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Posterior Reference Position Affects Intraoperative Kinematic and Soft Tissue Balance in Navigated Posterior-Stabilized Total Knee Arthroplasty

Kazunari Ishida, MD [a,*], Nao Shibanuma, MD [a], Koji Takayama, MD [b], Masahiro Kurosaka, MD [a], Ryosuke Kuroda, MD [b], Tomoyuki Matsumoto, MD [b]

[a] *Department of Orthopaedic Surgery, Kobe Kaisei Hospital, Kobe, Japan*
[b] *Department of Orthopaedic Surgery, Kobe University Graduate School of Medicine, Kobe, Japan*

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ABSTRACT

Background: The importance of medial compartment stability is recognized in total knee arthroplasty (TKA). To manage the medial extension-flexion gap, the posterior reference position can be changed from conventional posterior center to posterior medial in measured resection techniques. This study aimed to compare the intraoperative soft tissue balance and rotational kinematics between the posterior medial and posterior center reference groups.
Methods: We enrolled 57 consecutive patients with varus osteoarthritis undergoing posterior-stabilized (PS) TKA using an image-free navigation system. The detailed surgical plan in both groups and intraoperative kinematics were recorded using navigation, and soft tissue balance measured with an offset-type tensor was statistically compared between groups.
Results: Patients were divided into the posterior center reference group ($n = 32$) and posterior medial reference group ($n = 25$). The posterior medial and posterior lateral condyles were significantly thicker in the posterior center reference group ($P < .05$). Although preoperative rotational kinematics were comparable between groups, the tibial rotational position was significantly more externally rotated in the posterior center reference group than in the posterior medial reference group at 45°, 60°, and 90° of flexion ($P < .05$). The varus angle and joint component gap were significantly smaller in the posterior medial reference group than in the posterior center reference group at 60° and 90° of flexion ($P < .05$).
Conclusion: The posterior reference position affects intraoperative kinematics and soft tissue balance in navigated PS TKA. Posterior medial reference PS TKA decreases the excessive tibial external rotation during midflexion and increases the flexion stability compared with conventional posterior center reference PS TKA.

Total knee arthroplasty (TKA) is a well-established procedure that generally results in the relief of pain, improved physical function, and a high level of patient satisfaction. Accurate mechanical alignment and equal extension-flexion gap are key factors for the success of TKA. However, it is limited in acquiring a perfect extension-flexion gap [1,2]. In particular, managing the control of the extension-flexion gap is difficult because posterior cruciate ligament resection leads to a larger flexion gap of approximately 4 mm in posterior-stabilized (PS) TKA [3]. Several studies have reported the incidence of midflexion laxity [4] and abnormal intraoperative kinematics [5–7] in PS TKA. A recent review indicated that achieving medial stability throughout the range of motion should be a high priority in ligament balancing in TKA [8], and several medial-stabilizing surgical techniques that aim to achieve good medial stability have been reported in posterior cruciate-retaining [8] and PS TKA [9].

Anterior or posterior reference guides are used in measured resection techniques. However, posterior reference guides do not always maintain the size of the posterior femoral condyles in TKA because the posterior reference point varies if different reference guides are used [10]. For example, the conventional posterior reference guide references the center point between the medial

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* Reprint requests: Kazunari Ishida, MD, Department of Orthopaedic Surgery, Kobe Kaisei Hospital, 3-11-15, Shinohara-Kita, Nada, Kobe, 657-0068, Japan.

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and lateral condyles; thus, the measured resection technique using the conventional posterior reference guide results in an increase in bone resection thickness compared with implant thickness [10]. The condition might induce the risk of medial flexion instability in PS TKA. Therefore, it is important to comprehend the relevance of the reference position. Thus, a reference point–changeable sizer has been developed to manage the flexion gap. Changing the posterior reference position from center to medial is expected to result in stable extension-flexion gap and better kinematics. However, the detailed differences have not been clarified between conventional posterior center reference measured resection PS TKA and posterior medial reference measured resection PS TKA.

Thus, the aim of this study was to compare the intraoperative soft tissue balance and rotational kinematics between posterior medial reference and posterior center reference measured resection PS TKA. The hypothesis is that the posterior reference position affects the soft tissue balance and kinematic pattern in PS TKA.

Materials and Methods

Fifty-seven consecutive subjects (48 women and 9 men; mean age, 78 years; age range, 63-92 years) with varus osteoarthritis treated with navigated PS TKA between October 2015 and October 2017 were enrolled in this study. The exclusion criteria were valgus deformity, severe bony defect requiring bone graft or augmentation, revision TKA, active knee joint infection, posterior-retained TKA, and TKA without a navigation system. All surgical procedures were performed by the same experienced surgeon using PS TKA (Triathlon; Stryker Orthopedics, Mahwah, NJ) with an image-free navigation system (Stryker 4.0 image-free computer navigation system; Stryker).

