The Position of the Tibial Component Affecting the Postoperative Mechanical Axis in Total Knee Arthroplasty

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Abstract: The purpose is to identify whether the position of the tibial component in relation to the anatomical axis affects the postoperative mechanical axis in total knee arthroplasty for Korean patients. Preoperatively, 30 patients with varus deformity lesser than 10° were classified as group A, and 30 patients greater than 10° were classified as group B. Postoperatively, the distance between the midline of the tibial stem and anatomical axis (medial offset) was measured. The medial offsets were 2.5 ± 1.9 mm in group A and 3.9 ± 2.7 mm in group B ($P = .021$). The postoperative mechanical axes were varus 1.3 ± 1.2° in group A and varus 2.5 ± 2.0° in group B ($P = .004$). We think that the medial position of tibial component in relation to the anatomical axis affects the measurement of postoperative mechanical axis in total knee arthroplasty. **Keywords:** total knee arthroplasty, varus deformity, position of tibial component, postoperative mechanical axis.

In the anatomical studies for whites, it has been reported that the center of plateau tends to be located central or lateral from the tibial canal axis [1,2]. However, several studies have suggested that the anatomical features of the proximal tibia in Asians may be different from those of whites [3,4]. The center of plateau tends to be located medial from the tibial canal axis in Asians [5,6]. So, when the tibial component is positioned at the center of tibial prepared surface, the tibial stem could not be centered within the medullary canal. The center of the tibial prepared surface does not coincide with the point of the anatomical axis passing through the cut surface in some cases. This finding can make the postoperative alignment error even in cases that the coronal resection is accurate.

There are 2 methods for radiological evaluation after total knee arthroplasty. One is the American Knee Society's roentgengraphic evaluation method in which based on the anatomical axis [7], and the other is the measurement of angle between the femoral and tibial mechanical axes [8,9]. When the mechanical axis does not coincide with the anatomic axis of the tibial shaft, we have noticed that there is discordance between two methods for radiological evaluation [3,10–12].

Because there is no anatomical structure to decide the center of the knee joint during measuring the postoperative mechanical axis after total knee arthroplasty, the center of the femoral or tibial components was substituted for the center of the knee joint. As stated previously, the center of tibial component often does not coincide with the point of the anatomical axis passing through the undersurface of the component.

Our hypothesis was that the tibial component is located medial to the anatomical axis in knees with varus deformity in Koreans so that this affects the measurement of postoperative mechanical axis. To our knowledge, however, the study of this finding has not been reported. The purpose of this study is to examine the position of the tibial component in relation to the anatomical axis of the tibia in total knee arthroplasty for Korean patients and to identify the position of the tibial component affecting the measurement of postoperative mechanical axis.

Patients and Methods

Total knee arthroplasty was performed using Press-Fit Condylar knee (Johnson & Johnson, Warsaw, Ind) in 252 osteoarthritic knees with varus deformity between October 2005 and May 2008. α and β Angles were defined as the coronal femoral and tibial component angle using American Knee Society roentgenographic evaluation system, respectively [7]. The inclusion criteria

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were the cases with the accurate coronal alignment of component, in which α angle ranged from 94° to 96° and β angle ranged from 89° to 91°. In our study, we tried to focus on the position of tibial component affecting the postoperative mechanical axis. So, we had the narrow range of selection criterion in which outlier of α and β angle was less than ± 1°. I also considered that the angle between the anatomical and mechanical axes of the femur (A-MA A) may impact the overall malalignment of the leg. So, we selectively included the cases, in which A-MA A ranged from 4° to 6°. The mean preoperative A-MA A was 5.3° ± 0.9°. The exclusion criterion was the cases that didn't have any x-ray film available to make accurate measurement. Measurements were performed on the pre- and postoperative radiographs of 60 knees.

There were 59 females and one male, 24 cases of right knees and 36 cases of left knees. The mean age was 66.6 years (range, 54-79 years), and the body mass index was 27.0 kg/m^2 (range, 20.7-37.7 kg/m^2). The posterior cruciate ligament retaining prostheses were used in 10 cases, the posterior cruciate ligament substituting prostheses were used in 32 cases, and the rotating platform flexion prostheses, in 18 cases.

