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Reliability of the anteroposterior axis and the posterior condylar axis for determining rotational alignment of the femoral component in total knee arthroplasty*

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Abstract: We examined the reliability of the anteroposterior and posterior condylar axes for determining rotational alignment of the femoral component in total knee arthroplasty (TKA). A computed tomography scan was taken at the level of the femoral epicondyle in 84 knees (27 varus knees with medial femorotibial arthritis (FT-OA) in 26 patients, 17 knees with patellofemoral arthritis in 14 patients, and 40 normal knees in 40 volunteers). On the image, an anteroposterior axis, a line perpendicular to the anteroposterior axis, an epicondylar axis and a posterior condylar axis were drawn, and the relationship between the three axes was assessed. The mean values for the 84 knees were evaluated, and the posterior condylar axis was 6.0° ± 2.4° internally rotated relative to the epicondylar axis, while the line perpendicular to the anteroposterior axis was 1.4° ± 3.3° internally rotated relative to the epicondylar axis. The internal rotation angle of the posterior condylar axis relative to the epicondylar axis was 6.2° ± 1.9° in the knees with medial femorotibial arthritis, 6.4° ± 2.4° in the knees with patellofemoral arthritis, and 5.8° ± 2.7° in the normal knees, showing consistent values in normal and osteoarthritic knees. The internal rotation angle of the line perpendicular to the anteroposterior axis relative to the epicondylar axis was 0.1° ± 3.3°, 1.3° ± 3.3°, and 2.3° ± 3.1° in the three groups, respectively (i.e., there were significant differences between the medial FT-OA knees and the normal knees). The results demonstrated that the anteroposterior axis was rotated externally to a significant degree in medial FT-OA knees and was less reliable than the posterior condylar axis for use in alignment for TKA on medial FT-OA knees.

Key words: total knee arthroplasty, anteroposterior axis, epicondylar axis, posterior condylar axis

Introduction

In total knee arthroplasty (TKA), external rotation of the femoral component relative to a line connecting the posterior aspects of the femoral condyles (posterior condylar axis) can place the femoral component in the correct rotational position relative to the upper surface of the proximal tibia when the tibial surface is cut perpendicular to the long axis of the tibial shaft. Because the mean tibial angle in the normal knee is 93°,[6] the femoral component is inserted in a 3°–4° externally rotated position relative to the posterior condylar axis.[1,7,8] With this rotational position, the patella is able to track within the normal physiological position.[1,7] Usually, the posterior condyles are used to select the rotational position of the femoral component. However, the lateral femoral condyle in a valgus knee is abnormally small.[2] Under such conditions, the posterior condylar axis is abnormally rotated internally compared with that of normal knees and is thus not reliable for determining rotational alignment of the femoral component. Arima et al.[2] therefore devised an alignment based on the anteroposterior (AP) axis for use in TKA on valgus knees.

However, no detailed analyses have yet been performed on the reliability of this AP axis for determining alignment in varus knees or in knees with patellofemoral arthritis. The purpose of this study was to assess the reliability of the AP axis for determining alignment in such knees.

Patients and methods

We assessed 84 knees in total 27 knees with medial femorotibial osteoarthritis [FT-OA] in 26 patients, 17 knees with patellofemoral arthritis [PF-OA] in 14 patients, and 40 normal knees in 40 volunteers. All the patients and volunteers were Japanese women; their mean ages were 66.4 ± 8.8, 67.6 ± 10.7, and 50.2 ± 12.5

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years, respectively. The volunteers were significantly younger than the patients with osteoarthritic knees because it was difficult to find older volunteers with normal knees.

On anteroposterior view radiographs, the femorotibial angle (FTA) with the subject in the supine position was 178.6° ± 4.6°, 175.3° ± 3.1°, and 176.2° ± 3.8°, respectively.

The medial FT-OA knees and the normal knees were compared and the FTA was found to be significantly greater in the medial FT-OA knees, indicating that the medial FT-OA knees had varus deformity. The tibial angle was 96.8° ± 3.5°, 94.6° ± 2.7°, and 95.6° ± 2.7° in the three groups, respectively. In the medial FT-OA knees, either the medial femorotibial joint space had disappeared, or it had become severely decreased on anteroposterior radiographs taken with the subject in the standing position.

In PF-OA knees, the joint space between the lateral facet of the patella and the lateral femoral condyle had disappeared on axial radiographs done by the Merchant technique. Otherwise, the femorotibial joint space was either intact or only slightly decreased on anteroposterior radiographs taken with the subject in the standing position. The volunteers had experienced no subjective knee complaints, and no abnormalities were identified on their radiographs.

