The Relationship of Anteroposterior, Transepicondylar and Posterior Condylar Axis of the Femur: A Thai Cadaveric Study Using Digital Measurement

Sukit Saengnipanthkul MD*, Chatchawal Sarntipiphat MD*,
Amnart Chaichoon MD**, Gowit Chaisiwamongkol MD**

** Department of Orthopedics, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand*
*** Department of Anatomy, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand*

Objective: *To study the normal relationship of the anteroposterior (AP), transepicondylar (TE) and posterior condylar (PC) axis of cadaveric femoral bones using digital technology and special computer program.*
Material and Method: *Digital image of distal femur of 100 cadaveric bones of both sides and both sexes were taken using a special stand and clamp to ensure the same view and same distance from bone to camera. All still images were transferred into a specially developed computer program, then reference points were located by two observers, and were done twice at one week interval. The program reported the angle between AP-TE, AP-PC and TE-PC axes automatically. The data was then analyzed.*
Results: *The age of donor cadaveric bones ranged from 22 to 58 years (average 45.61 $\pm$ 7.73). The AP-TE, AP-PC and TE-PC angles were 92.43 $\pm$ 2.07, 86.65 $\pm$ 1.85 and 5.79 $\pm$ 1.26, respectively. The correlation coefficients of intra-observer reliability in observer 1 were 0.89, 0.87 and 0.91; in observer 2 were 0.92, 0.90 and 0.87. The correlation coefficients of inter-observer reliability were 0.81, 0.82 and 0.80. Limit agreement tests of AP-TE, AP-PC and TE-PC were 90.59%, 92.57% and 96.03%, in that order.*
Conclusion: *Using digital technology, the normal relationship of AP, TE and PC axes of femur from cadaveric bone could be more accurately studied comparing with the previous studies performing measurement on plain film, CT scan or MRI using goniometer.*

Keywords: *Cadaver, Femur, Distal femoral axis, Cadaveric study, Digital measurement*

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The anteroposterior (AP), transepicondylar (TE) and posterior condylar (PC) axis of the femur (Fig. 1) are important reference axes commonly used to determine correct rotational alignment of femoral component in total knee arthroplasty. Although the TE axis was found to be a reliable landmark to properly rotate the femoral component[1], the palpation of epicondyle, especially medial epicondyle, to correctly locate the exact site during the operation was sometimes difficult[2] and caused error in the determination of this axis. The observation of PC axis could be more simple but malformed medial or lateral condyle in severely deformed knee affected this axis[3]. The same precaution with the use of AP axis in knee with femoral trochlear dysplasia or valgus deformity.

Knowing the normal relationship of the AP, TE and PC axes can be helpful to the surgeon in selecting one or more than one appropriate reference axis to properly rotate the femoral component in any particular knee during the operation. Review of the literature found that there were some reports on this topic, but were studies in osteoarthritic knees during the procedure of arthroplasty[1,4], most of which could have deformed bone so the result might not represent the normal relationship. The study of these reference axis by measuring on plain film[5], CT scan[4,6] or MRI film[3] could be inaccurate due to the fact that the CT scan or MRI film used for the measurement might not

Correspondence to: Saengnipanthkul S, Department of Orthopaedics, Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand. Phone: 0 8961 93319, Fax: 0 4334 7988. E-mail: sukit@kku.ac.th

be the exact cut through the correct cross-section of both epicondyle or both posterior condyles.

The authors studied the relationship of the AP, TE and PC axes in cadaveric bones using digital technology instead of using manual measurement with goniometer.

Material and Method

One hundred dry cadaveric femoral bones without deformity or abnormality at the distal part of both sexes, both sides, from donors, aged between 20 to 60 years, were included in the present study. A special frame and stand (Fig. 2) was designed and made for the present study to ensure the placement of the bone at the same distance (30 cms) from the digital camera. The leveling meter was used to adjust each distal femur to the same position (Fig. 3) (parallel to the floor) before the picture was taken at the resolution of 3.1 megapixels.

The measurement of angles

All the images were transferred to a special computer program designed for the present study. The observer was assigned to 6 reference points on the deepest part of the femoral trochlear, the center of the intercondylar notch, the most prominent points of the medial and lateral epicondyles and the most posterior projections of the medial and lateral femoral condyles, respectively (Fig. 4). The program automatically drew lines connecting the points and measured the angle between AP-TE, AP-PC and TE-PC axis (Fig. 5). The measurement was done twice, one week apart, by two independent observers, at different times.

