The Comparison of Femoral Component Rotational Alignment with Transepicondylar Axis in Mobile Bearing TKA, CT-Scan Study

Polawat Witoolkollachit MD, MSc (IT-M)*,
Onuma Seubchompoo MD**

** Department of Orthopaedic Surgery Somdejprajaotakinmaharaj Hospital and Medical College, Affiliated with The Faculty of Medicine Narasuan University, Tak*
*** Deparment of Radiology Somdejprajaotakinmaharaj Hospital and Medical College, Affiliated with The Faculty of Medicine Narasuan University, Tak*

Objective: *The tibial axis referencing method with a balanced tension flexion gap at 90° knee flexion provides adequate femoral component rotation usually in external rotation, the trans-epicondylar line being parallel to the proximal tibial cut. The LCS mobile bearing TKA uses this technique to automatically determine the femoral component rotation with desired tension.*

The determination of the epicondyles may lead to some confusion. On the lateral side, the prominence of the lateral condyle makes it easy to define. However, on the medial side, some surgeons use the prominent part of the medial epicondyle (well recognized on CT scan as the most proximal ridge that gives insertion to the superficial collateral ligament) and use the anatomical transepicondylar axis (aTEA). Other surgeons use the depression below called sulcus that defines the surgical transepicondylar axis (sTEA).

Material and Method: *The authors evaluated 40 clinically successful mobile bearing TKA in 33 patients. All the knees were performed by single surgeon and the rotational alignment of the femoral component was applied with balanced flexion gap technique. Post-op CT-scans were done in all knees with 2-mm interval and measurement of the different angles (between aTEA and the prosthetic posterior condylar line and between the sTEA and the prosthetic posterior condylar line) with the UTHSCSA Imagetool (IT) version 3 from the University of Texas Health Science Center at San Antonio.*

Results: *The authors found that the mean femoral implant angle was in 2.39° (SD = 2.80°) of internal rotation with reference to the aTEA and in 1.34° (SD = 1.57°) of external rotation with reference to the sTEA when the medial sulcus was perfectly detected (nine knees, 22.5%). The angle between the aTEA and the sTEA was -3.98° (SD = 1.05°). No patella subluxation was identified. Nineteen or 47.5% of the femoral components were in internal or external femoral rotation of more than 3° to the aTEA. When sTEA was detected, no knee was in internal or external rotation more than 3° to sTEA.*

Conclusion: *The balanced flexion gap technique positions the femoral component in external rotation with the LCS TKA. Within 3° to aTEA or sTEA, this technique produced femoral rotational angle closer to sTEA when the sulcus was detected and produced a wide range of different angles when compared to aTEA. However, sTEA is not the consistent bony landmark. This technique is a reliable method to determine femoral rotational alignment.*

Keywords: *Arthritis, Balanced flexion gap technique, Total knee arthroplasty, Transepicondylar axis, Surgical transepicondylar technique, Anatomical transepicondylar axis, Mobile bearing, Surgical technique, Computer tomography*

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Correspondence to: Witoolkollachit P, 1/21-22 Kitikajorn Rd, Ampur Muengtak, Tak 63000, Thailand. E-mail: polawat.w@gmail.com

The determination of femoral component rotation is one critical step of successful total knee replacement (TKR). In order to determine the rotation, there are five popular techniques. The first is trans-epicondylar axis[1-3], which is based on the fixed anatomical landmarks, Whiteside's line or antero-posterior axis of distal femoral condyle[4,5], the posterior anatomical condylar reference[6], which is parallel to the medial and lateral posterior femoral condyles at 90° flexion and generally surgeons decide arbitrarily to put the femoral component in 3-4° of external rotation. The last technique is (pure) balanced flexion gap technique that is based on tibia axis and balanced ligament in knee flexion 90°. Stiehl[7] and Engh[8] have demonstrated the success of TKR with the balanced flexion gap techniques by using tibial axis referencing method. With this technique, the primary concern is ligament balancing without reference to the trans-epicondylar axis anatomical landmarks.

Many studies[5,9] have shown that the trans-epicondylar axis is the right axis of the femoral rotation. Due to the precise anatomy of the medial epicondyles, several transepicondylar axis have been defined. First the anatomical axis or clinical transepicondylar axis (aTEA)[1] refers to the more proximal and prominent ridge which gives insertion to the superficial collateral ligament and lateral epicondyle. It can be easily defined on CT scan but is more difficult to identify during the operation[3].

