The Rotational Axis of The Tibia and Relationship to The Tibial Torsion in Varus Osteoarthritic Knee

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Background: *A transepicondylar axis is a useful reference for femoral component rotation and is demonstrated as a functional flexion-extension axis of a knee. Conversely, a rotational orientation of the tibial component was less clearly demonstrated and many anatomical landmarks were proposed. It has been reported that Asian people had more medial torsion of the tibia particularly with an osteoarthritic knee. The present study aims to address the relationship between the torsion variation of the tibia and the rotational axis of the tibia.*

Material and Method: *Forty knees of 32 women (mean age of 73.3) with varus osteoarthritis underwent a preoperative CT images to identify a surgical epicondylar axis, an axis perpendicular to this line (femoral reference line), lines connecting between the PCL insertion and 3 reference point on the patellar tendon, an AP axis of the ankle and a tibial torsion angle.*

Results: *The mean value of the angle between the line connecting the PCL insertion and 3 different point of the patellar tendon including the medial border, medial one-third and middle of the patellar tendon and the femoral reference line was -4.22, +4.37 and +8.47 degree, respectively. The mean of a tibial torsion angle was +16.51 degree. There were 6 cases having the femoral reference line rotated internally to the medial border of the patellar tendon and having less torsion angle (medial tibial torsion) with a mean of +13.78 degree.*

Conclusion: *The femoral reference line in the Thai osteoarthritic knee is passed between medial edge of patellar tendon and medial 1/3 of patellar tendon. This line rotates more internally compared with the patellar tendon if the degree of medial tibial torsion is more severe. An excessive externally rotated tibial component when using the patellar tendon as guidance should be avoided in the knee presenting with medial tibial torsion.*

Keywords: *Rotational axis of tibial component, Tibial torsion, Transepicondylar axis, Total knee arthroplasty*

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During total knee arthroplasty, the transepicondylar axis has been shown to be useful as an anatomic reference axis and it has been demonstrated as a functional flexion-extension axis of a knee as well[1-3]. It has been reported that if the femoral component was aligned parallel to the transepicondylar axis, it has resulted in an optimum patellofemoral tracking, minimized femorotibial wear motion and instability[4,5]. However, a correct rotational orientation of the tibial component was less clearly demonstrated. There are many anatomical landmarks including a medial one third[6], center of the tibial tubercle[4], mediolateral axis of the tibial plateau and extra-articular landmarks such as transmalleolar axis and a second metatarsus bone axis[7] that are used to set the axial rotation of the tibial component. Therefore, if the tibia has anatomical variations, the landmarks may not be reliable to determine the tibial component rotation.

It has been reported that asian people had a tendency of medial tibial torsion which the distal tibia was internally rotated relative to the proximal tibia (Fig. 1). It may associate with asian life style that a deep-flexion of the knee is frequently performed during daily activities[8-10]. The position of the tibial tubercle and degree of tibial torsion varied by individual and was more prominent particularly in patients with pathology such as osteoarthritic knee and patellofemoral instability[11-13]. There are few reports in the literature that address the relationship between the torsional variation of the tibia and the rotational axis of tibia which is applied for the prosthesis aligning in total knee arthroplasty.

The objective of the present study was to compare the angle between an AP axis of the tibia defined as a line perpendicular to the transepicondylar

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Fig. 1 Medial torsion of the tibia was demonstrated with the tibial tubercle relatively moving outward, otherwise the feet moving inward

axis of the femur and other AP orientation determined by a line connecting the center of the PCL insertion to different landmarks of the patellar tendon by using the CT scan. The relationship between the degree of torsion of the tibia and the rotational axis of the tibia was also investigated.

Material and Method

The patients with varus osteoarthritis who were scheduled to undergo a total knee arthroplasty were enrolled. The knee with previous traumatic deformity and hardware implantation was excluded. Forty knees of 32 women (mean age of 73.3 $\pm$ 6.3 years, range between 60 to 84 years old) were included to have a radiograph and a preoperative CT scan. A femorotibial angle was measured in a standing AP long film radiograph and was defined as the angle between the longitudinal axis of the femur and the tibia. An accurate AP view of the knee was obtained by avoiding external rotation of the lower leg especially in patients with severe varus deformity and flexion contracture. Severity of osteoarthritis was classified with Alhback's classification.