Statistical analysis

The relationship of AP-TE, AP-PC and TE-PC axes was analyzed and reported as average angle. Analysis to find Pearson's correlation coefficient and limit agreement test were also done to demonstrate the intra and inter observer reliability and agreement between the two observers.

Results

The age of the donors of the cadaveric bones ranged from 22 to 58 years (average 45.61 $\pm$ 7.73). The relationship of the AP, TE and PC axes of femur, the AP-TE, AP-PC and TE-PC angles are 92.43 $\pm$ 2.07, 86.65 $\pm$ 1.85 and 5.79 $\pm$ 1.26 degrees, respectively. The correlation coefficients of intra-observer reliability (for each angle measurement) in observer 1 were 0.89, 0.87 and 0.91; in observer 2 were 0.92, 0.90 and 0.87, respectively. The correlation coefficients of inter-observer reliability were 0.81, 0.82 and 0.80, respectively. The agreement tests of the two observers (limited to less than 2-degree difference) were 90.59%, 92.57% and 96.03%, respectively.

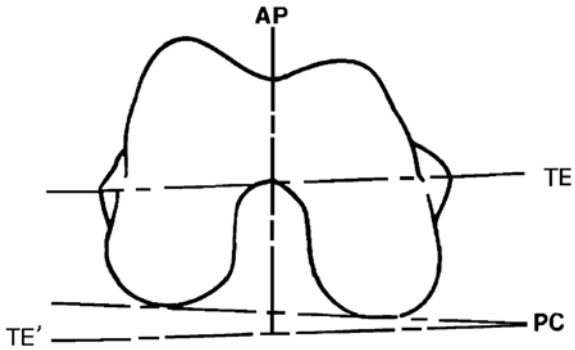

Fig. 1 Alignment axes in normal condylar shape: antero-posterior axis (AP) transepicondylar axis (TE) with parallel line (TE') and posterior condylar axis (PC)

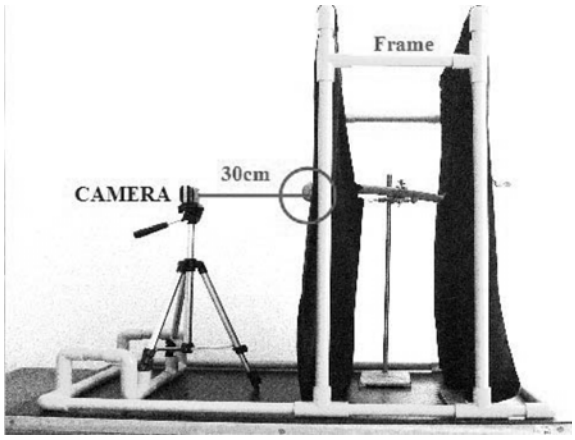

Fig. 2 Special frame and stand

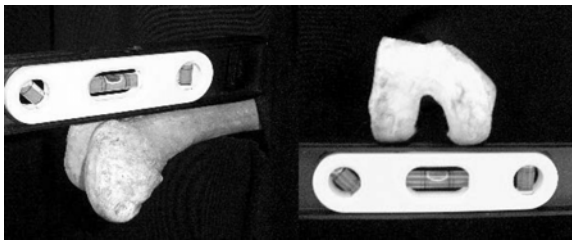

Fig. 3 The leveling meter was used to adjust each distal femur to the same position

