Axial Radiography of the Normal Distal Femur for Assessment of Rotational Alignment in Thai

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Background: *It is crucial to recognize and understand anatomical features of the distal femoral condyles especially for orthopedists that take care of the elderly patient with leg deformity.*
Objective: *Evaluate the rotational alignment of the distal femur by using axial radiographic technique.*
Material and Method: *Thirty-six normal volunteers (72 knees) were enrolled in the present study. Mean age was 39.47 years (range 20 to 57). Axes for rotational alignment of distal femur were outlined including posterior condylar (PC), anteroposterior (AP), anatomical epicondylar line (AEpi), and then angle between each pair of the axes were measured in the medial side including anteroposterior/posterior condylar (AP-PC) angle, anteroposterior/anatomical epicondylar (AP-AEpi) angle, and anatomical epicondylar/ posterior condylar (AEpi-PC) angle. Gender and side were compared to each other. Pearson correlation was calculated between age and all angles.*
Results: *Average AP-PC angle was 95.75 $\pm$ 1.79 degrees. Average AEpi-PC angle was 6.77 $\pm$ 1.97 degrees. Average AP-AEpi angle was 89.81 $\pm$ 1.86 degrees. Results showed no statistically significant difference between side, gender, and age. Intraobserver ICC were 0.6 to 0.92 and interobserver ICC were 0.68 to 0.87.*
Conclusion: *The axial radiographic technique is reliable. The results of the present study are comparable with a previous study using the computerized tomography (CT) technique.*

Keywords: *Knee, Rotational alignment, Distal femur, Thai, Axial radiographic study, Lower extremity*

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Rotational alignment of the femoral component in total knee arthroplasty (TKA) has an effect on the femorotibial kinemetics. Correct rotational influence on patellofemoral kinematics and on the balance of the flexion gap, which can give alignment, is an important factor to reduce patellofemoral maltracking[1], which prevent early failure and chronic pain postoperatively[2]. In the past, computed tomography (CT) has been used to assess the rotational alignment of the distal femur; however, it was expensive.

Rotational alignment could be evaluated more easily if rotational landmarks could be seen reliably on plain radiographic study. A few reports are available regarding radiographic techniques for evaluation of the rotational alignment of distal femur[3]. Kanekasu et al reported axial radiographic technique to assess distal femur while patients were sitting with flexed knees. Such a position was more comfortable for patients with knee pain. It should be noted that with this radiographic method, the interobserver variation is less than or comparable to CT scan method. The mean discrepancy was 0.5 $\pm$ 0.4 degrees and strong correlation was observed[4]. Yip et al reported not only racial difference of distal femur geometry between Chinese and Caucasians femora but also statistical difference between Chinese male and female was also reported[5]. Tanavalee et al reported rotational alignment in osteoarthritic Thai patients by using axial CT scan[6]. However, detailed measurement of the Thai normal distal femoral condyle geometry has not yet been investigated.

The purpose of the present study was to access the contours of the Thai distal femoral condyles by using the kneeling axial radiographic technique[4] and to evaluate inter/intraobserver variations of axial knee radiographic study and factors that may affect rotational alignment such as age, side, and gender.

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Material and Method

Thirty-six volunteers (72 knees) were enrolled. Inclusion criteria were volunteers who were willing to join after the information sheet was studied and no knee symptoms and no osteoarthritic changes were detected on plain radiographs. Exclusion criteria were pregnancy, past history of knee disease or knee injury, knee flexion less than 90 degrees, and age less than 20 years old. They gave informed consent and agreed to participate in the present study, which was approved by Siriraj institutional review board.

Axial radiographic technique as described by Kanekasu et al[4] was used. A wooden table (90 cm wide, 60 cm high, and 45 cm long) was set on a low platform on wheels. Volunteers sat on the table with their lower legs hanging down at neutral rotation (Fig. 1). The position of neutral rotation was taken as the position which the subject naturally placed his or her knees and lower legs without any specific instruction. This setting on the movable platform enabled the authors to obtain radiographs of both knees with minimum adjustments. The positions of the knee were adjusted so that the central ray of the x-ray beam was directed to the center of the patella. The x-ray beam was directed at 10 degrees upward and the angle was increased to 15 degrees in obese subjects to minimize the effect of soft tissue overlap. The distance between the x-ray tube and the film cassette was set at 100 cm apart.

Radiographic images of the distal femur (Fig. 2) were studied. Multiple referencing axes were drawn including posterior condylar line, anatomical epicondylar line, and anteroposterior line. The angles between each pair of reference line were measured by using a goniometer (Fig. 3-5).

