

# The Coronal Angulation of the Femur in Thai Osteoarthritic Knee Patients with Varus Deformity

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## ABSTRACT

**Objective:** To determine the angulation of the distal femoral axis - femoral mechanical axis and the coronal femoral bowing in varus OA knees. This information is necessary, because the routine distal femoral valgus cut can potentially lead to error in post-operative alignment.

**Methods:** Hip to ankle standing radiographs were ordered in 160 varus OA patients (200 limbs). The mean age of the patients was 63.8 years. In addition, 50 limbs of young volunteers with an average age of 28.8 years, were also studied for comparison. The distal femoral axis-femoral mechanical axis angle, femoral bow, and other angles were determined and compared between two groups.

**Results:** Mean distal femoral axis-mechanical axis angle was  $7.0^\circ \pm 1.5^\circ$  and mean femoral bow was  $2.4^\circ \pm 2.6^\circ$  in patients compared to  $5.7^\circ \pm 0.5^\circ$  and  $0.3^\circ \pm 0.5^\circ$  respectively, in controls. The varus deformity significantly correlated with femoral bowing. Thirty-five (17.5 percent) of OA limbs showed a distal femoral axis-mechanical axis angle of more than  $9^\circ$  and there were 42 OA limbs (21%) that had significant ( $> 3^\circ$ ) femoral bowing.

**Conclusion:** These findings have implications in deciding the optimum valgus angle at which to perform distal femoral resection during TKA in varus OA knee.

**Keywords:** Distal femoral axis-femoral mechanical axis angle, femoral bow, varus deformity

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Total knee arthroplasty (TKA) yields a promising result for the late stage osteoarthritic (OA) knee patients. However, one important factor for a successful result, is the restoration of the mechanical axis of the limb back to within  $3^\circ$  of normal which would decrease early loosening and increase survivorship of the prosthesis.<sup>1-5</sup> Therefore, it is required that the bone cut of both femur and tibia are perpendicular to the mechanical axis in a coronal plane.

However, there are some occasions that OA knee patients concomitantly have an extra-articular deformity, either acquired or congenital. One of the possible causes of this deformity is the coronal femoral bowing in varus. This bowing can alter the mechanical axis of the femur and potentially make the distal femoral bone cut to be erroneous from the desired angle. Conventional total knee surgery uses an intramedullary rod to identify the intra-

medullary canal and perform the distal femoral resection, which is usually performed at a fixed amount of 5- or 6-degree valgus to the anatomical axis of the distal femur. The intramedullary rods of all companies are usually only long enough to be inserted up to the middle one-third of a femur which does not refer to the true anatomical axis of the whole femur. This might result in an undesirable alignment of the prosthesis if the surgeon performs a routine 5- or 6-degree valgus cut on a bowed femur.

Unfortunately, the variations in femoral anatomy such as bowing and changes in neck shaft angle, are neither apparent clinically nor evident on short film radiographs centered at the knee.<sup>6-9</sup> The varus OA knee patient with coronal femoral bowing has a different angle between the mechanical and anatomical axis of the distal femur from the patient with a straight femur. If a surgeon can recognize these variations in the preoperative period, the surgeon can make a well-planned surgery and increase the accuracy of the distal femoral bone cut.

Recently, Mullaji et al reported the correlation between the femoral bow and the severity of varus deformity in Indian OA knee patients.<sup>10</sup> Therefore, this study aimed to evaluate the incidence and magnitude of the coronal

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femoral bow in Thai OA knee patients with varus deformity. The angulation of the distal femoral axis and femoral mechanical axis (these represent the angle at which the intramedullary cutting guide is used for the distal femoral cut during the surgical procedure) was also evaluated.

## MATERIALS AND METHODS

We studied 160 OA knee patients with varus deformity (200 lower limbs) who were scheduled for total knee arthroplasty at our institute. Patients with a history of previous surgery on their lower limbs, posttraumatic arthritis, inflammatory arthritis, and valgus deformity at the knee were excluded from this study. One hundred and fifty six limbs were measured in female and 44 in male patients. The mean age of the patients was 63.8 years (range, 56-86 years). In addition, we studied 50 limbs in 13 male and 12 female volunteers with an average age of 28.8 years (range 20-35 years). The volunteers with a history of previous surgery, deformity, or fracture of their lower limbs were excluded from the control group.