Computed tomography (CT) scans were performed to obtain an axial view of the distal femur. The patient was placed supine with the knees fully extended on the CT scanner, and the lower extremity was positioned so that the long axis of the tibial shaft was parallel to the bed in the sagittal and coronal planes, which was confirmed with a scanogram (Fig. 1). A CT scan was taken at the level of the femoral epicondyle so that the scan was perpendicular to the long axis of the tibial shaft. Because the FTA was different in each knee, the angle of the scan at the femoral epicondyle was different in each knee. However, the discrepancy did not affect the results for each axis. Figure 2 shows the coronal and axial views of the distal femur. Line 1 and line 2 represent different scan planes. X in Line 1 and X′ in Line 2 represent the length of the AP axis in the coronal view. The difference in the angle of the scan was denoted θ. The angle of the AP axis relative to the dotted line was denoted α, while the angle of the AP axis on Line 2 was denoted α′. The length of the AP axis along the dotted line in the axial view was denoted Y. When line 1 is perpendicular to the long axis of the tibia,

$$X' = X / \cos\theta$$

with

$$X' = Y\tan\alpha', X = Y\tan\alpha$$

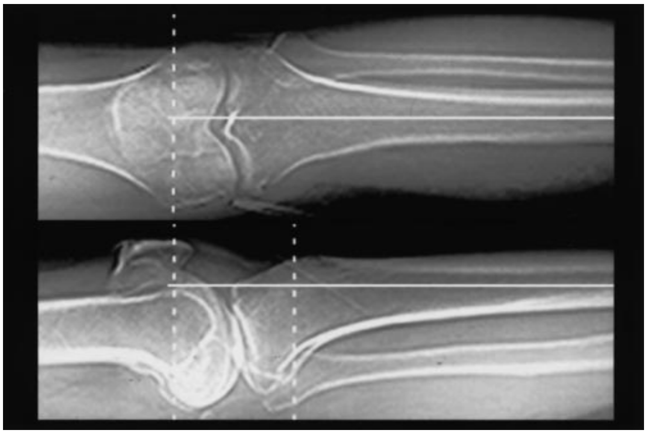

Fig. 1. The patient was placed supine on a computed tomography (CT) scanner, and the lower extremity was positioned so that the long axis of the tibia was parallel to the bed in the sagittal and coronal planes, which was confirmed with a scanogram. A CT scan was taken at the level of the femoral epicondyle so that the scan was perpendicular to the long axis of the tibial shaft

the solution can be given by

$$\tan\alpha' = \tan\alpha / \cos\theta$$

The maximum value of the FTA in this study was 183° an the difference of this value from the mean value in normal knees was 6.8°. Cos 6.8° was 0.998 and the difference between α′ and α was less than 0.1°.

When a slice 3 mm in thickness was obtained at the level of the femoral epicondyle, sometimes the image did not clearly reveal the medial epicondyle. If this occurred, the scan level was moved 2 mm distally or proximally and an additional CT scan was taken until the scan clearly revealed the medial and lateral epicondyles.

On the CT image, we constructed an AP axis, a line perpendicular to the AP axis, a posterior condylar axis, and an epicondylar axis (Fig. 3). The AP axis was the line described by Arima et al.[2] This axis was defined by two points, one on the deepest point in the patellar groove, and the other in the center of the intercondylar notch, determined by measurement of the distance between the posterior-most inner surfaces of the intercondylar notch. The mid-point was assigned as the center.

In the osteoarthritic knees, osteophytes were omitted and the contour of the intercondylar notch was drawn. The epicondylar axis was defined by two points, one each on the most prominent surface of the medial and of the lateral epicondyles. The posterior condylar axis was defined by two points, one each on the most posterior point of the medial and of the lateral posterior condyles. A line perpendicular to the AP axis was drawn.

