Femoral Mechanical-Anatomical Angle of Osteoarthritic Knees

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Background: *To perform total knee arthroplasty, some surgeons prefer to use a fixed valgus angle, for example 5° or 6°,for the distal femoral cut with every patient. This angle may be appropriate for some patients, but may not be for all.*
Objective: *To determine the proper angle of the distal femoral cut during total knee arthroplasty (TKA) in Thai patients with osteoarthritis of the knee.*
Material and Method: *A cross-sectional study was conducted of 80 osteoarthritic knees of 50 Thai patients with a mean age of 69 years (range 52-82, SD 7.64) who had received total knee arthroplasty at Chiang Mai University Hospital between January 2011 and March 2013. The femoral mechanical-anatomical (FMA) angle, femorotibial (FT) angle, mechanical femorotibial (MFT) angle,femoral bowing angle, femoral length, hip offset, gender, and age of the patients were analysed using multivariate regression analysis.*
Results: *Average FMA angle was 6.46° (range 4°-10°, SD 1.26°). The FMA angle was 6.85° and 5.28° in patients with varus and valgus deformity, respectively. Fifteen percent of all patients showed a FMA angle either less than 5° or greater than 7°.*
Conclusion: *The average FMA angle of patients with gonarthrosis was 6.46°. If it is not possible to measure the FMA angle in Thai patients, 7° valgus cut angle is recommended for patients with varus deformity. Variation in this angle was high. Pre-operative measurement of FMA angle is beneficial for precise TKA.*

Keywords: *Knee arthroplasty, Osteoarthritis, Femoral mechanical-anatomical angle, Femoral valgus cut, Thai*

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Osteoarthritis is the most common form of knee arthritis and has a high prevalence. It can cause significant pain, deformity, and dysfunction[1]. In cases where conservative treatment has failed, TKA is the treatment of choice. TKA can usually provide pain relief and functional improvement[2]. Unfortunately, failure after TKA occurrs in some patients. Reasons for failure include aseptic loosening, instability, infection, polyethylene wear and malalignment. Malalignment is one factor that a surgeon can prevent[3]. Neutral mechanical alignment of the knee is the goal of the TKA procedure. This can be achieved by cutting the distal femur and proximal tibia perpendicular to the mechanical axis of each bone. A TKA malalignment of more than 3 degrees can lead to a significantly higher rate of failure[4].

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A correct proximal tibial cut perpendicular to the mechanical axis of the tibia can be achieved by using an intra-operative tibial cutting guide. Pre-operative radiographic measurement is usually not required. But for the distal femur, cutting the bone perpendicular to the mechanical axis may require pre-operative radiographic measurement of the femoral mechanical-anatomical (FMA) angle (the angle formed between the femoral mechanical axis and the distal femoral diaphyseal axis) or the use of a computer navigator system[5].

Objective

To study the FMA angle in Thai patients with gonarthrosis and association of parameters of femur to the FMA angle.

Material and Method

A retrospective cross-sectional study of pre-operative standing whole limb radiographs of patients age >50 years who had been diagnosed with osteoarthritis and who had recieved treatment

by TKA at Chiang Mai University Hospital between January 2011 and December 2013 was accomplished. All patients had proper pre-operative whole limb standing radiographs including hip, knee and ankle.

The whole limb radiographs were used to measure parameters included femoral length, hip offset, femoral bowing angle, mechanical femorotibial angle and femoral mechanical-anatomical (FMA) angle (Fig. 1). The hip offset is the shortest distance between the anatomical axis of the proximal femur and the center of the femoral head (a). The femoral length is measured from the top of the femoral head to the most distal part of the medial femoral condyle (b). Femoral bowing angle is the angle formed by the intersection of the anatomical axis of the proximal half and distal half of the femur (c). The FMA angle isformed by the intersection of the anatomical axis of the distal femur and the femoral mechanical axis (the line between the center of the femoral head and the center of the distal femur) (d). The mechanical femorotibial angle is formed by the intersection of the femoral mechanical axis and the tibial mechanical axis (e).