Second, the sulcus of the medial epicondyle is easier to identify between the insertions of superficial and deep collateral ligament[10]. The line drawn from the sulcus to the most prominent lateral epicondyle is called surgical transepicondylar axis (sTEA)[3]. This line is parallel to the primary center of rotation of the knee.

The balanced flexion gap technique[11,12] is used for determining the femoral component external rotation without using any bony landmark. Stiehl and Abbott[9] studied the morphology of the transepicondylar axis, they found that this axis is perpendicular to the mechanical axis of the tibia and parallel to the knee flexion axis. Still, many authors have concerns about femoral rotation and like to refer to anatomical or surgical transepicondylar axis.

The purpose of the present study was to report on balanced flexion gap technique and to analyze if it is reliable to provide correct femoral component external rotational in LCS mobile bearing TKA and to measure this femoral component rotation with reference to both the anatomical transepicondylar axis and the surgical transepicondylar axis. CT-scan evaluation[13-15] is a way for assessing prosthesis rotational alignment compared to known anatomical landmarks.

Material and Method

Between November 2002 and September 2007, 211 consecutive primary total knee arthroplasties were performed in Somdejprajao Taksinmaharaj Hospital by a single surgeon (PW). One hundred seventy five knee arthroplasties were LCS mobile bearing rotating platform prosthesis (DePuy Int, Leeds, UK) and the rest were fixed bearing posterior stabilized prosthesis.

Forty knees in 33 patients who had undergone LCS mobile bearing total knee replacements were selected randomly within inclusion criteria: good or excellent clinical results according to knee society scores, no postoperative complications, a minimum of 6 months follow-up, and availability for the computer tomography study appointment. There were 25 females and eight males. The mean age was 67 years (53 to 79 years).

The balanced flexion gap technique with classical method[7] was used to determine the rotation of the femoral component. The flexion gap first technique or balanced flexion gap, the proximal tibial bone cut were performed first. The tibial cut should be perpendicular to the tibial mechanical axis. All the osteophytes were removed from tibial and femur in order to prevent tenting of the collateral ligament. The femoro-tibial alignment should be checked first in extension. If it is in neutral, no releases are needed. If the alignment is not correct, release of the posterior structures are necessary and then possibly of the primary stabilizer. Then, at 90° knee flexion, the AP femoral cutting block is positioned with femoral intramedullary rod and in relation to anterior femoral cortex. The C shape (horse shoe) femoral positioner is used to determine the femoral rotational alignment. The tension of collateral soft tissues can be adjusted by adjunction of shim plates on the tibial side. When the desired tension is obtained, the AP femoral cutting block is in proper rotation and the transepicondylar line should be close to parallel the tibial cut, paying attention not to overcorrect (Fig. 1). The AP cuts are performed and the flexion gap measured. The distal femoral cut is done last with the intramedullary guide to create neutral alignment with balanced and desired tension in extension. Now this knee has a rectangular gap at 90° and equal rectangular gap at 0°. The trial prosthesis can be inserted and tested before the final prosthesis.

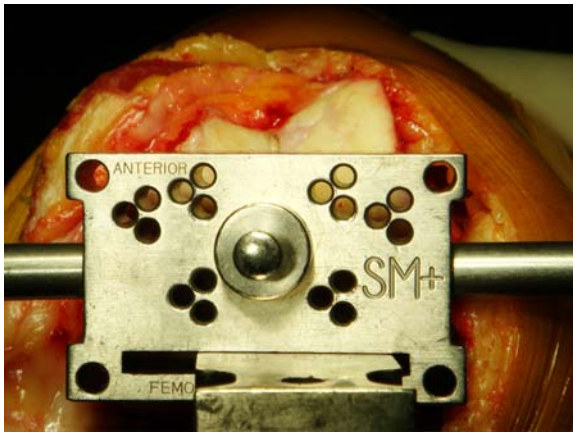

Fig. 1 This image shows the automatically external rotation of the femoral component with desired ligament tension by the C shape (horse shoe) femoral positioner. At the anterior part of femoral condyles, the height of lateral condyle was higher than the medial condyle