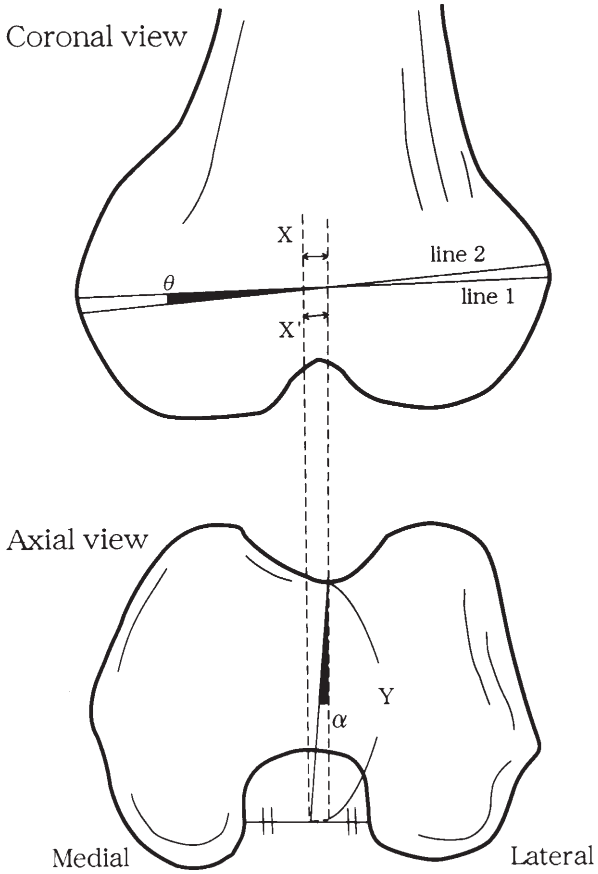

Fig. 2. Coronal and axial views of the distal femur. *Line 1* and *line 2* represent different scan planes. *X* in *line 1* and *X'* in *line 2* represent the length of the anteroposterior (AP) axis in the coronal view. θ denotes the difference in the angle of the scans. α denotes the angle of the AP axis relative to the *dotted line*, and α' denotes the angle of the AP axis on *line 2*. Y denotes the length of the AP axis along the dotted line in the axial view. The difference between the maximum value of the femorotibial angle from the mean value in normal knees in this study was 6.8° and the difference between α' and α was less than 0.1°. Different scan planes did not affect the AP axis value

In a preliminary study, to assess the reproducibility of the method, the angles were measured three times in one knee of a volunteer. The internal rotation angle of the line perpendicular to the AP axis relative to the epicondylar axis was 1.0°, 0.5°, and 0.5°. The results of the preliminary study showed that preparation of the lower extremity so that the long axis of the tibial shaft was parallel to the bed in the sagittal and coronal planes enabled high reproducibility.

The angle of the line perpendicular to the AP axis and the angle of the posterior condylar axis relative to the epicondylar axis were measured and the reliability of each axis for determining rotational alignment of the femoral component was assessed.

Statistical analysis was performed using the Scheffe *F*-test. P values of < 0.05 were taken as significant.

Results

The total of 84 knees were evaluated, and the mean value (±SD) for the posterior condylar axis was 6.0° (±2.4°) internally rotated relative to the epicondylar axis, while the line perpendicular to the AP axis was 1.4° (±3.3°) internally rotated relative to the epicondylar axis.

The internal rotation angle of the posterior condylar axis relative to the epicondylar axis was 6.2° ± 1.9° in the medial FT-OA knees, 6.4° ± 2.4° in the PF-OA knees, and 5.8° ± 2.7° in the normal knees. Therefore, the posterior condylar axis was about 6° internally rotated relative to the epicondylar axis in the three groups. The internal rotation angle of the line perpendicular to the AP axis relative to the epicondylar axis was 0.1° ± 3.3°, 1.3° ± 3.3°, and 2.3° ± 3.1°, in the three groups, respectively. The line perpendicular to the AP axis was rotated externally to a significant degree in the knees with medial FT-OA compared to the normal knees ($P < 0.05$). The SD was smaller with the posterior condylar axis than with the line perpendicular to the AP axis in all three groups (Table 1).

The differences between the line perpendicular to the AP axis and the posterior condylar axis were 6.1° ± 3.4°, 5.1° ± 2.4°, and 3.5° ± 4.0°, in the three groups, respectively.

Discussion

Rotational alignment of the femoral component affects varus/valgus stability in flexion and patellar tracking, which influences the longevity of TKA.[2] When the proximal tibia is cut perpendicular to the long axis of the tibial shaft, the femoral component should be inserted in an externally rotated position so as not to produce a gap in the lateral femorotibial joint in flexion. The mean tibial angle in normal knees is 93° and the femoral component is inserted in a 3°–4° externally rotated position in almost all total knee systems.[1,6–8,11,12]

Although many studies have been done on the anatomical configuration of the patellar groove, epicondyles, and condyles of the femur, cadaveric specimens were used in almost all these studies.[1,2,4,5,13] Poilvache et al.[10] in one of the few clinical studies on the rotational landmarks of the femur, evaluated 100 knees undergoing TKA, and concluded that the transepicondylar axis was a reliable landmark for precisely rotating the femoral component, and that it was easier to locate at surgery than was the AP axis.