Anterior-posterior radiographs of the whole-lower extremity (orthoroentgenography) were obtained with the patient in the double-limb standing position. Care was taken to place the lower extremities with the knees in the extended and neutral position. The feet were neutrally positioned in a consistent alignment for acquisition of films because the rotational variation would affect the accuracy of measurement. Three exposures were made in sequence and centered over the hip, knee, and ankle [13]. In the second exposure, the tube was over the knee at right angles to the joint line or tibial tray. Radiological measurements were taken from this orthoroentgenography using the picture acquiring communication system. The preoperative mechanical axis of the femur was defined as the line connecting the center of the hip, which was determined with use of Moss circles, and the highest point of the femoral trochlea. The preoperative mechanical axis of the tibia was defined as the line connecting the center of the tibial intercondylar eminences and the center of talus. The preoperative mechanical axis was defined as the angle between the femoral and tibial mechanical axes (Fig. 1) [11]. We classified the cases into 2 groups according to the preoperative mechanical axis. Thirty patients with varus deformity lesser than 10° were classified as group A and 30 patients greater than 10° were classified as group B. The postoperative mechanical axis was defined as the angle between a line passing the hip center and femoral component center and a line passing the tibial component center and ankle center (Fig. 1). The femoral anatomical axis was defined as the line connecting the centers of the intramedullary canal 10 cm distal to the hip and 10 cm proximal to the knee [3]. The tibial anatomical axis was defined as the line connecting the centers of the intramedullary canal 10 cm distal to the knee and 10 cm proximal to the ankle [3]. The coronal alignment of the femoral and tibial components was evaluated using American Knee Society roentgenographic evaluation system [7], based on these femoral and tibial anatomical axes [3]. Preoperatively, the center of tibial plateau was defined as the central point of mediolateral distance of tibial plateau excluding medial and lateral osteophytes. The distance between the center of tibial plateau and the point of anatomical axis passing through the plateau was measured, and this was called the preoperative medial offset (Fig. 2) [1,5,6]. Preoperative medial offset demonstrates the location of the central point of the tibial plateau relative to the anatomical axis of the tibia. Postoperatively, the distance between the midline of the stem and anatomical axis was measured at the level of tibial resection, and this was called a postoperative medial offset (Fig. 2). Postoperative medial offset demonstrates the location of the central point of the tibial component relative to the anatomical axis of the tibia. The pre- and postoperative medial offsets were compared between groups A and B. The postoperative mechanical axes were compared, as well. The Student t test

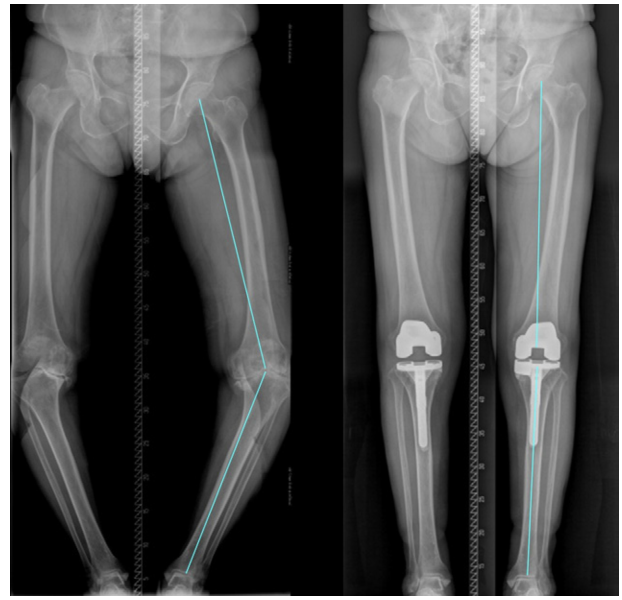

Fig. 1. Pre- and postoperative mechanical axis. Preoperatively, the mechanical axis of the femur was defined as the line connecting the center of the hip and the highest point of the femoral trochlea. The mechanical axis of the tibia was defined as the line connecting the center of the tibial intercondylar eminences and the center of talus. The preoperative mechanical axis was defined as the angle between the femoral and tibial mechanical axes. The postoperative mechanical axis was defined as the angle between a line passing the hip center and femoral component center and a line passing the tibial component center and ankle center.

