The effects of preoperative digital three-dimensional planning on the accuracy of implant positioning in total knee arthroplasty

INTRODUCTION: Accurate implant positioning in total knee arthroplasty (TKA) is crucial for successful clinical outcome and implant longevity. Recently, digital three-dimensional (3D) preoperative planning has been introduced in TKA, and its clinical utility has been reported in minimally invasive TKA (MIS-TKA) as well as revision TKA, in which several anatomical landmarks are distorted or difficult to be identified [1]. However, it remains unknown whether the digital 3D planning in TKA is effective on accurate implant positioning, as compared with conventional nonplanning TKA. This study aimed to examine the effects of digital 3D planning on the accuracy of femoral component positioning in MIS-TKA.

METHODS: This study prospectively analyzed 40 primary TKAs performed in our institute between November 2010 and May 2011. The series comprised 1 man and 27 women, with 12 bilateral cases. The mean age of the cases at the time of TKA was 74.2 years. Twenty-six cases had primary osteoarthritis of the knee and one patient had secondary osteoarthritis due to rheumatoid arthritis. All TKAs were performed by single surgeon using minimally invasive techniques and side-cutting guide was routinely used for bone cut of distal femur and proximal tibia. Posterior-stabilized prosthesis (LPS-FLEX; Zimmer, Warsaw, IN, USA) was used in all cases. Preoperatively, all 40 patients were subjected to CT scans of the knee and were divided into two groups based on with (n=20) or without CT-based preoperative planning (n=20) using digital 3D templating software, ATHENA® (Soft Cube, Osaka, Japan). Three indices were used for achieving ideal positioning of the femoral component, including condylar twisting angle (CTA: angle between trans-condylar axis and posterior condylar axis) for a axial alignment, femoral valgus angle (FVA: angle between anatomic axis and mechanical axis of the femur) for a coronal alignment, and entry point of intramedullary guide (distance between intercondylar notch and ideal entry point (Fig 1A)) for a sagittal alignment. The ideal entry point of intramedullary guide was defined as follows: first, the center of the intramedullary canal at the level of the top of intramedullary guide was determined (Fig 1B). Second, in the sagittal plane, ideal entry point existed at the intersection of the femoral surface and the line drawn from the intramedullary canal center with perpendicular to the central axis of the femoral component (parallel to the anterior cortex line) (Fig 1C). After long-leg radiograph of the limb was obtained 2 weeks postoperatively, accuracy of the femoral component positioning was evaluated by two independent, blinded assessors (Y. T. and H. K.) using shape-matching techniques. Regarding the evaluation of sagittal alignment, the distance between the tip of the anterior flap of femoral component and anterior cortex line of the femur (designated as anterior separation) was measured. The value of anterior separation is negative, if anterior flange of the femoral component shows anterior notching. Deviations from each ideal were measured for CTA, FVA, and anterior separation and expressed as ∆CTA, ∆FVA, and Aseparation, respectively. The incidences of >3º or >3mm deviation from ideal were compared between the groups with and without preoperative 3D planning.

RESULTS: With regard to FVA and anterior separation, there was no significant difference in the accuracy of femoral component position between the groups with and without preoperative 3D planning. However, as far as CTA, greater number of the cases in the group without 3D planning exhibited >3º of CTA (Fig.2). The proportion of these cases was significantly lower in the group with 3D planning than in the group without 3D planning (p<0.05, Table 1).

DISCUSSION: Preoperative planning using patient-specific digital 3D templating software is now growing in popularity particularly in Japan. It has been reported that preoperative understanding of rotational alignment of the femoral component and degree of bony defect were very useful in revision TKA where most anatomical landmarks were distorted during the operation [2]. To date, the role of navigation system in TKA have reached to a consensus that the number of the outliers of the component alignment which deviated 3º from ideal are reduced within 10% [3]. In this study, incidence of ≤3º or ≤3mm deviation from ideal femoral component position was 100%, 95%, and 90%, for the coronal, sagittal, and axial plane, respectively, which were equivalent to the results of past literature dealing with navigation TKA. Particularly, axial alignment of the femoral component significantly improved in the group with 3D planning compared with the group without 3D planning. This was explained by technical concerns of MIS-TKA that identification of anatomical landmarks for rotational alignment of the femoral component was difficult due to small operative field [4]. The present results supported the beneficial effects of preoperative 3D planning in MIS-TKA, however number of subjects were small and intra- or interobserver reliability of the 3D planning still remains to be clarified. Further study using larger cohort should be needed to demonstrate substantial advantages of the 3D planning prior to TKA.

SIGNIFICANCE: Preoperative digital 3D planning was successful to define ideal positioning of the femoral component in the coronal, sagittal, and axial plane, by using 3 indices. Particularly, axial alignment of the femoral component significantly improved in the group with 3D planning compared with the group without 3D planning.

REFERENCES