The posterior condylar axis was the line that was drawn tangentially between the posterior surfaces of both femoral condyles. Anatomical epicondylar axis was the line that was drawn between the most prominent part of the medial and lateral epicondyles. The anteroposterior line (Whiteside's line) was the line drawn from the deepest point of the trochlear groove to the mid-point of the intercondylar notch. The deepest point of the trochlear groove was identified by the lowest point in the groove between medial and lateral condyle of trochlea. The mid-point of the intercondylar notch was the highest point of intercondylar notch.

The PC-AEpi angle was the angle between the posterior condylar line and anatomical epicondylar line. The AP-AEpi angle was the angle between the anteroposterior line and anatomical epicondylar line.

Fig. 1 Positioning of the patient for axial radiography. The x-ray beam was directed at 10 degrees upward and central ray of the x-ray beam was directed to the center of the patella (black line)

Fig. 2 The radiographic image of distal femur was studied

The AP-PC angle was the angle between the posterior condylar line and anteroposterior line.

All angles were reported in mean, standard deviation (SD), range and 95% confidential interval (95% IC). Two orthopedic residents measured all

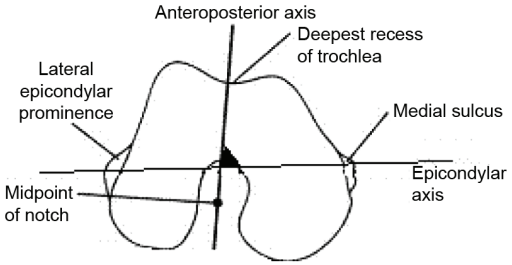

Fig. 3 Angle between anteroposterior (AP) line and anatomical epicondylar (AEpi) line

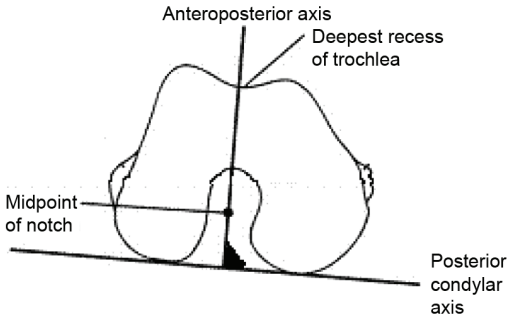

Fig. 4 Angle between anteroposterior line and posterior condylar (PC) line

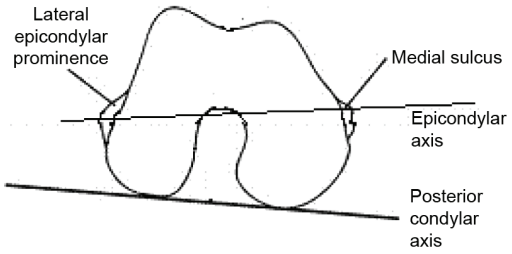

Fig. 5 Angle between anatomical epicondylar line and posterior condylar line

radiographic studies and three weeks later, the inter and intraobserver variation was evaluated by using interclass coefficient. The measured PC-AEpi, AP-PC, AP-AEpi angles were compared between gender and side. The relationship of the all angles and age was evaluated by using the Pearson correlation coefficient. A statistical analysis was performed to determine the number of digits required in each trial group to achieve an alpha value of 0.01 (degree of significance) and a power of 0.8 (a beta value of 0.2) then minimum sample size of approximately seventy-one knees in each group was calculated. The statistical significant was evaluated by using Student t-test with $p < 0.05$.

Results

The volunteers included 16 men and 16 women. Mean age was 39.47 years (range 22.5 to 59.83 years). The mean male age was 37.39 years (range 22.8 to 51.75 years). The average female age was 41.55 years (range 22.5 to 59.83 years).

The mean AP-AEpi angle was 89.81 degrees (range 85.75 to 94 degrees), the mean AP-PC angle was 95.75 degrees (range 92.38 to 99.38 degrees) and the mean AEpi-PC angle was 6.77 degrees (range 3.13 to 11 degrees) (Table 1). Intraobserver ICC were 0.6 to 0.92 and interobserver ICC were 0.68 to 0.87.

There were no significant differences of these angles between men and women ($p > 0.05$) and no significant differences between left/right side ($p > 0.05$). Pearson correlation between age and Ap-Epi, AP-PC, Epi-PC angle showed low correlation of all angles (-0.096, -0.005, and 0.204 respectively).