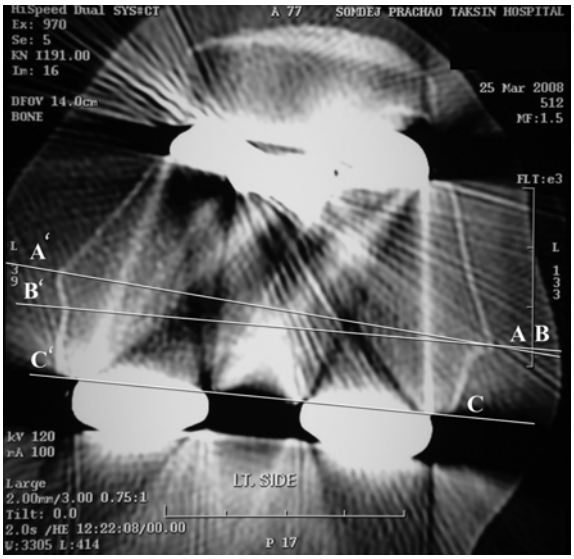

Fig. 2 This is the sample CT-scan image of 9 (22.5%) of knees which was detected in all the fixed bony reference landmarks

Post-operative CT-Scan was done in all knees with 2 millimeters interval to determine femoral component rotation. The digital subtraction technique was used to decrease the scatter artifact for the femoral component. All images were digitized. The important anatomical land marks: lateral epicondyle, prominent ridge of the medial epicondyle, medial sulcus of the medial epicondyle, prosthesis rotational alignment were measured by an independent radiologist. The 3D reconstruction of the distal femoral condyle was performed to reconfirm the bony landmarks as they can be in different slices. Therefore, the axes were defined: the anatomical transepicondylar axis (aTEA, AA' line), the surgical transepicondylar axis (sTEA, BB' line), and the prosthesis posterior condylar line (CC' line) (Fig. 2, 3). The UTHSCSA Imagetool (IT) version 3[16] from the University of Texas Health Science Center at San Antonio was used to measure the angles. The different angles between AA' line and CC' line (ΔAC) were measured as well as the angle between BB' line and CC' line (ΔBC) and the angle between AA' line and BB' line (ΔAB). These measurements were performed twice for each knee at one-week interval to minimize intra-observer errors. The values for each angle were averaged.

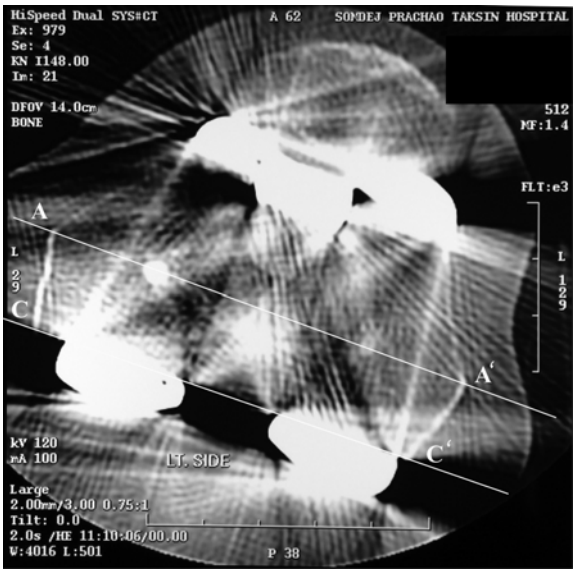

Fig. 3 The sample CT-Scan image of 31 (77.5%) of knees which detected only the most prominent medial ridge and prosthesis posterior condylar line and this knee shows the different angle (ΔAC) between prosthesis posterior condylar line and aTEA in internal rotation

Results

Statistical analysis was done using the standard descriptive technique. The mean prosthesis rotation axis was 2.39° (SD = 2.80°) of internal rotation with reference to the aTEA (Fig. 5) with a wide range of variation from 8.29° (Fig. 4) in internal rotation to 2.22° in external rotation (Fig. 4). In nine knees, the medial