The preoperative CT images were obtained with Philips Medical System software (Koninklijike Philips Electronics NV). The scan direction was aligned perpendicular to the longitudinal axis of the tibia with 0.9 mm thickness at the area of the knee and ankle. The imaging slice in which the lateral epicondylar prominence and the sulcus of medial epicondylar prominence could be clearly identified was selected for determining a surgical epicondylar axis (SEA) that was the line drawn connecting the sulcus of the medial epicondyle and the lateral epicondyle. A posterior condylar axis (PCA) was defined as a line connecting between the posterior aspect of the femoral condyles. The angle between the SEA and the PCA was measured and the angle was defined as a minus value when the PCA was rotated internally relative to the SEA (Fig. 2A). Line A-B was the femoral reference line, which was perpendicular to the projection of surgical epicondylar axis and superimposed onto the tibia (Fig. 2B).

The tibial slice was done at 6-8 mm below the lateral tibial plateau surface that represented an osteotomy level in the proximal tibia during performing the TKA. Because of tibial tubercle was not clear to identify, the author would define the rotation position of the tibial component relative to the patellar tendon. The patellar tendon was used as an anterior aspect reference for tibial component rotation with a measurement tool in CT images program. The patellar tendon was clarified into 3 region consisted of just medial, medial 1/3 and middle. The PCL insertion was recognized in every knee and the center of the PCL was used as a posterior aspect reference for the tibial component rotation (Fig. 3). All 3 lines were compared to the line A-B and it was expressed as minus value if the line was rotated internally relative to the line A-B.

At the ankle level, the CT slice that clearly traversed both malleoli and talus was selected. A line C-D connecting anterior aspect of bimalleolar was determined and line D-E that defined as an AP axis of the ankle was drawn perpendicular to the projection of line C-D (Fig. 4). The angle between line D-E and the line that connected between middle point of patellar tendon and PCL insertion was measured to represent the degree of tibial torsion. When the line D-E was rotated internally relative to the line connecting between the middle of patellar tendon and the PCL insertion, the angle was expressed as minus value.

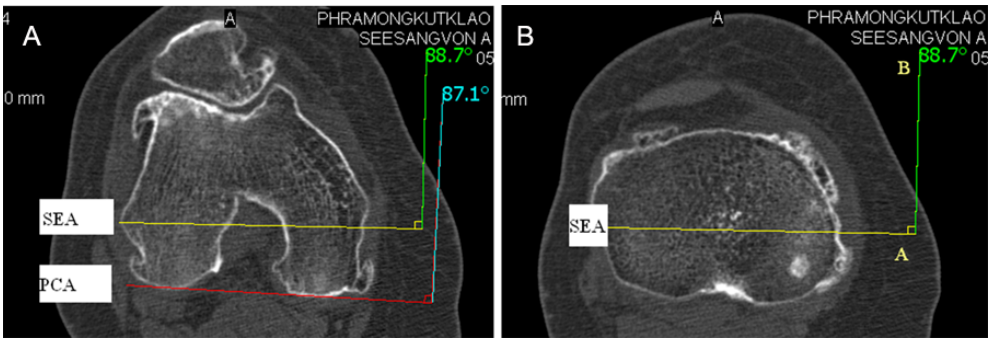


Fig. 2 A) The surgical epicondylar axis (SEA) and the posterior condylar axis (PCA). B) Line A-B,The femoral reference line superimposed onto the tibial plateau

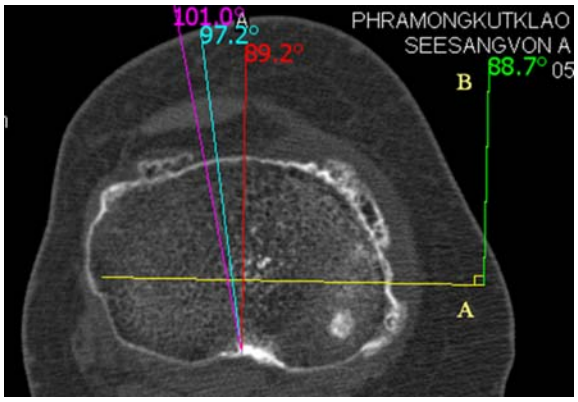


Fig. 3 Comparison between the femoral reference line (line A-B) to other rotational landmarks of the tibia

All measurements were repeated by two independent orthopaedics surgeons. The mean value of the two observer's measurements for each knee was used for analysis.