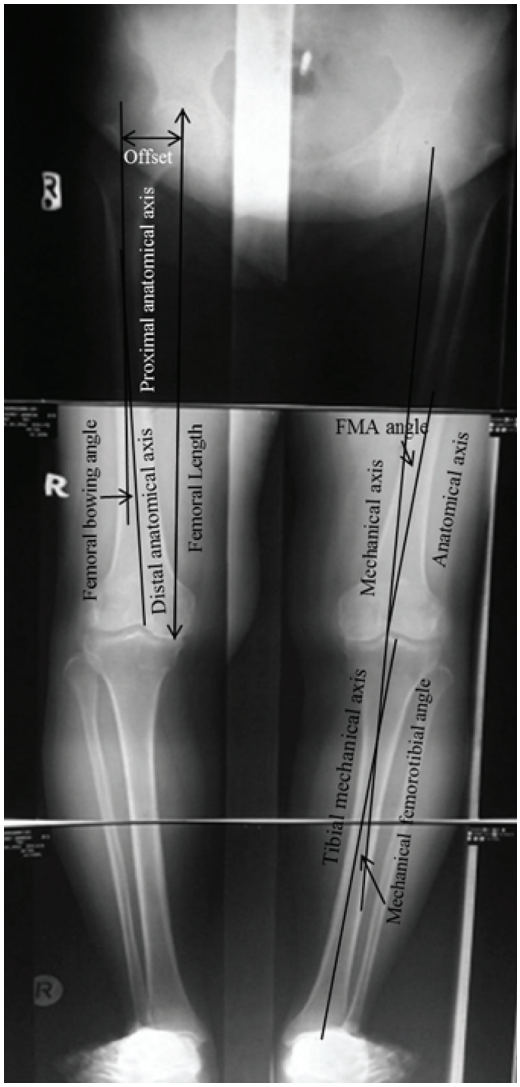

Fig. 1 Whole limb standing radiograph demonstrating hip offset, femoral length, femoral bowing angle, femoral mechanical anatomical (FMA) angle, and mechanical femorotibial angle.

Statistical analysis

Multiple regression was used to analyze factors related to femoral mechanical anatomical (FMA) angle. The analysis was considered significant when *p*-values were less than 0.05. All statistical analyses were performed with STATA software version 10.0 (Stata. Corp. LP, college station, Texas, USA).

Results

Eighty standing whole limb radiographs of 50 patients (16 males and 34 females) were studied. The mean age was 69 years (52-82 years, SD 7.644 years). The mean FMA angle was 6.46° (4°-10°, SD 1.26°). Seventy knees (87.5%) had varus deformity (medial tibiofemoral joint narrower than the lateral tibiofemoral joint). Three knees (3.75%) had neutral gonarthrosis (equal joint space narrowing). Seven knees (8.75%) had valgus deformity (lateral tibiofemoral joint narrower than medial tibiofemoral joint). Average femoral mechanical-anatomical (FMA) angle of the varus group, neutral group and valgus group were 6.85°, 5.67° and 5.28°, respectively. Twelve knees (15%) showed an FMA angle of either less than 5° or greater than 7°.

Multivariate regression analysis of the mechanical femorotibial (MFT) angle, hip offset, femoral length and femoral bowing angle showed significant correlation with the FMA angle ($p = 0.029$, 0.004, 0.002 and 0.000, respectively). Higher hip offset, femoral bowing angle, and mechanical femorotibial angle tended to correlate with higher FMA angles. However, higher femoral length tended to correlate with lower FMA angles.

Discussion

The goals of TKA are to relieve pain, improve function, and correct deformities. The ideal alignment after TKA is neutral mechanical alignment. Outliers of more than 3° can cause significant poor long term

Table 1. Variation of the femoral mechanical-anatomical angle in osteoarthritic knees among studies and world regions

Authors	Region	FMA angle, mean (range, SD)
Kharwadkar et al.[6]	UK	5.40° (range 3.3° to 7.6°, SD 0.9°)
Deakin et al.[9]	USA	5.70° (range 2° to 9°, SD 1.2°)
Bardakos et al.[8]	UK	5.60° (range 2° to 9°, SD 1.0°)
Curtin et al.[12]	USA	5.35° (range 1° to 10°)
Mullaji et al.[7]	India	7.30° (SD 1.6°)
This study	Thailand	6.46° (range 4° to 10°, SD 1.26°)
Varus deformity		6.85°
Neutral		5.67°
Valgus deformity		5.28°

FMA = femoral mechanical anatomical

results[4]. The bone cut should perpendicular to the mechanical axis of each of the bones (femur and tibia)[4]. The ideal angle of the valgus cut of the distal femur is equal to femoral mechanical-anatomical (FMA) angle.

Kharwadkar et al[6] reviewed pre-operative CT scout films of osteoarthritic knees in 83 consecutive Indian patients who presented for total knee arthroplasty. The mean FMA angle was 5.4° (range 3.3°-7.6°, SD 0.9°). Estimated 95% confidence interval of the mean for the population was 5.2°-5.6°. There were no significant differences for age, gender or laterality of the limb. He suggested routinely using 5°-6° as the distal femoral cut for an uncomplicated primary TKA.