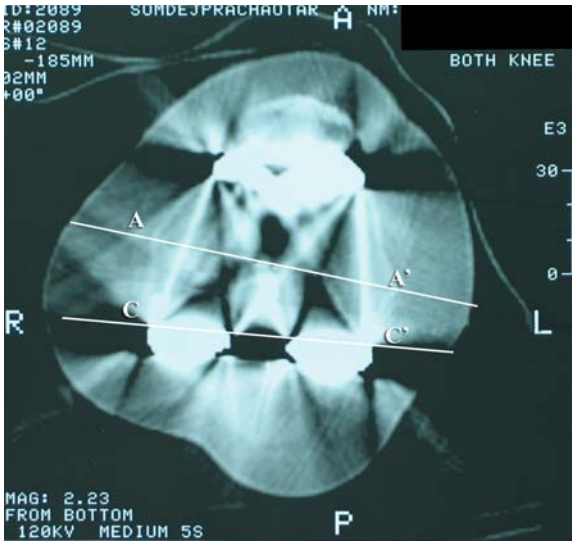

Fig. 4 This image shows the CT-scan image of the different angle (ΔAC) between prosthesis posterior condylar line and aTEA in internal rotation up to 8.29° without patella subluxation

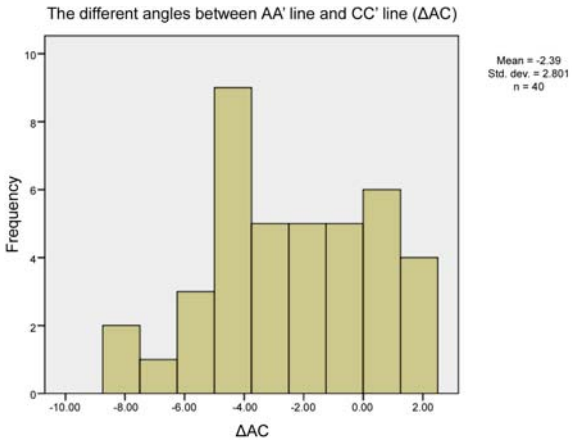

Fig. 5 This histogram shows number of knees with the different angle between prosthesis posterior condylar line and aTEA, ΔAC (mean = -2.39° SD = 2.80°)

sulcus was well identified on CT scan and the femoral rotation was 1.34° (SD = 1.57°) in external rotation with reference to the sTEA (Fig. 6) and no knee was in internal or external rotation more than 3° to sTEA. Nineteen femoral components were in internal or external femoral rotation of more than 3° to the aTEA and no patella subluxation was detected. Twenty-one knees were in internal and external femoral rotation within 3° to the aTEA and the mean different angle was 0.15° (SD = 1.42°) internally rotate to aTEA (Fig. 8). When the medial sulcus was detected the different angle between aTEA and sTEA was 3.98° (SD = 1.05°) internally rotate to aTEA (Fig. 7). Table 1 shows the summary of the result of the present study.

Discussion

Femoral component rotation is a critical factor in TKR to optimize patellofemoral and tibiofemoral kinematics[2,17-19]. Improper femoral component rotation creates instability in flexion with a tighter medial and more lax lateral compartment and occurs when the femoral component is internally mal-rotated. This is frequently combined with lateral patello-femoral subluxation and instability (lift-off)[20] of the lateral compartment in flexion. Anterior knee pain after TKR is frequently associated with femoral component in internal rotation[21]. There are five popular intraoperative methods to determine femoral component rotation during total knee arthroplasty: Whiteside's line[4,5], the transepicondylar axis[1,3], an arbitrary line in 3° of external rotation relative to the posterior condyles[6] and balancing flexion gap method[7,8]. Miller[22] showed femoral component rotation parallel to the epicondylar axis resulted in the most normal patellar tracking and minimized patellofe moral forces. The epicondylar axis has a wide spectrum of anatomical variations. Two types of transepicondylar axis[3] have been used in the literature, the anatomical epicondylar axis where the surgeon palpates the most prominent ridge of the medial epicondyleand the surgical epicondylar axis[10]

Table 1. This table shows the different angle between each axis reference to aTEA and number of the cases which internally or externally rotate within 3°

Δ (The different angle)	Mean	SD	No. of case	No. of case within ± 3°
ΔC (Prosthesis-aTEA)	-2.39°	2.80°	40	21
ΔAB (aTEA-sTEA)	-3.98°	1.05°	9	9
ΔBC (Prosthsis-sTEA)	1.34°	1.57°	9	9