Discussion

Proper rotational alignment of femoral component is one of the most important factors for successful total knee arthroplasty (TKA). Correct rotational alignments play the key role to reduce patellofemoral problems. Current cutting guides

Table 1. Result of rotational alignment of knees (16 men and 16 wowen)

	Mean	SD	Range	95% CI
AP-Epi angle				
Total	89.81	1.86	85.75-94.00	89.38-90.24
Male	89.79	2.03	84.00-100.00	89.13-90.45
Female	89.83	1.72	84.00-97.00	89.27-90.39
Right	89.71	2.16	84.00-100.00	89.00-90.42
Left	89.92	2.29	84.00-98.00	89.17-90.67
AP-PC angle				
Total	95.75	1.79	92.38-99.38	95.34-96.16
Male	95.08	2.08	90.00-102.00	94.51-95.65
Female	96.42	1.59	90.00-102.00	95.90-96.94
Right	95.67	2.08	90.00-102.00	94.99-96.35
Left	95.08	2.05	90.00-102.00	95.16-96.50
Epi-PC angle				
Total	6.77	1.97	3.13-11.00	6.31-7.23
Male	6.19	1.89	2.00-13.00	5.53-6.85
Female	7.34	1.79	2.00-12.00	6.76-7.92
Right	6.72	1.89	2.00-12.00	6.10-7.34
Left	6.82	2.23	2.00-13.00	6.09-7.55

during TKA procedure for the distal femoral cut usually allow external rotation of the femoral component at three degrees by using posterior condylar line referencing. Akagi et al reported that lateral release rate and patellofemoral complications that occur after TKA increased when external rotation setting of femoral component decreased[7]. Posterior condylar axis is more reliable for use in alignment for TKA on medial femorotibial osteoarthritic (OA) knee than anteroposterior axis[8]. However, Posterior condylar angle is significantly decreased in valgus knee deformity. Therefore, posterior condyles are a potentially unreliable reference in this situation[9].

Anteroposterior axis appears to be a reliable landmark for rotational alignment of the femoral component in a valgus knee. Arima et al reported a line drawn perpendicular to AP axis consistently approximated four degrees of external rotation relative to posterior condylar surface with low variation[10]. Furthermore, Whiteside et al reported valgus knee deformity arthroplasty that use AP axis reference decreased intraoperative medial tibial tubercle transfer and postoperative patellofemoral instability[11].

Transepicondylar axis (EPi) has two lines. Clinical or anatomical epicondylar axis (AEpi) line tangentially crossed between the medial and lateral epicondylar prominences. Surgical epicondylar axis (SEpi) line tangentially between the medial sulcus and lateral epicondylar prominence. However, medial epicondylar sulcus appeared only 68 to 80% of knee axial CT scan[12,13]. Chu et al reported the lowest rate of femorotibial component rotational mismatch when AEpi axis is used compared with SEpi axis. Therefore, they recommended to use AEpi more than SEpi axis[14]. Olcott et al reported transepicondylar axis most consistently recreated a balanced flexion space in valgus knee compared with AP and PC axis[15]. However, epicondylar axis has high inter-observer variation[16], high inter-individual discrepancy[17], less predictable[18] and may produce a large error range of femoral component alignment when SEpi axis reference is used[19].

Anatomical features of the distal femur has many variations in various deformities, and the use of one fixed reference axis for all knees may result in inappropriate rotational alignment of the femoral component in some patients. It is crucial to understand the anatomical feature of the distal femoral condyles. Takai et al[3] first described the kneeling view, a novel radiographic technique that makes it easier to see the epicondyles and posterior condyles. They found that patients with knee symptoms sometimes could not kneel because of anterior knee pain and a feeling of instability. Kanekasu et al reported that the kneeling view is more comfortable for the patients who have knee pain. The patients can use both hands for stabilization and do not complain of pain or instability. The closed contact of the posterior aspect of the thigh with the table contributed to clear images of the radiography by avoiding soft tissue superimposed. Furthermore, the current radiographic technique can be regarded as stress radiography of the flexed knee.

Table 2. Results of rotational alignment compared with previous published study

	Year	Sample	Method	PC-AEpi	AP-AEpi	AP-PC
Yoshioka et al[20]	1987	Cadaver		Male: 6.00° ± 2.40°		
				Female: 5.00° ± 1.80°		
Berger et al[21]	1993	Cadaver		Male: 5.20° ± 4.10°		
				Female: 4.70° ± 3.50°		
Arima et al[10]	1995	Cadaver		4.40° ± 2.90°		93.80° ± 2.00°
Yip et al[5]	2004	Cadaver		Male: 5.10° ± 1.90°	Male: 91.59° ± 2.80°	Male: 96.73° ± 2.50°
				Female: 5.80° ± 1.80°	Female: 92.36° ± 1.60°	Female: 98.24° ± 2.40°
Akaji et al[7]	1999	OA	CT	6.80° ± 1.70°		
Tanavalee et al[6]	2001	OA	CT	All: 5.70° ± 1.70°	All: 90.20° ± 1.00°	All: 95.90° ± 2.00°
				Male: 5.60° ± 1.80°	Male: 90.30° ± 0.90°	Male: 95.70° ± 2.00°
				Female: 5.80° ± 1.70°	Female: 90.20° ± 1.10°	Female: 96.00° ± 2.00°
Matsuda et al[22]	2004	Normal	MRI	6.40° ± 1.80°	90.10° ± 3.20°	96.30° ± 12.40°
Present study		Normal	Axial film	All: 6.77° ± 1.97°	All: 89.81° ± 1.86°	All: 95.75° ± 1.79°
				Male: 6.19° ± 1.89°	Male: 89.79° ± 2.03°	Male: 95.08° ± 2.08°
				Female: 7.34° ± 1.79°	Female: 89.83° ± 1.72°	Female: 96.42° ± 1.59°