Every patient and volunteer took the hip to ankle radiograph in a standing position without shoes. The knee was kept in full extension and the lower limb was in a neutral rotation with the patellae facing forwards. A single technician kept the x-ray tube at a fixed distance from the patient and centered the x-ray beam at the level of knee. Neutral rotation of the limbs was confirmed by observing the position of the patella and the profile of the lesser trochanter on the radiograph (Fig 1).

The length of the femur, which was measured from the most proximal point of a femoral head to the most distal point of a femoral condyle, was recorded. The

landmark positions were assigned in every hip to ankle radiograph as described by Mullaji et al by the following definitions.<sup>10</sup>

H : is the center of the femoral head (was found using Mose's circles)

K : is the lower end of the femur (was defined by the apical midpoint of the intercondylar notch)

T : is the upper end of the tibia (was taken to be the midpoint between the tips of the 2 tibia spines)

A : is the center of the ankle (was determined to be the center of the talar dome)

Three points were marked on the femoral shaft as follows:

Fp : a point bisecting the shaft at the lower junction of the lesser trochanter with the shaft

Fd : a point bisecting the shaft at 10 cm proximal to the knee joint

Fc : a point bisecting the shaft midway between Fp and Fd

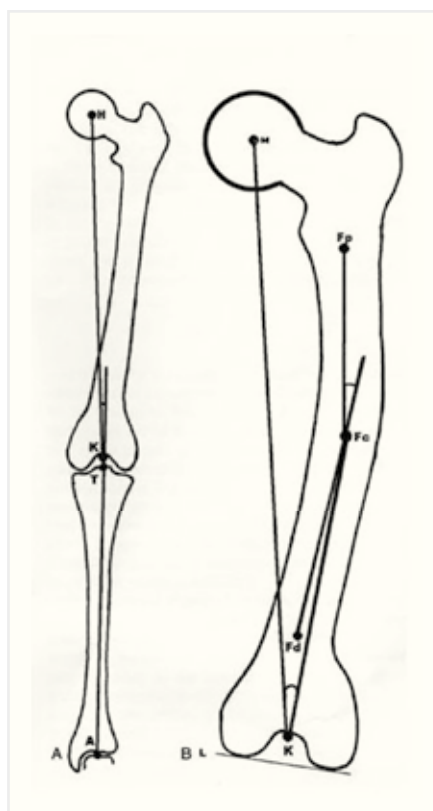
The femoral mechanical axis is a line connecting the center of the femoral head to center of the knee (HK). The distal femoral axis is a line connecting Fc to K. This closely approximates to the femoral anatomical axis 1 described by Moreland et al<sup>8</sup> and closely matches the track followed by the intramedullary rod of the femoral cutting jig.

The following angles were determined for each knee using a goniometer. (Fig 2)

1. Angle HK-TA (mechanical axis of the limb : the angle between the femoral and the tibial mechanical axes)
2. Angle HK-Fc (angle between the distal femoral axis and the mechanical axis)
3. Angle HK-L (angle between the condylar line and the mechanical axis of the femur)



**Fig 1.** A pre-operative hip to ankle radiograph of the OA knee patient. Note the significant femoral bowing.



**Fig 2.** Diagrams showing the measurement of various angles.

**TABLE 1.** The comparison of distal femoral axis-mechanical axis angle, condylar-mechanical axis angle and femoral bowing in healthy controls and patients with varus osteoarthritic knees.