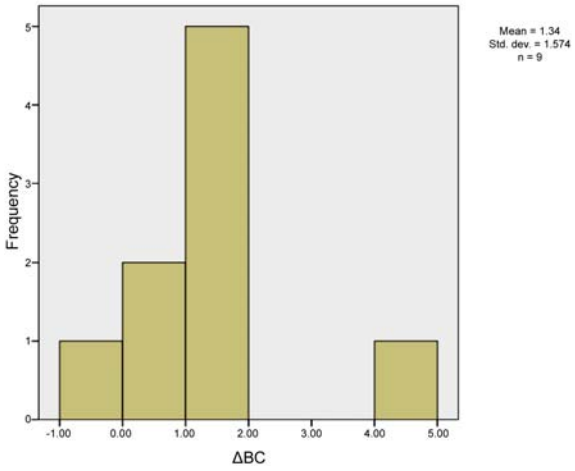

Fig. 6 This histogram shows the number of knees with the different angle between prosthesis posterior condylar line and sTEA, ΔBC (mean = 1.34° SD = 1.57°)

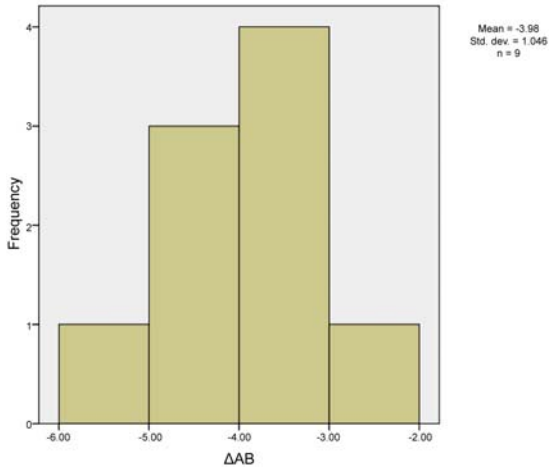

Fig. 7 This histogram shows the number of knees with the different angle between sTEA and aTEA, ΔAB (mean = -3.98° SD = 1.05°)

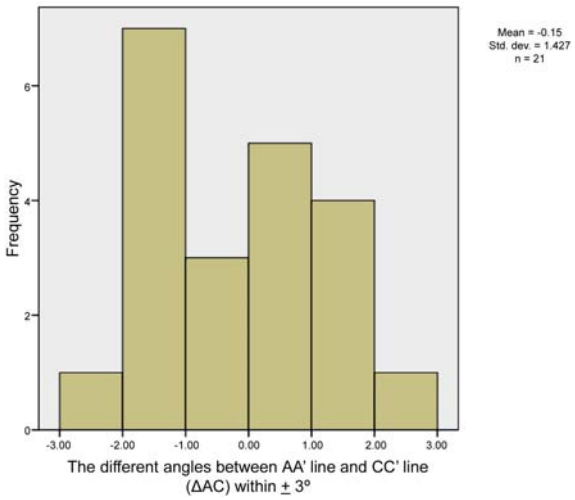

Fig. 8 This histogram shows the distribution of 21 knees with the different angle between prosthesis posterior condylar line and aTEA, ΔAC within 3° internal or external rotation (mean = -0.15° SD = 1.43°)

where the surgeon has to detect the medial sulcus of medial epicondyle. The study of axial CT-scan of distal osteoarthritis femur[13] showed that only 33 out of 96 have a medial sulcus. However, Tanavalee's[15] study showed only 5% of the cases have a medial sulcus. They also acknowledged the difficulty to identify medial epicondyle in osteoarthritic knees. They suggested that medial sulcus of the medial epicondylar axis is more difficult to locate than the ridge of the medial epicondyle. Jenny[23]has shown that the transepicondylar axis has low reliability in intra-operative measurement. The range of variation occurred either internal rotation or external rotation.

However, Olcott[24,25] demonstrated transepicondylar axis as the most consistent method to create balanced flexion space. Fehring[12] showed that the most reliable intraoperative rectangular flexion gap is created by the classical balanced flexion gap method. Clinical studies by Stiehl[7] compared the tibial axis method to other methods for determining femoral rotation in four different fixed bearing knee systems utilizing a femoral first approach. With the posterior condylar reference method, 72% required lateral release with 7% patella fractures reported. With arbitrary 3° to 4° of external rotation method, there was a reported incidence of lateral release in 28%. When tibial axis method was utilized, femoral component placement was reported to be within 1° of external rotation with reference to the transepicondylar axis. With tibial axis referencing technique, decreased numbers of lateral releases were required and there were no patella complications. Katz[26] has shown in a cadaveric study of eight knees (a three-surgeon evaluation) that determination of femoral component rotational positioning was more reliable using a balanced flexion gap and the anteroposterior axis. Boldt et al[27] demonstrated in a CT-scan study on femoral component rotation by tension spacing that the femoral component rotation was within 3° of the surgical transepicondylar axis. However, in their study, the surgical transepicondylar

axis is the line from most prominent on the medial side to the lateral epicondyle and they did not report the detection of the medial sulcus.