Mullaji et al[7] used standing full-length radiographs to compare coronal femoral axes between 250 limbs in Indian patients with varus osteoarthritis with 50 healthy controls. In patients, the mean FMA angle was 7.3°±1.6° and mean femoral bow was 3.6°±2.5° compared to 5.5°±0.8° and 0.4°±1.2° in controls. Varus deformity was significantly correlated with femoral bowing (p<0.05; correlation coefficient, 0.4). Nineteen percent of the osteoarthritic limbs showed an FMA angle of more than 9°.

Bardakos et al[8] measured radiographs of 174 extremities in patients undergoing TKA. The average FMA angle, which was defined as the valgus cut angle (VCA) in this study, was 5.6° (SD 1.0°, range 2° to 9°). He also found that 30% to 51% of patients required a VCA of either less than 5° or greater than 6°. Patients with coxa valga or reduced hip offset generally require a VCA of less than 5°. Patients with coxa vara or increased hip offset generally require a VCA of greater than 6°.

Deakin et al[9] analysed 174 pre-operative hip-knee-ankle radiographs of osteoarthritic knees of 157 patients (87 female and 70 male, mean age 70 years and mean BMI 31.8). Measurements of mechanical femorotibial (MFT) and FMA angles were made. The mean FMA angle was 5.7° (SD 1.2°, range 2° to 9°). The study showed a wide distribution of FMA angles in the osteoarthritic population, males tending to have larger FMA angles than females (p<0.001). There was a statistically significant correlation between MFT and FMA angle (r = -0.499) with varus knees tending to have larger FMA angles (p<0.001). The authors concluded that a fixed valgus resection angle is not suitable for all patients and that it may be preferable to adjust the distal femoral cut according to individual FMA angles.

Tang et al[10] measured axial alignment of lower limbsin weight-bearing radiographs of twenty-five adult male and twenty-five adult female healthy volunteers of southern Chinese origin with a mean age of 24 years for the males and 23 years for the females. They found the Chinese subjects had a significantly larger medial inclination of the knee joint (knee-joint obliquity) and that the female Chinese subjects had significantly more varus alignment of the lower extremity than that reported in the white population[11].

Curtin et al[12] retrospectively reviewed 250 preoperative full-length standing radiographs in a consecutive series of TKAs. Mean FMA angle was 5.35°, range 1° to 10°. They concluded that routine relianced on a single fixed resection angle could result in malalignment in 10% of patients.

The present study found a wide range of femoral mechanical-anatomical (FMA) angles (4°-10°, SD 1.26°) among patients with gonarthrosis, with an average of 6.46°. Patients with varus deformity showed a higher FMA angle than patients with straight or valgus deformity. The average femoral

mechanical-anatomical angle (FMA) of the varus group (70 knees) was 6.85°. The mean FMA angle of the straight knee group (3 knees) was 5.67°. The final group, those with valgus gonarthrosis (7 knees), had an average FMA angle of 5.28°. Measurement of the FMA angle of each knee is important for achieving accurate alignment of the lower extremity after TKA. However, if no pre-operative whole limb radiography, whole femur radiography, CT scan, or computer navigator systemis available, a 7° valgus cut angle is recommended for patients with varus deformity, a 6° valgus cut angle for patients with straight knees, and a 5° valgus cut angle for patients with valgus deformity in Thai patients with gonarthrosis.

Many factors affect the coronal alignment of the lower extremities including gender, age, race, femoral geometry, and hip defromity. Chinese people have more obliquity of the knee compare to whites[10]. Studies from India[7] and China[10] showed that Asian people tend to have a higher femoral mechanical-anatomical (FMA) angle than the white population[11,12]. This finding was also confirmed in Thai people by this study (Table 1).

Multivariate regression analysis found that the FMA angle was significantly correlated with the mechanical femorotibial (MFT) angle, hip offset, femoral length and femoral bowing angle (p = 0.029, 0.004, 0.002 and 0.000, respectively). In most provincial hospitals in Thailand, cassettes for whole limb radiographs are usually not available as the cost of computerized tomography and computer navigator systems are usually high. If whole femur radiography is available, the FMA angle can be measured.

