and rotational alignments of both components were analysed using the Chi-square test. When the analysis of variance was observed to be significant, a Chi-square *post hoc* analysis was performed to determine which groups were significantly different from one another. A p value of < 0.05 was considered statistically significant.

Results

Table 3 shows the femoral- and tibial-component positions, the average differences between the intra- and postoperative measurements, and the rates of outliers. For the coronal alignment, the rates of outliers for the femoral and tibial components were 17.4% (4/23) and 13% (3/23), respectively. For the sagittal alignment, the rates of outliers were 21.7% (5/