Results

The femorotibial angle was 4.6 ± 3.67 degree in valgus and all knees were in Alhback's classification stage 5.

The mean value of the angle between the line connecting the center of the PCL insertion and 3 different point of the patellar tendon including the medial border, medial one-third and middle of the patellar tendon and the femoral reference line (line A-B) was -4.22, +4.37 and +8.47 degree, respectively (Table 1).

Degree of the tibial torsion was defined as an angle between the middle part of the patellar tendon axis and the AP axis of the ankle (line D-E). It was expressed as a positive value if the AP axis of the ankle was rotated externally relative to the middle part of the patellar tendon axis and the mean value was +16.51 degree (range, +3.6 degree to +30.7 degree). There were 6 cases having the line connecting the PCL insertion and the medial border of the patellar tendon was externally rotated to the femoral reference line (line A-B) with the mean value of +2.3 degree (range, +1.2 degree to +3.5 degree) (Table 2). These knees had less torsion angle (medial tibial torsion) with a mean of

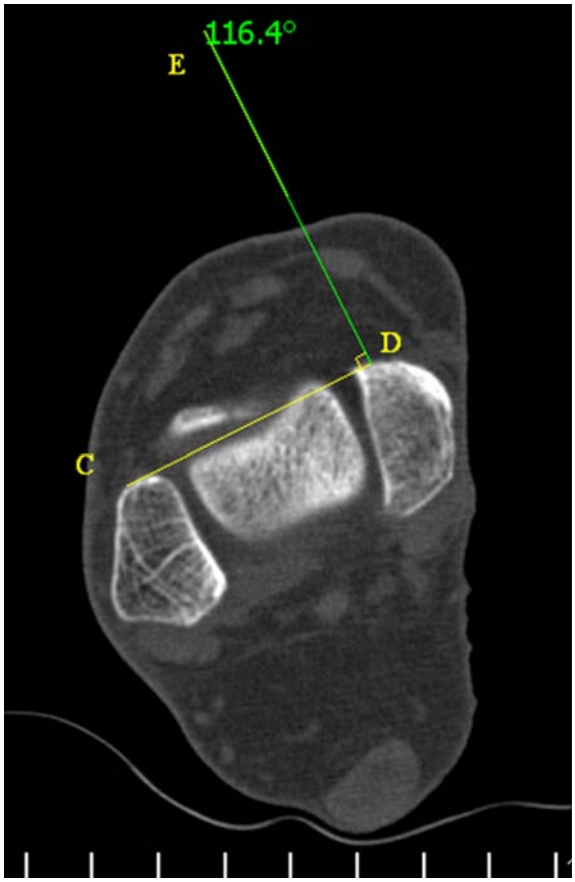


Fig. 4 AP axis of ankle (line D-E)

Table 1. Result of the Angular Measurements (degree) of 40 knees

	PCA and SEA	Medial border of patellar tendon and femoral reference line	Medial 1/3 of patellar tendon and femoral reference line	Middle of patellar tendon and femoral reference line	Ankle axis and middle of tibial tubercle
Mean angle 1 (SD)	-1.52 (± 2.45)	-4.22 (± 4.74)	+4.37 (± 4.95)	+8.47 (± 4.87)	+16.51 (± 6.09)

* negative value of the angle means that the axis is internally rotated to the femoral reference axis

Table 2. Result of the Angular Measurements (degree) of 6 knees that the femoral reference line located medial to the border of the patellar tendon

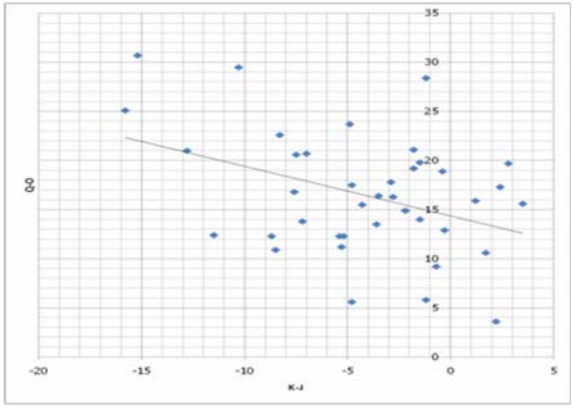
	PCA and SEA	Medial border of patellar tendon and femoral reference line	Medial 1/3 of patellar tendon and femoral reference line	Middle of patellar tendon and femoral reference line	Ankle axis and middle of tibial tubercle
Mean (degree) (SD)	-1.07 (± 2.32)	+2.30 (± 0.81)	+11.27 (± 2.27)	+14.65 (± 2.08)	+13.78 (± 5.81)

* negative value of the angle means that the axis is internally rotated to the femoral reference axis

+13.78 degree.