Axial radiography not only provide the same level of information obtained by CT scan but also has several advantages over CT such as time, cost, and radiation dose[4]. Results of rotational alignment compared with previous published study are shown in Table 2. The present study showed average AP-PC angle is 95.75 degrees and average AP-AEpi angle is 89.81 degrees that comparable to previous studies[5,6,22] and minimal difference between gender was found[5,6] in both angles. The results also showed that the AP-PC angle and the AP-AEpi angle were comparable in Thai normal and osteoarthritis knee[6]. The present study showed average PC-AEpi angle is 6.77 degrees, which is slightly bigger than a previous study especially when compared with the result from Berger's study[21]. That may be cause by interracial difference which several studies reported significant osteometric racial variation between Southern Chinese and Caucasian individuals[23,24]. Daniel et al reported gender variation of posterior condylar-epicondylar axis angle (PC-AEpi) was statistically significant. This may also be a factor in the difference in the incidence of osteoarthritis between genders in the Chinese population[5]. However, no statistically significant difference in side and gender were found in the present study.Inter and intra observer interclass coefficients in the present study are high in all angles (0.68 to 0.87) because axial radiographic study was highly reproducible due to the anatomical landmarks were identified clearly. The present study results in all angles were comparable with MRI study in a normal knee sample[22].

The present study has some limitations. The possible limitation of axial radiography is the reproducibility in the detection of anatomic landmarks especially trochlear notch that may interfered Whiteside's line drawing. The present study could be strengthened by increasing the number of samples. In summary, axial radiographic study of the distal femur provided more information about rotational alignment that can be applied without racial and gender differences in Thai populations.

Potential conflicts of interest

None.

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การศึกษาแนวการหมุนของปลายกระดูกต้นขาในคนไทยปกติด้วยภาพรังสีตามแนวแกน

ปัญญา ลักษณะพฤกษา, วัฒนชัย โรจนวณิชย์, ศัลยพงศ์ สรรพกิจ

ภูมิหลัง: *มีความจำเป็นอย่างยิ่งที่จะตระหนักและทำความเข้าใจเกี่ยวกับลักษณะทางกายวิภาคของปลายกระดูกต้นขา โดยเฉพาะศัลยแพทย์กระดูกแ ละข้อที่ได้มีโอกาสดูแลผู้ป่วยสูงอายุที่มีแนวขาผิดปกติ*

วัตถุประสงค์: *เพื่อศึกษาแนวการหมุนของปลายกระดูกต้นขาโดยใช้ภาพรังสีตามแนวแกน*

วัสดุและวิธีการ: *ผู้เข้าร่วมศึกษาจำนวน 36 คน (72 เข่า) อายุเฉลี่ย 39.47ปี (20- 57 ปี) เส้นแนวกระดูกที่ใช้ศึกษาได้แก่ posterior condylar (PC),anteroposterior (AP) และ anatomical epicondylar line (AEpi) ทั้งนี้การวัดมุมระหว่างเส้นแนวกระดูกแต่ละคู่จะวัดจากมุมด้านใกล้กลาง ประกอบด้วยมุม anteroposterior/posterior condylar (AP-PC), anteroposterior/anatomical epicondylar (AP-AEpi) และ anatomical epicondylar/ posterior condylar (AEpi-PC) โดยแต่ละมุมที่ได้จะถูกเปรียบเทียบระหว่างเพศ อายุ และข้างที่ทำการวัดโดยค่าสถิติ Pearson correlation*

ผลการศึกษา: *ค่าเฉลี่ยมุม AP-PC, AEpi-PC, AP-AEpi เท่ากับ 95.75 $\pm$ 1.79, 6.77 $\pm$ 1.97 และ 89.81 $\pm$ 1.86 องศา ตามลำดับ นอกจากนี้จากผลการศึกษาไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่าง เพศ อายุ และข้างของเข่าที่ทำการศึกษา ค่าความแปรปรวนในตัวผู้วัด (Intraobserver ICC) คือ 0.6-0.92 และค่าความแปรปรวนระหว่างผู้วัด (interobserver ICC) คือ 0.68-0.87*

สรุป: *เทคนิคการถ่ายภาพรังสีตามแนวแกนมีความน่าเชื่อถือ และผลของการศึกษาในครั้งนี้ใกล้เคียงกับการศึกษาก่อนหน้านี้โดยใช้ภาพถ่ายรังสีคอมพิวเตอร์*