Parameter	Controls (n = 50) (Mean ± SD)	Patients (n = 200) (Mean ± SD)	Significance ANOVA)
Distal femoral axis-mechanical axis angle	5.7 ± 0.5	7.0 ± 1.5	p < .05
Condylar-mechanical axis angle	91.3 ± 1.1	90.8 ± 1.3	p < .05
Femoral bowing	0.3 ± 0.5	2.4 ± 2.6	p < .05

#### 4. Angle FpFc-FdFc (femoral bow)

All radiographs were measured by one observer (S.P.) twice and the mean values were used for analysis. We performed Student t-test and analysis of variance, and p-value of less than 0.05 was taken as significant. All materials and methods used in the study were approved by the Sirindhorn Institutional Research Board.

## RESULTS

### Control groups

In the 50 lower limbs of normal control subjects, the mean femoral length was 44.4 ± 1.9 cm. The mean HKTA angle was 180.1° ± 1.8°, the mean distal femoral axis-femoral mechanical axis angle was 5.7° ± 0.5°, the mean femoral condylar-mechanical axis angle was 91.3° ± 1.1°, and the mean femoral bow was 0.3° ± 0.5°.

### Patients with varus osteoarthritic knee

In the 200 lower limbs with varus OA knees, the mean femoral length was 42.6 ± 1.8 cm. The mean HKTA angle was 171.2° ± 5.1°, the mean distal femoral axis-femoral mechanical axis angle was 7.0° ± 1.5°, the mean femoral condylar-mechanical axis angle was 90.8° ± 1.3°, and the mean femoral bow was 2.4° ± 2.6°. There were 42 limbs (21%) that had significant (> 3°) femoral bowing. We compared the means of various angles in the 50 control limbs with the respective means of 200 limbs with varus osteoarthritis (Table 1). The mean distal femoral axis-mechanical axis angle and the femoral bow were significantly higher, and femoral condylar-mechanical axis angle was significantly lower in the osteoarthritic patients. The mean femoral bow was 2.4° ± 2.6° (0°-8°) in the osteoarthritic group. There was a statistically significant positive correlation between the mechanical axis (HKTA) and the femoral bow (p < 0.05; Pearson's correlation coefficient, 0.34). However, there was no significant correlation between the femoral length and bow.

The mean distal femoral axis-mechanical axis angle (HKFc) in the osteoarthritic group was 7.0° ± 1.5° (5°-11°). There was a statistically significant positive correlation between the femoral bow angle and the distal femoral axis-mechanical axis angle (p < 0.05; Pearson's correlation coefficient, 0.61).

In 35 limbs from 200 OA limbs (17.5%), the distal femoral axis-mechanical axis angle (HKFc) was 9° or more. The mean mechanical axis varus of the limb (HKTA) was 164.5° ± 7.6° in this group of 35 limbs as opposed to 172.2° ± 5.6° in the group of 165 limbs with the distal femoral axis-mechanical axis angle of less than 9° (Table 2). The difference between the mean mechanical axis varus (HKTA) in these 2 groups was statistically significant (p < 0.05). Similarly, the mean angle of femoral bow was 6.5° ± 2.1° and 2.1° ± 1.6° respectively, in these groups. The difference in the mean angle of femoral bow in these 2 groups was also statistically significant (p < 0.05). Moreover, we found that in patients with severe varus deformity (HKTA < 170°), the mean distal femoral axis-mechanical axis angle and femoral bow were significantly higher than the patients with mild varus deformity (8.7° ± 3.1° and 5.1° ± 2.5° compared to 6.7° ± 2.4° and 2.2° ± 1.7°, respectively).

The mean femoral condylar-mechanical axis angle (HK-L) in patients was 90.8° ± 1.3° (86° - 94°), whereas it was significantly greater (91.3° ± 1.1°) in the controls (p < 0.05).

## DISCUSSION

In order to achieve a good result and long term survivorship of the total knee replacement, a neutral post-operative mechanical axis of the limb must be obtained. Jeffrey et al<sup>5</sup> suggested that there should not be more than 3° of varus or valgus angulation postoperatively (considering 7° as the normal valgus angulation at the knee between the anatomical axes of the tibia and femur) otherwise it can lead to an increased incidence of loosening of the components.