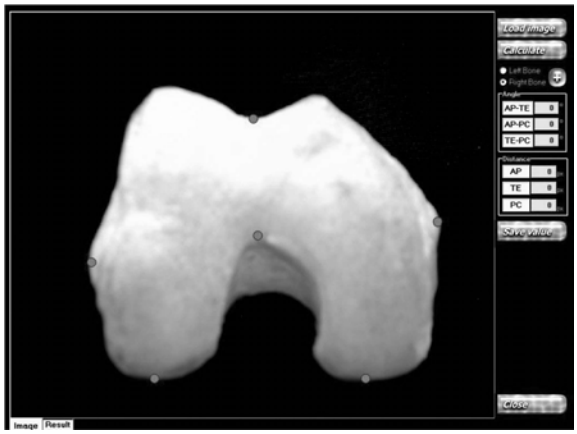

Fig. 4 Six reference points were located by the observer

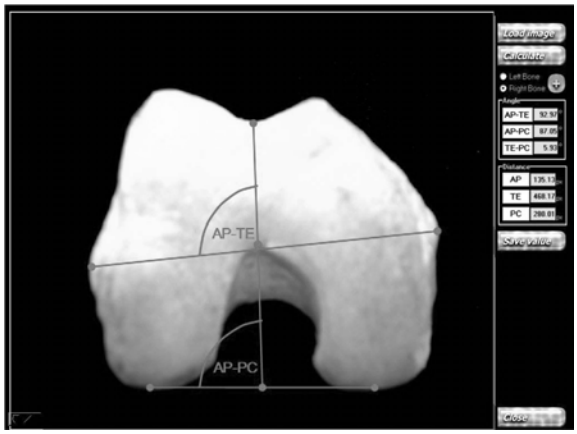

Fig. 5 The computer program automatically connects AP, TE and PC lines, and measurement of AP-TE, AP-PC and TE-PC angles are automatically reported

Discussion

Rotation alignment of the femoral component in total knee arthroplasty is critical for the outcome of the surgery[7,8]. Malrotation of the femoral component on the femur may lead to patellofemoral dislocation or subluxation[2,9], to wear or loosening of the patellar component[10].

Although there are many reports on the relationship of the AP-TE, AP-PC and TE-PC axes in the literature, it is noted that the reported angles vary which might be explained by the difference in methodology of each study. The study in normal, or osteoarthritic or deformed (varus, valgus) knees, should show variations in results. Measurement on bone during arthroplasty, measurement on dissected cadaveric bone or measurement on MRI film, also could be different in accuracy.

Poilvache et al[1] reported their study on 100 arthritic knees undergoing a total joint replacement, using goniometer to measure the AP-TE, AP-PC and TE-PC angle, as follows, 90.33 $\pm$ 2.44, 86.92 $\pm$ 2.71 and 3.60 $\pm$ 2.02 degrees, respectively. The study of Masuda et al[3] evaluating femoral condyle geometry in 30 normal and 30 varus knees using magnetic resonance imaging showed the AP-PC and TE-PC angles of 83.70 $\pm$ 2.44, 6.03 $\pm$ 3.60 degrees in normal knees, 83.43 $\pm$ 2.54 and 6.00 $\pm$ 2.35 degrees in varus knees (no report on AP-TE angle). These two studies are examples reflecting the different results of study in arthritic bone by visual measurement and normal or varus knees by measurement on MRI film. Apart from the slight difference in the AP-PC and TE-PC angles, the standard derivations of both studies are quite wide, reflecting the accuracy of measurement. Arima's study[2] in 30 normal cadaveric femora demonstrated clearly the difference between visual and radiographic measurement of the same group of specimens using a goniometer. The AP-PC and TE- PC angles by visual measurement were 86.2 $\pm$ 2.0 and 4.4 $\pm$ 2.9 degrees, by radiographic measurement were 86.9 $\pm$ 1.7 and 5.7 $\pm$ 1.7 degrees. The standard derivation of radiographic measurement is obviously less than visual measurement.

Using digital technology and a specially developed computer program to study the relationship of AP, TE and PC axes in normal cadaveric femora in the present study can assure the minimal error of measurements. The possible error can occur at the step of locating the reference point on the image prior to the processing of the program. The standard deviation of each angle in the present study is considerably less than the previous studies in the literature. The correlation coefficients of intra and inter observer reliability are acceptably high and the limit agreement test is higher than 90%.

The normal relationship of the AP, TE and PC axes is helpful to surgeons when performing total knee arthroplasty. Via standard exposure of knee with severe deformity, multi-reference axes should be used rather than relying on a single axis of reference to properly rotate the femoral component. With minimally invasive technique of knee arthroplasty, the small incision usually limits visualization of TE[11] and PC axes and can increase the risk of component malalign-ment[12]. Knowing the normal relationship

of AP-TE and AP-PC axes can assure the surgeon in aligning the femoral component using only AP axis.

