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In Vivo Kinematic Analysis of a High-Flexion, Posterior-Stabilized, Mobile-Bearing Knee Prosthesis in Deep Knee Bending Motion

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Abstract: The objective of this study was to evaluate the kinematics of a high-flexion, posterior-stabilized, mobile-bearing total knee arthroplasty (TKA) in weight-bearing, deep knee bending motion. Thirteen patients implanted with the Legacy Posterior Stabilized Flex (Zimmer, Warsaw, IN) mobile-bearing TKA were examined during a deep knee bending motion using fluoroscopy. Femorotibial motion was determined using a 2-dimensional to 3-dimensional registration technique, which used computer-assisted design models to reproduce the position of metallic implants from single-view fluoroscopic images. The average flexion range of motion between the metallic implants was 116°. The average rotation of the femoral component was 9.3° external rotation. The mean kinematic pathway was early rollback, lateral pivot with external rotation, and bicondylar rollback. We found that the kinematic pattern of the Legacy Posterior Stabilized Flex mobile-bearing TKA was different than normal knee kinematics. **Keywords:** total knee arthroplasty, mobile bearing, deep knee bending.
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The number of patients undergoing total knee arthroplasty (TKA) is increasing annually, and TKA demonstrates reliable clinical results. The range of motion is an important factor affecting patient satisfaction with the outcome of TKA [1,2]. Lifestyles in Middle Eastern and Asian countries have led to a greater need for the development of knee implants that can accommodate deep knee bending, as people bend the knees deeply when kneeling or sitting on the floor with legs bent in their daily life.

Recently, knee implants designed for high flexion have been introduced [3-6]. These high-flexion prostheses were designed to perform deep knee bending safely with a normal knee kinematic pattern. It has been reported that the clinical postoperative range of motion after posterior-stabilized (PS) implants is better than posterior cruciate–retaining implants [7,8]. Therefore, the high-flexion design of PS implants that can support the desired postoperative range of motion certainly is desirable.

One of the important considerations in attaining high flexion is axial rotation. In the normal knee, the amount of axial rotation is about 30° through 120° of knee flexion [9]. Axial rotation provides a mechanical advantage for the extensor mechanism in deep knee flexion and so is desirable in a TKA [10], but is not an absolute requirement. If fixed-bearing PS implants rotate more than 30°, the contact stress at the postcam interface in some designs may increase; and wear and fracture of tibial post may occur [11]. In terms of axial rotation, the potential advantage of

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mobile-bearing TKA designs is that the mobile-bearing insert can rotate and the contact stress may decrease. Another important aspect of high-flexion motion is femoral rollback. Because most posterior cruciate ligament–retaining knee implants have a potential for paradoxical roll forward [12,13], it is preferable to select PS implants to assist high flexion. Posterior-stabilized knee implants create a femoral rollback pattern by the action of the postcam mechanism. Therefore, the PS mobile-bearing knee prosthesis may be advantageous with regard to axial rotation and femoral rollback.

The Legacy Posterior Stabilized Flex (LPS-FLEX) mobile-bearing knee prosthesis (Zimmer, Warsaw, IN) was designed to safely perform 155° of knee flexion. This prosthesis has a mobile bearing that allows up to 25° internal or external rotation on an anteriorly placed rotation center. The posterior femoral condyles extend to increase the articular contact area at deep knee flexion, and the femoral cam is sitting low on the tibial post with a greater jump distance [3,4].

Although a number of researchers have developed image-matching techniques to analyze in vivo knee kinematics under weight-bearing conditions after TKA [9,10,13-21], there were few reports focused on high flexion range of more than 120° flexion [10,13,15-18]. Since 1999, we have developed a 2-dimensional to 3-dimensional (2D/3D) registration technique, which uses computer-assisted design models to reproduce the spatial position of femoral and tibial components from single-view fluoroscopic images (Fig. 1). We can analyze a deep knee bending motion of more than 120° flexion in our institution.

Using this system, we analyzed an in vivo kinematic pattern of a weight-bearing, deep-bending activity with the high-flexion, PS, mobile-bearing knee prosthesis. We hypothesized that the kinematics of LPS-FLEX mobile-bearing knee prosthesis in axial rotation and anteroposterior (AP) translation reproduces the normal knee kinematics in deep knee bending motion.

Patients and Methods

Thirteen knees (13 patients, 2 men and 11 women) that underwent TKA with LPS-FLEX mobile-bearing knee prosthesis were assessed in this study. Only patients who underwent successful TKA resulting in more than 90 points of Knee Society knee score were chosen for this study, representing a convenient sample of the best performers. The Review Board Committee of the authors' institution approved this study, and informed consent was obtained from all patients. Mean age at the time of surgery was 63.9 ± 8.9 years (range, 52-79 years). Preoperative range of motion was 110.5° ± 15° (range, 95°-135°). Diagnosis was osteoarthritis in 5 patients and rheumatoid arthritis in 8 patients. One senior author (TT) performed all

Fig. 1. The 2D/3D registration techniques uses computer-assisted design models to reproduce the spatial position of femoral and tibial components from single-view fluoroscopic images.

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