# Variability in Femoral Component Rotation Reference Axes Measured During Navigation-Assisted Total Knee Arthroplasty Using Gap Technique

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**Abstract:** The basic objective in total knee arthroplasty is to achieve the correct amount of femoral component rotation, and this can be achieved either with a measured resection technique or indirectly with a flexion/extension gap equalization technique. We studied variability in the reference axes (posterior condylar axis, Whiteside's line, transepicondylar axis) when soft tissue tension was managed intraoperatively using a navigation system. The mean angles for the transepicondylar line, Whiteside's line, and the posterior condylar line from the proximal tibia resection plane were 1.29° ± 3.67° (mean ± SD; range, −7° to 10.5°), 3.90° ± 4.17° (mean ± SD; range, −3° to 15.5°), and −4.03° ± 2.71° (mean ± SD; range, −9.5° to 1.0°), respectively. The coefficients of variation (SD/mean ×100) for these 3 variables were 283%, 106%, and 67%, respectively. Of the 3 reference axes used widely for femoral component rotation, the angles from the posterior condylar line to the proximal tibia resection plane showed the smallest range of variance. **Keywords:** reference axis, femoral component rotation, navigation, total knee arthroplasty.


Total knee arthroplasty (TKA) is the gold standard for the treatment of symptomatic late-stage osteoarthritis of the knee. Although surgical techniques and implant designs have improved, there are still complications associated with this procedure.

Femoral component malrotation has been shown to be a major cause of patellofemoral complications and anterior knee pain after primary TKA [1-4]. Internal rotation of the femoral component relative to the transepicondylar axis is associated with lateral maltracking of the patella, subluxation, and dislocation [1,4]. Internal rotation can also cause differences in the flexion and extension gaps, resulting in gapping on the lateral sides [5,6] by altering the relative dimensions of the posterior condyles in the flexion position. Excessive external rotation increases the medial flexion gap, leading to symptomatic flexion instability [6,7].

The basic objective of TKA is to achieve the correct amount of femoral component rotation, and this can be achieved either with a measured resection technique or indirectly with a flexion/extension gap equalization technique. Several reference axes have been proposed in establishing proper rotational alignment of the femoral component, including the posterior condylar axis [1], Whiteside's line (anteroposterior axis) [8-10], the transepicondylar axis [7,11,12], and the tibia shaft axis [13]. Among these, tibia shaft axis has been shown to be particularly useful because it facilitates balancing of the flexion space when perpendicular proximal tibial cuts are made for TKA [13].

Computer-assisted navigation systems have been recently developed, and it has been reported that they improve osteotomy accuracy in TKA [14,15]. Objective quantification of the soft tissue tension is also afforded by a recent version of the computer-assisted navigation system.

The authors wanted to determine the variability in the reference axes—the posterior condylar axis, Whiteside's line (anteroposterior axis), and the transepicondylar axis—when soft tissue tensioning was done intraoperatively using a navigation system. In this prospective study, the authors sought to determine the reference axis with the least variability during total knee replacement done by gap equalization technique.

## Materials and Methods

The study population consisted of 28 patients (27 women, 1 man; 30 cases) who underwent total knee

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replacement because of osteoarthritis. The average patient age was 71 years (range, 63-83 years). Plain standing long-leg anteroposterior radiographs in patellar forward-facing position were obtained in all patients. The angle between the femoral mechanical axis and the tibial mechanical axis was measured preoperatively. Patients with traumatic osteoarthritis or osteonecrosis of the knee were excluded from the study. The tibial plateau/tibial shaft angle was measured to exclude patients with severe tibia vara (tibial plateau/tibial shaft angle >4°). Severe varus knees (femoral mechanical axis – tibial mechanical axis angle >16°) and valgus-deformed knees were also excluded from the study because they have the potential to exhibit large variabilities in the reference axes [4,10,16,17].

All patients in this study underwent a cruciate-sacrificing technique. The prosthesis used in this study was the PFC Sigma RP-F prosthesis (Depuy, Johnson&-Johnson, Warsaw, Ind), which features an articular geometry that offers very high conformity from extension to 40° of flexion. The Ci software system (v. 1.1.2, DePuy International, Leeds, UK) was used for intraoperative navigation.