After placing tracker pins, the knee joint was exposed via a medial parapatellar approach. The osteophytes were removed, the minimum medial and lateral soft tissue was released for bone resection, and the anterior cruciate ligaments as well as the anterior horn of the medial and lateral meniscus were resected in preparation for bone resection and navigation registration. Subsequently, a standard registration procedure was conducted according to the system's instructions, followed by kinematic measurements. Kinematic measurements of the knee were performed as previously reported [5,11]. Briefly, the extension movement initially began with the heel supported, to record the position of maximum extension. While supporting the heel with an open palm and touching the thigh with the opposite hand, the surgeon gently flexed the hip and knee to their final points, with knee flexion being assisted by gravity. As the kinematic data were affected by the registration point, the results varied among patients. Therefore, the data obtained at maximum extension before surgery were determined to be the reference point, and the results were expressed as differences compared with the reference point.

After the registration, navigation proposed the surgical plan for femoral implantation. The femoral implantation plan was perpendicular to the femoral mechanical axis in the coronal plane, flexion $<5°$ to the femoral mechanical axis in the sagittal plane, and parallel to the rotational axis determined by the navigation registration. In this navigation system, the rotational axis was defined as the midline between the perpendicular line of Whiteside's line [12] and the surgical epicondylar axis determined using registration points. If the difference between the 2 lines is $> 5°$ during the registration, reregistration should be performed until the difference is $< 5°$. Furthermore, the plan proposed the appropriate implant size. In this navigation plan, the anteroposterior implant position was coordinated to avoid anterior notching of the femur, and the bone resection thickness of the center point between the posterior medial and posterior lateral condyles was set to be approximately 8 mm, according to the implant thickness. In this surgical plan, the surgical techniques were based on the results obtained after conventional posterior center reference measured resection techniques (center reference group; Fig. 1A). Therefore, the posterior medial bone resection thickness was planned to be > 8 mm. After the surgical proposal from navigation, the plan was modified to a medial reference measured resection technique in which the posterior medial bone resection thickness was about 8 mm because the thickness of the posterior condyles of this single-radius implant was 8 mm (medial reference group; Fig. 1B). The modification was performed in the following order: (1) rotational adaptation via changing the planned femoral rotation with reference to the difference of bone resection thickness between the medial and lateral directions; (2) flexion up to 5° and posterior shift up to 2 mm to reduce the posterior medial bone resection thickness up to the implant thickness; (3) one size up, which resulted in keeping the anterior bone cut surface and reducing both the posterior medial and posterior lateral bone resection thicknesses, if step 2 could not acquire the modification; and (4) if one size up resulted in excessive reduction of posterior bone resection thickness, the implant

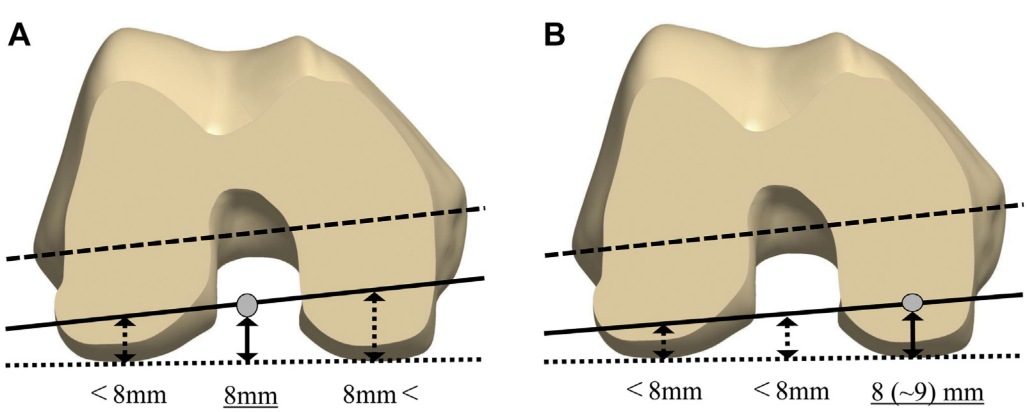

Fig. 1. Explanation of 2 surgical plans using different posterior reference positions. (A) Center reference group: the bone resection thickness of the center point between the posterior medial and posterior lateral condyles was set to be approximately 8 mm, according to implant thickness. As the femoral component was implanted externally toward the posterior condylar line, the posterior medial and posterior lateral bone resection thicknesses were planned to be thicker and thinner than 8 mm, respectively. (B) Medial reference group: the bone resection thickness of the posterior medial condyles was set to be approximately 8 mm because the implant thickness of the posterior condyles was 8 mm. As the femoral external rotational angles were not changed in this measured resection technique, the bone resection thickness of the center point between the posterior medial and posterior lateral condyles was planned to be thinner and that of the posterior lateral condyles was further thinner than 8 mm. A 1-mm difference of up to 9 mm as compared with the implant thickness in the posterior medial bone resection thickness was allowed for the modification.