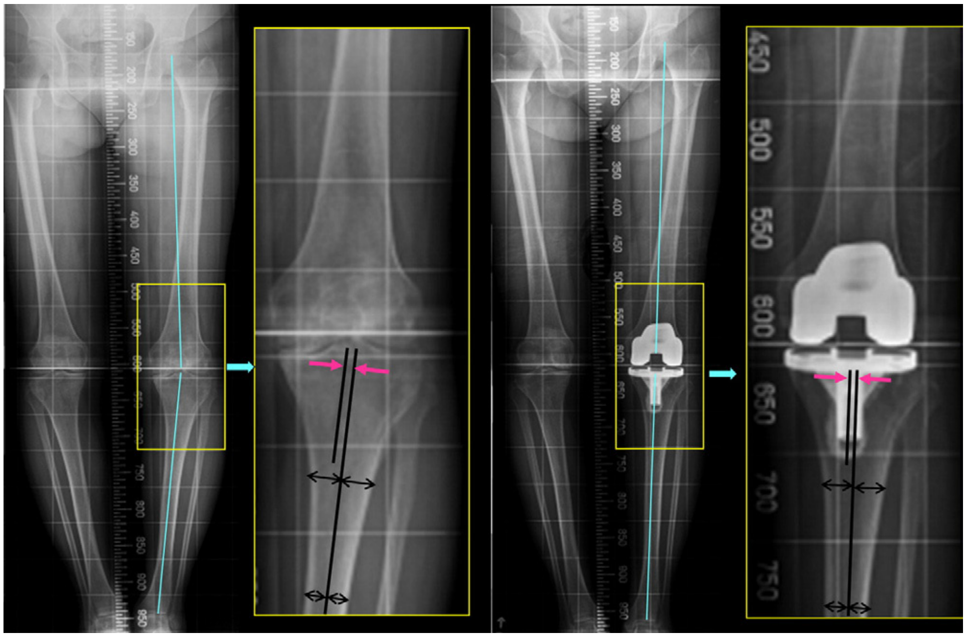

Fig. 2. Pre- and postoperative medial offset. Preoperatively, the distance between the center of tibial plateau and the point of anatomical axis passing through the plateau was measured, and this is called a preoperative medial offset. Postoperatively, the distance between the midline of the stem and anatomical axis was measured at the level of tibial resection, and this is called a postoperative medial offset.

was used for statistical analysis. To reduce any observation bias, 2 independent investigators repetitively performed all the radiographic measurements. In this study, intraclass correlation coefficient values of all measurements were greater than 0.8 both for intra- and interobserver reliabilities. Statistical analysis was performed using SPSS version 12.0 software (SPSS Inc, Chicago, Ill) and $P < .05$ was considered to be significant.

All the operations were performed using a standard operative technique comprising a modified measured resection technique. Specialist II instrument, standard cutting block (1.4-mm slot), and standard saw blade (1.27 mm thick) of the PFC Sigma System (Johnson & Johnson, Warsaw, Ind) were used for bone resection. Femoral intramedullary cutting guide was positioned with the cutting jig at the angle of valgus cut angle, which was preoperatively planned considering the anatomical and mechanical axes angle of the femur. The position of the cutting jig was reconfirmed with extramedullary rod. When performing resections of tibia, the intention was to produce a surface perpendicular to the intramedullary canal of tibia shaft aiming mid portion of talus using extramedullary guide. After the resections, the prepared bone surface of the tibia was checked carefully whether the surface was perpendicular to the longitudinal axis of the tibia or not. If the surface was not thought to be perpendicular, it was adjusted using a narrow saw blade (0.6mm thick). The tibial component was placed centrally, avoiding medial or lateral overhang of the tibial tray and keeping the anteroposterior axis accurate. We tried that the reference line for tibial rotation was accurately aimed at a line passing through the medial third of the tibial tubercle and the second metatarsal or the middle of talus, which is practically 3 to 5 mm medial to the center of ankle.