## Surgical Procedure

A single surgeon performed all operations using a straight midline incision. The length of the skin incision ranged from 12 to 14 cm. After tourniquet inflation, the knee was approached anteriorly using a median parapatellar approach. The patella was subluxated laterally, and the tibia was subluxated anteriorly. The cruciate ligaments were sacrificed, and the medial meniscus and osteophytes were removed. Soft tissue balancing was accomplished before any bone cuts were made. The array for the computer navigation system (Ci, v. 1.1.2, DePuy International) was set up by means of a femoral tracker mounted to a screw. These 2 screws (pins) were fixed to the medial aspect of the femur and the tibia, respectively. The positions of the selected points required for the system were registered. The navigation system identified the posterior condyle reference axis by mapping multiple points on the distal and posterior femoral condyles. The clinical epicondylar axis was determined by identifying the most prominent points on the medial and lateral epicondyles. The anteroposterior axis of the femoral sulcus, described by Whiteside [10], was determined by aligning along the deepest part of the trochlear groove anterior to the center of the intercondylar notch posteriorly. The center of the proximal tibia was visually identified, and its coordinates were put into the computer using the navigation system–specific pointer. After these localizations, the tibial mechanical axis was determined based on a line joining the center of the proximal tibia and on the calculated center of the ankle joint. After all reference points were marked, correction of the varus deformity to neutral axis was accomplished by means of medial release in extended position. The tibia cut was done first after neutral axis was achieved. It was important that the plane be directly perpendicular to the mechanical axis of the tibia. The whole resection plane was assisted by the navigation system, and the resection plane was verified after each step. Any remaining flexion contracture was managed by posterior capsular release and removing osteophytes situated at posterior condyle area to achieve 0° of extension in the sagittal plane.

After the tibia cut was made and the appropriate medial release balancing the collateral ligaments was achieved, the knee was brought into extended position. Spacer blocks of various thicknesses were inserted to identify the adequate collateral tension. A similar procedure was done at 90° of knee flexion. These gap data were shown on the monitor as numerical values. The surgeons then used these data to achieve a rectangular flexion gap by rotating the femoral component (Fig. 1). The monitor of the navigation system displayed the relation of the femoral reference axes (clinical transepicondylar axis, Whiteside's line, posterior condylar axis) with the proximal tibia resection plane. These data were then recorded.

Patellar tracking was tested intraoperatively using a towel clip method after final implantation. None of the cases showed subluxation, tilting, or maltracking, so lateral retinacular release was unnecessary.

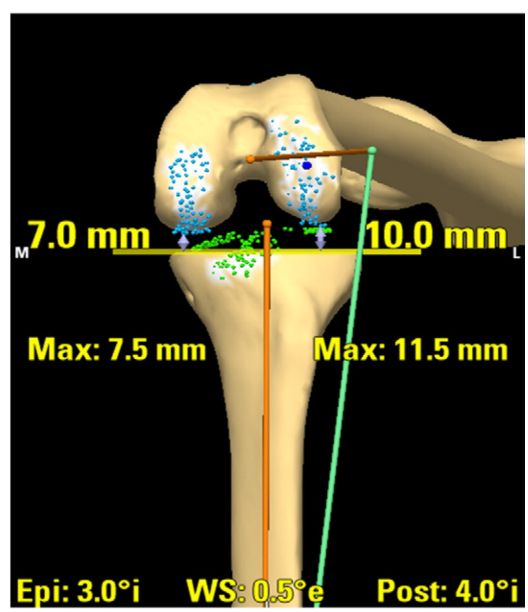


**Fig. 1.** Tibia rotation is set by aligning the mechanical axis (green line) with the tibial mechanical axis (orange line). The space values (mm) shown are measured from the tibia resection plain to the most prominent points on the posterior femoral condyle. The rotational orientation of the femur is shown in relation to the tibial surface. The values (degrees) on the bottom represent the clinical transepicondylar axis, Whiteside's line, and the posterior condylar line.