Regarding the distal femoral bone cutting, most orthopaedic surgeons use the intramedullary jig with the fixed 5- or 6-degree valgus. In a healthy knee, femoral anatomical axis and the mechanical axis are angulated 5- to 6-degree to each other, while in patients with varus osteoarthritis, the anatomy of the lower limbs could have been changed as demonstrated in this study. Mullaji<sup>10,11</sup> studied OA knee patients with varus deformity and reported that the distal femur almost always had varus angulation. Anatomical variations have been observed before in the femur of OA

**TABLE 2.** The comparison of varus deformity and bowing in OA patients with distal femoral axis-mechanical axis angle of less than 9 degrees and patients with 9 or more degrees.

Parameter	Patients with distal femoral axis-mechanical axis angle < 9° (n = 165) Mean ± SD	Patients with distal femoral axis-mechanical axis angle ≥ 9° (n = 35) Mean ± SD	Significance (ANOVA)
Distal femoral axis-mechanical axis angle	6.3 ± 0.7	9.1 ± 0.8	p < .05
Varus deformity (mechanical axis)	172.2 ± 5.6	164.5 ± 7.6	p < .05
Mean femoral bowing	2.1 ± 1.6	6.5 ± 2.1	p < .05

knees, but have not been quantified.<sup>12-15</sup> Until now, there are no reports that describe the amount of variation or anatomical changes of the femur in Thai OA knee patients. Compared to the Mullaji study, our findings showed some similarities in terms of the incidence of femoral bowing and the correlation between the degree of varus deformity and femoral bow. These anatomical variations will change the angular relationship between the anatomical axis and the mechanical axis of the femur. Thus, the reliability of using a fixed 5- or 6-degree valgus distal femoral cut in all TKAs for restoring a neutral mechanical axis is questionable. The use of 5- or 6-degree valgus cut in every case can lead to error in a bowed femur, and the neutral mechanical axis of the lower limbs cannot be obtained.

This study found that the distal femoral axis-mechanical axis angle and the varus femoral bow were significantly higher in Thai OA knee patients, when compared with that of normal control subjects ( $p < .05$ ). The reason that we selected young volunteers instead of age-matched controls was because we intended to study the really normal subjects and excluded any confounding factors from osteoarthritic process which might be present in seemingly normal elderly. Therefore, in the varus OA patient, the distal femoral resection valgus angle has to be matched to the distal femoral axis-mechanical axis angle (as measured on the long-leg radiograph) in order for the distal femoral cut to be perpendicular to the femoral mechanical axis.

When facing with a significant femoral bowing of more than  $3^\circ$  (which happened in approximately 21% of varus OA knees in our study), the angle between the distal femoral axis and the mechanical axis is increased. In such circumstance, it is strongly recommended that the distal femoral valgus resection angle to be increased more than  $6^\circ$  to decrease the errors. Our study also showed that the more severe the varus deformity, the more severe the femoral bowing. Eighteen per cent or about 1 out of every 5 varus OA knees had distal femoral axis-mechanical axis angle  $\geq 9^\circ$  and even up to  $11^\circ$  was also found. In these knees, the deviation of the mechanical axis of the lower limb after TKA by more than  $3^\circ$  would definitely occur with the use of a fixed 5- or 6-degree valgus distal femoral cut.

We believe that our data is reliable in terms of the determination of the coronal bow, because we controlled the patient's knee position to be neutral while taking a radiograph. The varus OA knee also had a lower incidence of lateral patellar subluxation than the valgus knee, therefore it is very unlikely that with the patellae facing forward, the patient's hip would be internally rotated and the bowing would actually be an anterior bow.

In summary, our study revealed that there is a correlation between the varus OA knee and the degree of coronal femoral bowing. The use of pre-operative long leg radiographs or a computer assisted surgery in these patients can prevent inaccuracy of the distal femoral cutting. This is even more essential in severe varus OA patients. Currently, we routinely order the pre-operative long leg x-ray in every varus OA knee undergoing TKA at our institutions. However, the application of this study nationwide may still require the data from other institutions to validate our findings.

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