Three Dimensional Assessment of Medial-lateral Stability after TKA with A Femoral Single-radius Design

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Introduction: One of the important factors for successful Total Knee Arthroplasty (TKA) is to achieve proper stability of the knee joint both in extension and flexion. The mid-flexion stability of the knee is also important function for activities of daily living. A single-radius femoral component has been proposed to enhance the mid-flexion knee stability by ensuring consistent tension in the collateral ligaments throughout the functional range of movement. The Medial-Pivot total knee prosthesis is characterized by the spherical femoral component, that is, the sagittal and coronal radii are identical circles. Previous literatures have shown the Medial-Pivot total knee prosthesis is more patient preferred and stable during the stance phase of gait. However, it is currently unknown about the postoperative coronal joint stability throughout the full range of motion in this prosthesis. We hypothesized that the coronal knee joint stability at mid-flexion would be maintained by using the single-radius femoral component. Therefore, the purpose of this study was to investigate the postoperative coronal joint laxity throughout the full range of motion by the 3-dimensional in vivo analysis, in the femoral single-radius TKA.

Methods: Using the EVOLUTION® Medial-Pivot Knee System (MicroPort Orthopedics), we implanted 5 knees with Posterior-Stabilized (PS) TKA and 5 knees with Cruciate-Retaining (CR) TKA. All the patients were women suffered from osteoarthritis. The mean age was 70.3 years (range, 64-77 years).

Surgical procedure: We performed all operations with a measured resection technique. The knee was exposed through a medial parapatellar approach. We performed distal femoral osteotomy perpendicular to the mechanical axis of the femur. The rotational position of the femoral component was determined based on the epicondylar axis of the femur with posterior reference for anteroposterior sizing. We made the proximal tibial cut perpendicular to the mechanical axis of the tibia in the coronal plane with a slight posterior tilt in the sagittal plane. The rotational position of the tibial component was aligned with medial 1/3 of the tibial tubercle. After the bone cuts had been completed, we performed standard soft tissue balancing using a spacer block.

Post-operative assessment of knee joint stability: Three weeks after TKA, the valgus- and varus-stress radiographic assessments were performed at the five flexion angles from full extension to maximum flexion. The patients sat on the radiolucent chair with their lower legs hanging down. The examiner held their thigh, and a force of 50N was applied 30 cm distal to the tibiofemoral joint at a right angle with a spring scale (Fig.1).

The series of static fluoroscopic images via a flat panel detector were stored digitally (Fig.2A). After the detection of contours of the femoral and tibial components, a 2-dimentional to 3-dimentional matching technique was employed to determine the relative 3-
dimensional positions of the femoral component and tibial component in each fluoroscopic image (KneeMotion; LEXI, Tokyo) (Fig.2B). On the coronal plane of the tibial component, the angle between the tangent line of the condyles of the femoral component and the tibial plateau was measured as the joint laxity for valgus ($\alpha_{\text{valgus}}$) or varus ($\alpha_{\text{varus}}$) (Fig.3). The knee flexion angles (that is the flexion angle between the femoral component and tibial component) were also measured, and we categorized them to full extension, early mid-flexion (up to 30 degrees), late mid-flexion (up to 75 degrees), and maximum flexion.

Data were compared among tilting angles ($\alpha_{\text{valgus}}$ or $\alpha_{\text{varus}}$) at each knee flexion, both in PS and CR TKA. Data are expressed as average ± standard error. Statistical analysis was performed using an analysis of variance with a Fisher’s PLSD post hoc test with a significance level of 0.05.

**Results:** PS TKA (Fig.4): In valgus stress, the mean tilting angles ($\alpha_{\text{valgus}}$) were 1.5, 2.7, 3.3, 3.2, 1.7 degrees at 3.7, 33.1, 45.2, 73.5, 88.4 degrees of knee flexion, respectively. The tilting angle ($\alpha_{\text{valgus}}$) measured at late mid-flexion was significantly larger than that measured at full extension ($p<0.05$). In varus stress, the mean tilting angles ($\alpha_{\text{varus}}$) were 1.3, 1.2, 2.0, 3.0, 1.7 degrees at 4.3, 25.6, 41.5, 73.5, 88.0 degrees of knee flexion, respectively. There were no significant differences among each tilting angle.

The total laxity ($\alpha_{\text{valgus}} + \alpha_{\text{varus}}$) increased until late mid-flexion and then decreased in maximum flexion. The total laxities were 2.8, 3.9, 5.3, 6.2, 3.4 degrees at extension, early mid-flexion, late mid-flexion, and maximum flexion, respectively. The total laxity measured at late mid-flexion was significantly larger than that measured at full extension ($p<0.05$).

CR TKA (Fig.5): In valgus stress, the mean tilting angles ($\alpha_{\text{valgus}}$) were 2.0, 1.6, 2.9, 3.1, 2.2 degrees at -7.9, 18.3, 42.8, 60.1, 79.2 degrees of knee flexion, respectively. In varus stress, the mean tilting angles ($\alpha_{\text{varus}}$) were 1.4, 2.3, 3.8, 4.0, 2.7 degrees at -9.4, 23.0, 40.3, 62.1, 79.6 degrees of knee flexion, respectively. There were no significant differences among each tilting angle.

The total laxity ($\alpha_{\text{valgus}} + \alpha_{\text{varus}}$) increased in late mid-flexion and then decreased in maximum flexion. The total laxities were 3.4, 3.9, 6.7, 7.1, 4.9 degrees at extension, early mid-flexion, late mid-flexion, and maximum flexion, respectively. The total laxity measured at late mid-flexion was significantly larger than that measured at full extension ($p<0.05$).

**Discussion:** In this study, the postoperative coronal joint stability of the knee at early mid-flexion (up to 30 degrees) was maintained and was similar to that in full flexion after single-radius TKA, both in PS and CR types. The coronal joint laxity at late mid-flexion (up to 75 degrees), however, was significantly larger than that measured at full extension. Nevertheless, the coronal laxity remained within clinically recommended laxity (less than 4 degrees in varus or valgus orientations) throughout the functional range of motion in the single-radius TKA.

**Significance:** The single-radius TKA ensured medial-lateral stability throughout the full range of motion except for late mid-flexion phase.
Figure 1

Figure 2

Figure 3

Figure 4: Joint laxity in PS TKA
Figure 5: Joint laxity in CR TKA

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