The present study reports femoral component rotation using balanced flexion gap technique. This technique has demonstrated that the femoral implant was in 2.39° (SD = 2.80°) of internal rotation with reference to the aTEA and in 1.34° (SD = 1.57°) of external rotation with reference to the sTEA when the medial sulcus was perfectly detected (9 knees). The authors found that when the knee reference with the aTEA, only 21 knees (52.5%) were internal or external rotate within 3° reference to aTEA which is different from 10% in the prior study by Boldt[27]. According to the detected medial sulcus, the balanced flexion gap technique provided a mean femoral rotation angle within 3° of the sTEA with close range of angle and no knee was out from the range.

The present study also shows that the line between medial sulcus and lateral epicondyle (sTEA) always internally rotates to the aTEA when the mean of different angle was -3.98° (SD = 1.05°).This referred to the medial sulcus locate just below the medial prominent ridge. This balanced flexion gap technique can recreate femoral rotation close to the technique using fixed bony landmarks intraoperatively. With this technique, knee flexion ligamentous balancing can be achieved simultaneously with correct femoral component rotation without any patella problems.

With the balanced flexion gap technique, surgeon recreates rectangular flexion gap and balancing ligament. The proper ligament balancing technique may result in decreased wear, decreased incidence of anterior knee pain, better range of motion, prevent patellofemoral maltracking, and provide better long-term results. This technique has a definite advantage in patients when the surgical transepicondylar axis is difficult to define at surgery. It is a simple technique with the femoral positioning instruments during the TKR procedure. The authors also believe that the present study can be used to convince some surgeons who are looking for any easy reliable techniques to positioning femoral component during performing total knee replacement.

Conclusion

Balanced flexion gap technique provides external rotation of femoral component in LCS mobile bearing TKA. The mean degree of femoral component rotation showed closer relation to sTEA within 3°. According to the medial sulcus, the surgical transepicondylar axis (sTEA) is not always a consistent bony landmark at surgery especially in osteoarthritis knees. During the operation, the surgeons use the most medial prominent ridge to double check the femoral component rotation from the balance flexion gap. Internal rotation from the aTEA can be the consequence from this balanced flexion technique after the ligament balancing. The balanced flexion gap technique is a reliable method to determine femoral rotational alignment.

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การศึกษาเปรียบเทียบระหว่าง transepicondylar axis กับแนวการหมุนของข้อเข่าเทียมของกระดูกต้นขาส่วนปลายโดยใช้ภาพตัดขวางจากเครื่องเอกซเรย์คอมพิวเตอร์