Results

The mean preoperative mechanical axis was varus 12.5° ± 5.8°, and the mean preoperative medial offset was 3.1 ± 2.8 mm. In the American Knee Society's roentgenographic evaluation method, α angle was 94.9° ± 0.7°, and β angle was 90.2° ± 1.0°. The mean postoperative medial offset was 3.3 ± 2.5 mm ($r = 0.288$, $P = .020$). The tibial stems were located medial to anatomical axis in 80% (48/60 cases). The mean postoperative mechanical axis was varus 2.0° ± 1.8° ($P = .000$).

The mean preoperative mechanical axis was varus 7.4° ± 2.3° in group A and varus 16.9° ± 4.0° in group B ($P = .000$). α angle was 95.0° ± 0.5° in group A and 94.9° ± 0.8° in group B ($P = .312$). β Angle was 90.3° ± 0.9° in group A and 90.1° ± 1.0° in group B ($P = .267$). The mean postoperative medial offsets were 2.5 ± 1.9 mm (range, −3.6 to 5.9 mm) in group A and 3.9 ± 2.7 mm (range, −1.1 to 10.2 mm) in group B ($P = .021$). The tibial stems were located medial to anatomical axis in 73.3 % (22/30 cases) of group A and 86.7% in group B (26 / 30 cases). The mean postoperative mechanical axes were varus 1.3° ± 1.2° (range, varus 3.6° to valgus 1.6°) in group A and varus 2.5° ± 2.0° (range, varus 5.9° to valgus 2.1°) in group B ($P = .004$) (Figs. 3 and 4).

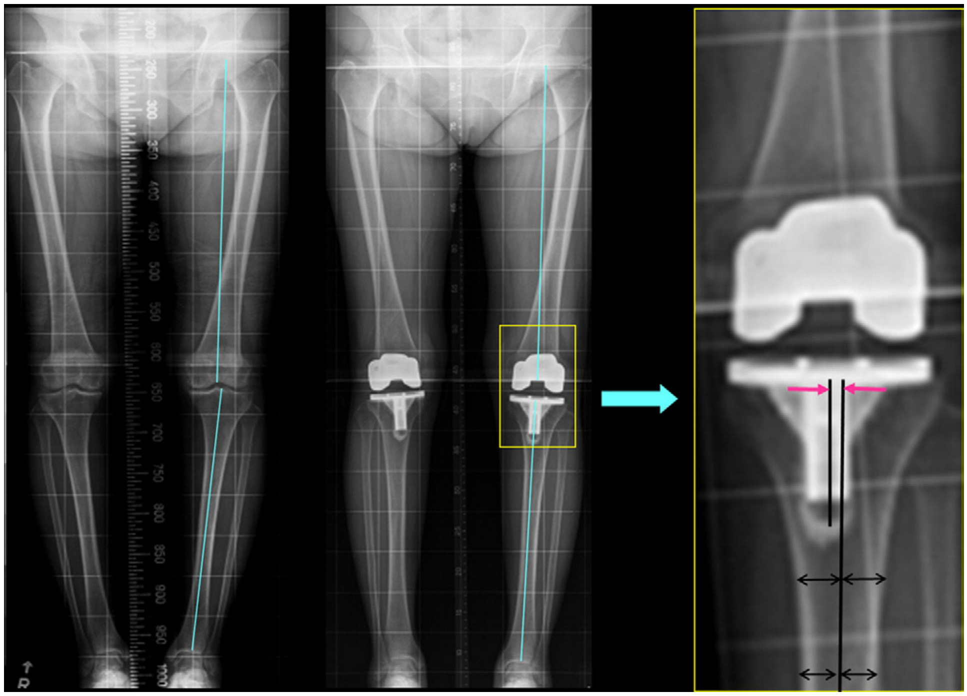

Fig. 3. A 65-year-old woman received total knee arthroplasty for left osteoarthritic knee with varus deformity. The preoperative mechanical axis was varus 4.4°. Thus, according to the classification method, she is classified to group A. Postoperatively, *α* angle was 95.8°, and *β* angle was 89.5°. The postoperative medial offset was 2.7 mm, and postoperative mechanical axis was varus 1.8°.