We believe that the epicondylar line is the most reliable axis for precisely rotating the femoral component when the medial and lateral epicondyles are clearly visible.[3,10,13] However, in TKA, soft tissue covers the

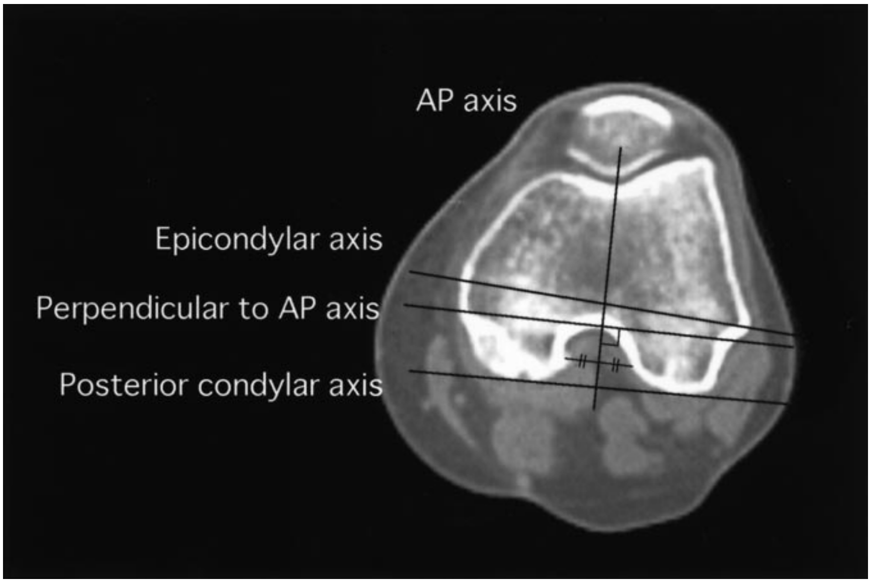

Fig. 3. On the CT image, we constructed an anteroposterior axis, a line perpendicular to the anteroposterior axis, a posterior condylar axis, and an epicondylar axis

Table 1. Angles of the posterior condylar axis and the line perpendicular to the AP axis relative to the epicondylar axis in normal and osteoarthritic knees

	FT-OA Knees	PF-OA Knees	Normal Knees
FTA	178.6° ± 4.6°	175.3° ± 3.1°	176.2° ± 3.8°
Tibial angle	96.8° ± 3.5°	94.6° ± 2.7°	95.6° ± 2.7°
Epi-PC angle	6.2° ± 1.9°	6.4° ± 2.4°	5.8° ± 2.7°
EPi-AP angle	0.1° ± 3.3°	1.3° ± 3.3°	2.3° ± 3.1°

All values are means ± SD.
ET-OA, Medial femorotibial arthritis; PF-OA, patellofemoral arthritis; FTA, femorotibial angle; Epi-PC, internal rotation angle of the posterior condylar axis relative to the epicondylar axis; Epi-AP, internal rotation angle of the line perpendicular to the anteroposterior axis relative to the epicondylar axis.

epicondyles and it is difficult to localize the central point or peaks of the epicondyles.[2] The posterior condylar axis and the AP axis are directly visible and are thus easier to use under such conditions. We undertook this study to assess which axis was more consistent relative to the epicondylar axis, the posterior condylar axis or the axis perpendicular to the AP axis. If the extent of the internal rotation of the two axes is similar, varus/valgus stability of the knee at 90° of flexion and normal patellar tracking can be achieved using either axis. But if the direction of the two axes is different, we must select the more suitable axis. We strongly feel that varus/valgus stability at 90° of flexion should be established first, because good patellar tracking can then be obtained using lateral retinacular release, which can be confirmed by the no-thumb technique.

Our results demonstrated that, in normal knees, the line perpendicular to the AP axis was externally rotated 3.5° relative to the posterior condylar axis. These data confirm the results of Arima et al.[2] The rotational position of the femoral component in which an osteotomy was performed using a 3°–4° externally rotated position relative to the posterior condylar axis was found to be identical to that achieved using the line perpendicular to the AP axis.