The relationship between the degree of the tibial torsion and the angle between the femoral reference axis and the medial border of the patellar tendon axis was shown in Fig. 5. The femoral reference line was more internally rotated comparing to the medial border of the patellar tendon if the tibial torsion angle decreased.

The mean angle between PCA to SEA was -1.52 degree (range, -5.5 to +2.4 degree) and there was no correlation with the femorotibial angle (p-value = 0.23). The angle between the medial border of the patellar tendon and the femoral reference line (line A-B) and the torsion angle had no correlation with the femorotibial angle (p-value = 0.49, 1.00, respectively) as well.



X axis: angle between the femoral reference axis and the medial of the patellar tendon axis. Y axis: angle between the AP axis of the ankle and middle of the tibial tubercle

Fig. 5 The Relationship between the tibial torsion angle and the angle between the femoral reference axis and the medial border of the patellar tendon axis

Discussion

As a reflection of the traditional focus on axial alignment, many reports have addressed the proper rotational alignment of the prosthesis and also identified its correlation with the risk of failure and revision of total knee arthroplasty. The transepicondylar axis has been well described and also reported as a useful reference to optimize the femoral component positioning and patellofemoral articulation[5,14]. Asano et al[3] studied an *in vivo* functional flexion-extension axis of the knee with a three dimensional knee model constructed by CT scan in healthy males performing 0-90 degree of knee flexion under weight-bearing situation. The authors demonstrated that this axis passed through the sulcus of medial epicondyle and lateral epicondyle of the femur (surgical epicondylar axis). Many authors proposed a proper rotational axis of the tibial component based on this functional flexion-extension axis.

Akagi et al[15] studied the anteroposterior axis of the tibia in 20 healthy men (mean age of 38.4 years)

and 19 healthy females (mean age of 42.2 years) with the computed tomography. They demonstrated that the mean angle between the anteroposterior axis of tibia that was perpendicular to the transepicondylar axis and a line drawing from the middle of the PCL insertion to the medial edge of patellar tendon was 0.0 $\pm$ 2.8 degree. The angle between the anteroposterior axis of tibia and a line drawing from the middle of the PCL insertion to the medial 1/3 of the patellar tendon was 10 $\pm$ 4.2 degree that inferred as more externally rotated. Aglietti et al[16] reported a corresponding result that the angle between Akagi's line and the perpendicular line to transepicondylar axis in 100 patients with osteoarthritic knee was 0.1° $\pm$ 3.3° in males and 0.0° $\pm$ 3.9° in females. With large standard deviations, they stated to consider an individual variability using the Akagi's line. In the present study, the perpendicular line to transepicondylar axis or the femoral reference line is passed between medial edge of patellar tendon (just medial) and medial 1/3 of patellar tendon and the femoral reference line was about 4 degree away from both axes. It could be tibio femoral component mismatch about 4 degree if both tibial landmarks was used in the present population.

The present study demonstrated that the knee with the medial tibial torsion showed the tendency of the tibial tubercle moving outward from the femoral reference line (Fig. 5). Six knees (15% of 40 knees) in the present study with the torsional angle of +13.78° ($\pm$ 5.81) had the femoral reference line internally rotated to the medial edge of patellar tendon and medial 1/3 of patellar tendon about 2.3 and 11 degree, respectively. If the surgeon set the tibial component rotation according to the tibial tubercle in these knees, it may bring the tibial component too much externally rotated. Nagamine et al[17] studied the result of computed tomography in 24 knees with medial tibio femoral osteoarthritis and 28 normal knees and also stated that the foot would be extremely internally rotated if the medial 1/3 of the tibial tuberosity was used to set the tibial component rotation in patient with severe medial torsion. They proposed that the angle between ankle AP axis and middle of the tibial tubercle axis less than 15 degree should be cautious for the intoeing foot following total knee arthoplasty which might cause a high shear stress between the tibio femoral articulation. Alternatively, surgeons might not encounter with the anatomical variation problem of the tibia if the self align technique for setting the tibial component rotation was applied. Otherwise, a mobile bearing surface of the total knee arthroplasty could be a useful option.