พลวรรธน์ วิทูรกลชิต, อรอุมา สืบชมภู

การใช้เทคนิค tibial axis ร่วมกับ balanced tension flexion gap ขณะงอเข่า 90 องศา กำหนดแนวการหมุนของข้อเข่าเทียมกระดูกต้นขาส่วนปลายนั้นต้องอาศัยแนวแกนของกระดูกปลายขาเสมอ โดยแนวการหมุนตามเทคนิคนี้นั้นต้องอาศัยการตัดกระดูกปลายขาส่วนต้นให้ได้ตั้งฉากกับ mechanical axis ของกระดูกปลายขาเสียก่อน แล้วทำการปรับแต่งเส้นเอ็นหัวเข่าทั้งด้านนอกและด้านในให้สมดุล หลังจากนั้นทำการยกกระดูกต้นขาส่วนปลายให้ได้ความตึงที่ต้องการขณะที่หัวเข่างอ 90 องศา ก็จะได้แนวตัดกระดูกต้นขาส่วน posterior condyle ซึ่งต้องขนานไปกับแนวการตัดกระดูกปลายขาส่วนต้นเสมอ ซึ่งวิธีดังกล่าวนี้จะทำให้เกิดแนวการหมุนของข้อเข่าเทียมกระดูกต้นขาส่วนปลายโดยอัตโนมัติ โดยทั่วไปแล้วการกำหนดปุ่มกระดูก epicondyle เพื่อหาแนวแกน transepicondylar axis อาจจะทำให้เกิดการสับสนในระหว่างการผ่าตัดเสมอ โดยทั่วไปแล้วปุ่มกระดูก lateral epicondyle มักจะนูนมาก สามารถคลำ ด้ง่าย แต่ด้านในมักจะคลำได้ยากจึงทำให้มีข้อสังเกตดังนี้ แนวแกนสมมุติที่ลากจาก lateral epicondyle ไปยังปุ่มกระดูกด้านในหัวเข่าที่คลำได้เด่นชัดที่สุด ซึ่งเป็นที่เกาะของ superficial medial collateral ligament หรือที่สามารถสังเกตได้ชัดเจน จากภาพตัดขวางของเอกซเรย์คอมพิวเตอร์เรียกว่า anatomical transepicondylar axis (aTEA) ส่วนแนวแกนสมมุติที่ลากจาก lateral epicondyle ไปยังร่องด้านในที่อยู่ต่ำกว่าปุ่มกระดูกที่สังเกตได้จากภาพตัดขวางของเอกซเรย์คอมพิวเตอร์หรือคลำได้ระหว่างการทำผ่าตัดเรียกว่า surgical transepicondylar axis (sTEA) คณะผู้ศึกษาได้ทำการศึกษาผู้ป่วยที่ได้รับการผ่าตัดข้อเข่าเทียมจำนวน 33 คน รวมทั้งสิ้น 40 ข้อเข่าเทียม ทุกรายได้รับการผ่าตัดโดยการใช้เทคนิค balanced tension flexion gap กำหนดแนวการหมุนของข้อเข่าเทียมกระดูกต้นขาส่วนปลาย และใช้ข้อเข่าเทียมแบบ LCS mobile bearing พบว่าไม่มีการหลุดเคลื่อนของกระดูกสะบ้า ค่าเฉลี่ยของการหมุนของข้อเข่าเทียมของกระดูกต้นขาส่วนปลาย หมุนเข้าทำมุม 2.39 องศา SD 2.8 องศา เมื่อเทียบกับ aTEA แต่มีเพียง 9 ข้อเข่าเทียม ที่สังเกตพบร่องด้านในหัวเข่าที่สามารถกำหนด sTEA พบว่าค่าเฉลี่ยของการหมุนของข้อเข่าเทียมของ กระดูกต้นขาส่วนปลายหมุนออกทำมุม 1.39 องศา SD = 1.57 องศา กับ sTEA คณะผู้ศึกษายังพบว่ามีเพียง 21 รายหรือ 52.5% ของเข่าทั้งหมด ที่มีมุมหมุนของข้อเข่าเทียมของกระดูกต้นขาส่วนปลายหมุนเข้าและหมุนออกระหว่าง 3 องศาเมื่อเทียบกับ aTEA คณะผู้ศึกษาสรุปว่าด้วยการผ่าตัดโดยการใช้เทคนิค balanced tension flexion gap ขณะงอเข่า 90 องศา กำหนดแนวการหมุนของข้อเข่าเทียมกระดูกต้นขาส่วนปลายสามารถทำให้เกิดการหมุนของข้อเข่าเทียมของกระดูกต้นขาส่วนปลาย ใกล้เคียงกับการใช้ aTEA หรือ sTEA โดยใกล้เคียงกับแนว sTEA มากกว่า ดังนั้นในระหว่างการผ่าตัดถ้าสามารถคลำร่องกระดูกหัวเข่าด้านในได้ ก็สามารถที่จะใช้ยืนยันแนวการหมุนของข้อเข่าเทียมของกระดูกต้นขาส่วนปลายได้ หรือ ในรายที่คลำหาปุ่มกระดูกต้นขาส่วนปลายด้านในได้ยาก วิธีการผ่าตัดโดยการใช้เทคนิค balanced flexion gap ขณะงอเข่า 90 องศา ใช้กำหนดแนวการหมุนของข้อเข่าเทียมกระดูกต้นขาส่วนปลาย ก็เป็นอีกวิธีที่สามารถเชื่อถือได้ในการกำหนดแนวการหมุนของข้อเข่าเทียมของกระดูกต้นขาส่วนปลาย เช่นกัน