Conclusion

The normal relationship of AP, TE and PC axes of normal cadaveric femora was studied using digital technology. The result obtained should be more accurate compared with the previous studies on arthritic or deformed bone using visual or radiographic measurement.

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การศึกษาความสัมพันธ์ของแนวแกนแอนทีโรโพสทีเรีย, ทรานส์อิพิคอนดัยและโพสทีเรียคอนดัยของกระดูกฟีเมอร์จากศพคนไทยโดยใช้การวัดดิจิตัล

สุกิจ แสงนิพันธ์กูล, ชัชวาล ศานติพิพัฒน์, อำนาจ ไชยชุน, โกวิท ไชยศิวามงคล

วัตถุประสงค์: *เพื่อศึกษาความสัมพันธ์ของแนวแกนแอนทีโรโพสทีเรีย (AP), ทรานส์อิพิคอนดัย (TE) และโพสทีเรียคอนดัย (PC) ของกระดูกฟีเมอร์ปกติโดยการใช้เทคโนโลยีดิจิตัลและโปรแกรมคอมพิวเตอร์*

วัสดุและวิธีการ: *ภาพถ่ายดิจิตอลของส่วนปลายกระดูกฟีเมอร์ จำนวน 100 ชิ้น ซึ่งถ่ายบนอุปกรณ์ยึดจับที่สร้างขึ้นเพื่อให้ภาพที่ได้รับอยู่ในแนวระนาบเดียวกัน ตำแหน่งเดียวกัน แล้วนำภาพถ่ายดิจิตอลที่ได้ย้ายลงในโปรแกรมคอมพิวเตอร์ ซึ่งเขียนขึ้นเพื่อการวัดมุมข้างต้นโดยเฉพาะ ผู้วัด 2 คน จะทำการกำหนดจุดอ้างอิง ลงบนตำแหน่งต่าง ๆ ในภาพ ต่างวาระกัน และแต่ละคนทำการกำหนด 2 รอบ ในระยะห่างกัน 1 สัปดาห์ โปรแกรมจะทำการอ่านค่ามุม AP-TE, AP-PC และ TE-PC โดยอัตโนมัติ จากนั้นนำข้อมูลที่ได้มาวิเคราะห์ทางสถิติ*

ผลการศึกษา: *อายุของเจ้าของกระดูกที่ถูกนำมาศึกษาอยู่ระหว่าง 22 ถึง 58 ปี (เฉลี่ย 45.61 $\pm$ 7.73) มุม AP-TE มีค่าเฉลี่ย 92.43 $\pm$ 2.07 องศา มุม AP-PC มีค่าเฉลี่ย 86.65 $\pm$ 1.85 องศา มุม TE-PC มีค่าเฉลี่ย 5.79 $\pm$ 1.26 องศา*

ค่าสัมประสิทธ์ความสัมพันธ์ของการวัดมุม ภายในผู้กำหนดจุดวัดมุมคนแรก เท่ากับ 0.89, 0.87 และ 0.91 ตามลำดับ และคนที่สอง เท่ากับ 0.92, 0.90 และ 0.87 ตามลำดับ ค่าสัมประสิทธ์ความสัมพันธ์ของการวัดมุมระหว่างผู้กำหนดจุดวัดมุมทั้งสอง เท่ากับ 0.81, 0.82 และ 0.80 ตามลำดับ การประเมินผลความเหมือนของการวัดมุม AP-TE, AP-PC และ TE-PC ระหว่างผู้วัดมุมทั้งสองเท่ากับร้อยละ 90.59, 92.57 และ 96.03 ตามลำดับ

สรุป: *การใช้เทคโนโลยีดิจิตอล ทำให้การศึกษาเพื่อทราบความสัมพันธ์ของแนวแกนแอนทีโรโพสทีเรีย, ทรานส์อิพิคอนดัย และโพสทีเรียคอนดัยของกระดูกฟีเมอร์จากศพ เป็นไปได้โดยมีความแม่นยำมากขึ้น เมื่อเทียบกับการศึกษาที่เคยรายงานการวัดจากฟิล์มเอกซเรย์ จากภาพสแกนคอมพิวเตอร์โทโมกราฟี หรือภาพคลื่นแม่เหล็กไฟฟ้าโดยใช้ไม้วัดมุม*