Discussion

The tibial tray in total knee arthroplasty must be positioned so that it covers the maximum area of the prepared bone surface of the tibia. This has important role to distribute the load and to prevent subsidence and loosening [14]. Ultimately, the tibial tray should be positioned at the center of the prepared bone surface in order to increase the long-term survival rate [14].

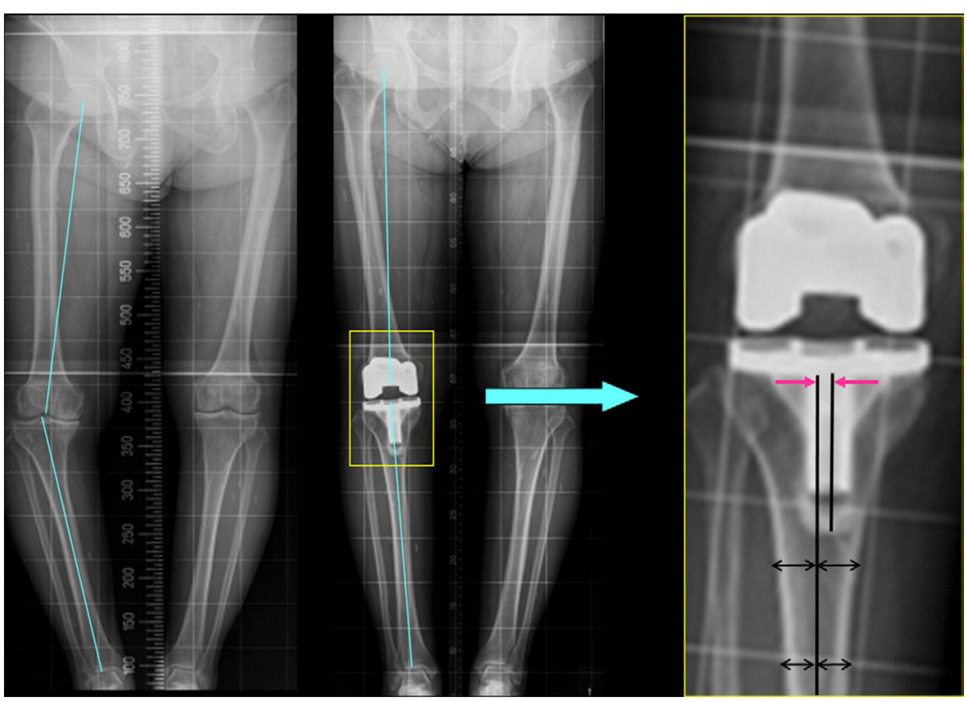

Fig. 4. A 66-year-old woman received total knee arthroplasty for right osteoarthritic knee with varus deformity. The preoperative mechanical axis was varus 17.6°. She is classified to group B. The coronal alignment of component was accurate, too. However, the postoperative medial offset was 3.4 mm, and postoperative mechanical axis was varus 3.3°.

During preoperative radiological planning for Korean patients undergoing total knee arthroplasty, we have sometimes noticed that there is discordance between the center of tibial plateau and the point of anatomical axis passing through the plateau (Fig. 2). Hicks et al [1] performed an anatomical study in whites to determine the relationship of the tibial plateau and the intramedullary canal of the tibia. They reported that the center of tibial plateau varied from medial 4 to lateral 8 mm from the center of tibial canal at the 10-mm resection level. In our previous 3-dimensional analysis for Koreans, the center of tibial plateau was located medially 4.4 ± 2.0 mm and posteriorly 10.7 ± 2.4 mm from the center of tibial canal on the plateau [6]. This finding is more apparent in cases with severe lateral bowing of the tibia, which is a common finding in Asians. This is thought to be from the racial difference in the anatomical feature of the proximal tibia [3,4]. In this study about the total knee arthroplasty using the tibial component with symmetrically shaped tray and centrally positioned stem, the stem of the tibia was located medial to the tibial anatomical axis in 80% (48/60 cases) of the patients.