In normal knees in our study, there was no abnormality of anatomical configuration of the tibia or the femur. The volunteers in this study were all Japanese. The study of Arima et al.[2] examined the cadaveric femora of Caucasians. Our present results demonstrate that the line perpendicular to the AP axis is internally rotated 2° relative to the epicondylar axis, and the posterior condylar axis is internally rotated 6° relative to the epicondylar axis, and is consistent in normal knees, regardless of race.

The medial FT-OA knees in our study had varus deformity and, the FTA in these knees was significantly greater than that in the normal knees. The line perpendicular to the AP axis was significantly rotated externally in the medial FT-OA knees compared to that in the normal knees, indicating that the patellar groove was directed distally and medially. In PF-OA knees, we have previously reported that the patellar groove was positioned laterally to a significant degree compared to its position in normal knees.[9] Our present results demonstrated that osteoarthritic knees may undergo anatomic variations prior to the occurrence of osteoarthritic changes.

In patients with osteoarthritic knees, there may be excessive external rotation of the femoral component when the AP axis is used to determine rotational alignment. Under such conditions, varus/valgus instability will occur in flexion. However, we found that the posterior condylar axis was internally rotated 6° relative to the epicondylar axis, and this value was consistent in normal knees and in the knees with osteoarthritis. We therefore recommend using the posterior condylar axis for alignment in TKA in knees with medial FT-OA, unless the posterior condylar surfaces have been destroyed.

In knees in which the posterior condylar surfaces have been destroyed, it is still possible to use the AP axis if its externally rotated direction is taken into account. If the corresponding axis were to be externally rotated, two problems would occur. Firstly, a larger portion of the anterior part of the lateral femoral condyle would need to be resected. Secondly, the femoral component would be inserted in an externally rotated position. Under such conditions, the rotational flexibility of the lateral femorotibial joint in knee flexion would decrease. However, our previous study has shown that popliteus tendon release can compensate for the reduced rotational flexibility, thus maintaining the varus/valgus stability.[8]

Conclusion

In normal knees, the line perpendicular to the anteroposterior axis was externally rotated 4° relative to the posterior condylar axis. In knees with medial femorotibial osteoarthritis, the anteroposterior axis was rotated externally to a significant degree and was thus less reliable, compared to the posterior condylar axis, for use in alignment during total knee arthroplasty.

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References

1. Anouchi YS, Whiteside LA, Kaiser AD, et al. The effects of axial rotational alignment of the femoral component on knee stability and patellar tracking in total knee arthroplasty demonstrated on autopsy specimens. Clin Orthop 1993;287:170–7.
2. Arima J, Whiteside LA, McCarthy DS, et al. Femoral rotational alignment, based on the anteroposterior axis, in total knee arthroplasty in a valgus knee. J Bone Joint Surg Am 1995;77:1331–4.
3. Berger RA, Rubash HE, Seel MJ, et al. Determining the rotational alignment of the femoral component in total knee arthroplasty using epicondylar axis. Clin Orthop 1993;286:40–7.
4. Eckhoff DG, Burke BJ, Dwyer TF, et al. Sulcus morphology of the distal femur. Clin Orthop 1996;331:23–8.
5. Feinstein WK, Noble PC, Kamaric E, et al. Anatomic alignment of the patellar groove. Clin Orthop 1996;331:64–73.
6. Moreland JR, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. J Bone Joint Surg Am 1987;69:745–9.
7. Nagamine R, Whiteside LA, White SE, et al. Patellar tracking after total knee arthroplasty. The effect of tibial tray malrotation and articular surface configuration. Clin Orthop 1994;304:263–71.
8. Nagamine R, White SE, McCarthy DS, et al. Effect of rotational malposition of the femoral component on knee stability kinematics after total knee arthroplasty. J Arthroplasty 1995;10:265–70.
9. Nagamine R, Miura H, Inoue Y, et al. Malposition of the tibial tubercle during flexion in knees with patellofemoral arthritis. Skeletal Radiol 1997;26:597–601.
10. Poilvache PL, Insall JN, Scuderi GR, et al. Rotational landmarks and sizing of the distal femur in total knee arthroplasty. Clin Orthop 1996;331:35–46.
11. Rhoads DD, Noble PC, Reuben JD, et al. The effect of femoral component position on patellar tracking after total knee arthroplasty. Clin Orthop 1990;260:43–51.
12. Stiehl JB, Cherveny PM. Femoral rotational alignment using the tibial shaft axis in total knee arthroplasty. Clin Orthop 1996;331:47–55.
13. Yoshioka Y, Siu D, Cooke TDV. The anatomy and functional axes of the femur. J Bone Joint Surg Am 1987;69:873–80.