From the present study, it could be concluded that the perpendicular line to transepicondylar axis in the Thai osteoarthritic knee passed between the medial edge of patellar tendon and the medial 1/3 of patellar tendon. This line move more internally compared to the tibial tubercle if the degree of medial tibial torsion is more severe. The surgeon should be careful of applying the tibial component too much externally rotated in this situation when using the patellar tendon or tibial tubercle as the guidance.

Potential conflicts of interest

None.

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แกนของ Tibial ในระนาบของการหมุนและความสัมพันธ์ต่อการบิดหมุนของกระดูก tibia ในข้อเข่าเสื่อมชนิด varus

ธไนนิธย์ โชตนภูติ, รัฐศิริ ศรีสวัสดิ์, ปิติ รัตนปรีชาเวช, อาทิตย์ เหล่าเรืองธนา

วัตถุประสงค์: *เนื่องจากแกนอ้างอิงสำหรับการวางตำแหน่งของ tibial component ในระนาบของการหมุนนั้นยังมีความไม่แน่ชัดสำหรับการผ่าตัดเปลี่ยนข้อเข่าเทียม การศึกษานี้จึงทำเพื่อเปรียบเทียบความสัมพันธ์ระหว่างแกนในระนาบของการหมุนของ tibia ที่อ้างอิงตามกายวิภาคของหัวเข่าแบบต่างๆ และความสัมพันธ์กับการบิดหมุนของกระดูก tibia (torsion of tibia)*

วัสดุและวิธีการ: *ทำการศึกษา CT scan ในข้อเข่าจำนวน 40 เข่า จากผู้ป่วยหญิง 32 ราย ที่มีข้อเข่าเสื่อมชนิด varus deformity อายุเฉลี่ย 73.3 ปี โดยทำการกำหนดแกน surgical epicondylar axis (SEA) จาก CT scan แล้วลากเส้นตั้งฉากกับแกนนี้เป็นไว้เป็นเส้นอ้างอิง (femoral reference line) เพื่อทำการเทียบกับแนวแกนของ tibia ในระนาบของการหมุนเมื่อกำหนดด้วยวิธีอื่น ๆ*

ผลการศึกษา: *ผลจากการศึกษาแกนอ้างอิงแบบต่าง ๆ ของ tibial component ในระนาบของการหมุนในข้อเข่าจำนวน 40 เข่า พบว่าแกนอ้างอิงที่เชื่อมระหว่างจุดเกาะของ PCL กับขอบด้าน medial ของเอ็นลูกสะบ้า, medial one-third, และ middle of the patellar tendon มีการทำมุมกับ femoral reference line เฉลี่ยเท่ากับ -4.22, +4.37 และ +8.47 ตามลำดับ ทั้งนี้มีข้อเข่าจำนวน 6 รายที่พบว่า femoral reference line จะมีการมุมไปในทิศทาง internal เมื่อเทียบกับขอบด้าน medial ของเอ็นลูกสะบ้า โดยจะทำมุมเฉลี่ย +2.30 องศา และพบว่าการบิดหมุนของกระดูก tibia ในข้อเข่ากลุ่มนี้มีค่าเฉลี่ยเท่ากับ +13.78 องศา ซึ่งแสดงถึงลักษณะของ medial tibial torsion เมื่อเทียบกับการบิดหมุนของกระดูก tibia ในข้อเข่าทั้งหมด 40 ราย ซึ่งมีค่าเฉลี่ยเท่ากับ +16.51 องศา*

สรุป: *ศัลยแพทย์จึงควรระมัดระวังการวาง tibial component ไปอยู่ในตำแหน่งที่มีการหมุนไปในทิศทาง external มากเกินไปหากว่าใช้เอ็นลูกสะบ้าหรือ tibial tubercle เป็นจุดอ้างอิงโดยเฉพาะอย่างยิ่งในกรณีที่ข้อเข่านั้นๆ มีลักษณะของ medial tibial torsion*