Conclusion

The average FMA angle of Thai patients with gonarthrosis was 6.46° (4°-10°, ±1.26°), 6.85° for varus deformity, and 5.28° for valgus deformity. There was variation among patients. Fifteen percent showed a FMA angle either less than 5° or greater than 7°. Before performing TKA, the FMA angle of each knee should be measured. If it is not possible to measure the FMA anglein Thai patients, the use of a 7° valgus cut angle for patients with varus deformity, 6° valgus cut angle for patients with straight knees, and 5° valgus cut angle for patients with valgus deformity with gonarthrosis is suggested.

Limitation of the study

The study included only seven knees with valgus deformity. This number is probably not enough to be representative of the population of valgus gonarthrosis. Further study in a larger group of patients with that deformity may be needed.

What is already known on this topic?

Average FMA angle in Cauacsian was 5-6 degrees valgus.

What this study adds?

Average FMA angle was 6.46° (range 4°-10°, SD 1.26°). The FMA angle was 6.85° and 5.28° in Thai patients with varus and valgus deformity, respectively.

This study demonstrated that the fixed angle distal femoral valgus cut; 5 or 6 degrees, which is popular in Caucasian is not always appropriate for Thai patients.

Measurement of FMA angle is beneficial for precise total knee replacement.

If FMA angle cannot be measured, 7 degrees valgus cut is recommended for patients with varus osteoarthritic knees.

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Potential conflicts of interest

None.

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ค่ามุมระหว่าง mechanical axis และ anatomical axis ของกระดูกต้นขาในผู้ป่วยข้อเข่าเสื่อม

วรากร จริงจิตร, ภาคภูมิ ภูมิเจริญ, สักกาเดช ลิ้มมหากุล, กสิสิน กลั่นกลิ่น, ธนินนิตย์ ลีรพันธ์, สัตยา โรจนเสถียร

ภูมิหลัง: *ในการผ่าตัดเปลี่ยนข้อเข่าเทียม ศัลยแพทย์บางคนนิยมตัดกระดูกส่วนปลายกระดูกต้นขาด้วยมุมคงที่ในผู้ป่วยทุกราย เช่น valgus 5 หรือ 6 องศา ซึ่งมุมนี้อาจเหมาะสมกับผู้ป่วยบางรายแต่อาจไม่เหมาะสมกับผู้ป่วยทุกราย*

วัตถุประสงค์: *เพื่อหาค่ามุม femoral mechanical-anatomical (FMA) angle ที่เหมาะสมในผู้ป่วยข้อเข่าเสื่อม*

วัสดุและวิธีการ: *การศึกษาประเภท cross-sectional study แบบย้อนหลังในผู้ป่วยข้อเข่าเสื่อม อายุ 50 ปีขึ้นไป ที่ได้มารับการผ่าตัดในโรงพยาบาล มหาราชนครเชียงใหม่ และมีภาพรังสีแบบทั้งขา (whole limb radiograph) ที่เหมาะสมศึกษาหาค่า femoral mechanical-anatomical (FMA) angle และปัจจัยที่มีผลต่อมุมนี้ได้แก่ เพศ, อายุ, femoral length, hip offset, femoral bowing angle, mechanical femorotibial (MFT) angle วิเคราะห์ข้อมูลด้วยวิธี multivariated regression analysis*

ผลการศึกษา: *ในผู้ป่วย 50 ราย จำนวน 80 เข่า อายุเฉลี่ย 69 ปี (52-82 ปี) มีค่า FMA angle เฉลี่ย 6.46 องศา (กลุ่มเข่าโก่ง 6.85 องศา กลุ่มเข่าตรง 5.67 องศา กลุ่มเข่าฉิ่ง 5.28 องศา) ปัจจัยที่มีผลบวกต่อ FMA angle คือ MFT angle ($p = 0.029$), hip offset ($p = 0.004$), และ femoral bowing angle ($p = 0.000$) ปัจจัยที่มีผลลบต่อ FMA angle คือ femoral length ($p = 0.002$)*

สรุป: *ค่าเฉลี่ยของ FMA angle ของคนไทยที่เป็นข้อเข่าเสื่อมคือ 6.46 องศา (พิสัย 4-10 องศา) เพื่อให้ได้แนวขาที่ดีในการผ่าตัดเปลี่ยนข้อเข่าเทียม แพทย์ควรวัดค่ามุม FMA angle ก่อนการผ่าตัด หากไม่สามารถวัดค่ามุม FMA angle ได้ ควรตัดส่วนปลายกระดูกต้นขา ทำมุมกางออก 7 องศาในกรณีเข่าโก่ง 6 องศาในกรณีเข่าตรง และ 5 องศาในกรณีเข่าฉิ่ง*