Two basic technical methods can be used to align the tibial cut, either intramedullary or extramedullary alignment guides. The surgical technique aim is a 90° cut to the longitudinal axis of the tibia shaft. The β angle of American Knee Society roentgenographic evaluation system will be 90° if the tibial resection is perfect and radiographic measurement is accurate. The center of the medially placed tibial component after reduction with femoral component is off centered laterally from the line of mechanical axis from hip center to center of talus, which results in varus mechanical axis (Fig. 5). The center of the laterally placed tibial component is off centered medially from the line of mechanical axis which results in valgus. In this study using Press-Fit Condylar knee, the mean distance of the midpoint of the stem from the anatomical axis of the tibial shaft axis was 3.3 mm, and postoperative mechanical axis was varus 2.0°. Although we have used this implant most commonly without any selection criteria, we experienced similar results in different implants. In our previous anatomical study [6], it was reported that the center of the tibial resected surface is located more medial to the anatomical axis as the varus or lateral bowing deformity is more severe. In addition, from this study, the stem of tibial component in group B, which was with severe varus deformity, was located more medial and the postoperative mechanical axis was more varus than in group A. Our findings are in agreement with the previous studies [15,16] that the postoperative varus deformity is still existent as the preoperative varus deformity is severe when the total knee arthroplasty was performed in osteoarthritis with varus deformity more than 10°.

In general, α angle is aimed to be 95° to 96° and β angle is to be 90° postoperatively in total knee arthroplasty by the conventional method in relation to the anatomical axis [17,18]. However, even in cases that the coronal alignment of the component is perfect, the postoperative mechanical axis is measured to be varus because the tibial component is located medial from the anatomical axis of the tibia.

In summary, the tibial component in relation to anatomical axis tends to be located medial in total knee arthroplasty for Korean patients with varus deformity. The postoperative mechanical axis remained more varus in spite of the accurate coronal alignment of the component as the preoperative varus deformity was more severe. We think that the medial position of tibial component in relation to the anatomical axis affects the measurement of postoperative mechanical axis in total knee arthroplasty.

We think that the mean postoperative medial offset of 3.3 mm and mean postoperative mechanical axis of 2.0° were within the permissible range in this study. It is important that other general factors affecting the postoperative leg alignment do not make the leg to be more varus and to get over the permissible range, especially in a patient with large medial offset. For example, we should

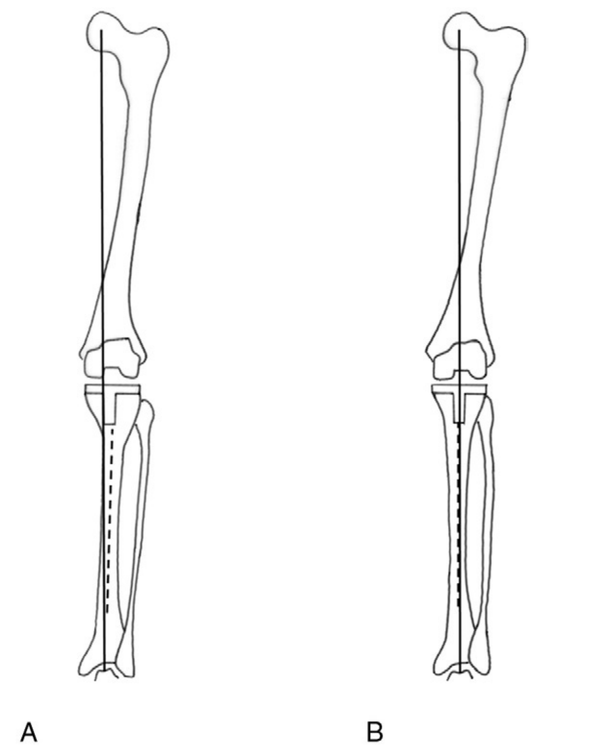

Fig. 5. Medial offset affecting the mechanical axis. (A) If β angle is 90° but the position of tibial component is located medial in relation to the anatomical axis (dotted line) of the tibia, the proximal tibia is rotated laterally based on the center of ankle in order to match to femoral component during the reduction of the knee. This results in varus mechanical axis (solid line). (B) If β angle is 90° and the position of tibial component is located central in relation to the anatomical axis of the tibia, there is no medial offset affecting the mechanical axis. This results in neutral mechanical axis (solid line).

be careful so as not to get the femoral component to be varus and to be positioned medially.

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