Distal femoral rotational axes in Indian knees

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ABSTRACT

Purpose. To measure the angular relationships of distal femoral rotational axes in 100 normal Indian knees.

Methods. 42 men and 8 women aged 26 to 40 (mean, 31) years, with 100 normal non-arthritic knees were recruited. Anatomic landmarks were measured using computed tomography. They included the posterior condylar axis, the transepicondylar axis, the anteroposterior axis (Whiteside’s line), the posterior condylar angle (PCA), the Whiteside-epicondylar angle (W-EP), and the Whiteside-posterior condylar angle (W-PC).

Results. The mean PCA, W-EP, and W-PC were 5º, 90.8º, and 95.8º, respectively. The mean femorotibial alignment was 179.6º. The differences between the left and right sides were significant only for the W-EP and W-PC. Only the PCA and W-EP were weakly correlated (r=0.338, p=0.001).

Conclusion. There are differences in distal femoral rotational axes among Indian, Caucasian, and Japanese knees. Our data can be used to evaluate changes in those axes in ageing or arthritic patients.

Key words: axis; arthroplasty, replacement, knee; ethnic groups; rotation

INTRODUCTION

Improper rotation of the femoral implant during total knee arthroplasty (TKA) may lead to abnormal patellofemoral kinematics, asymmetrical flexion gaps, and early failure. Improper rotation of the femoral implant during total knee arthroplasty (TKA) may lead to abnormal patellofemoral kinematics, asymmetrical flexion gaps, and early failure.1–6 Three rotational axes can be referenced for placement of the femoral component: the posterior condylar axis,1,2,7,8 the transepicondylar axis,3,9,10 and the anteroposterior (AP) axis (Whiteside’s line).11,12

The posterior condylar axis may be misleading, because of degeneration of the posterior femoral condyles, especially in valgus knees.3,11–17 Similarly, the transepicondylar axis is difficult to define, as the most prominent point5,11–13,18–21 or the sulcus4 of the medial epicondyle are covered by soft tissue, resulting in wide inter- and intra-observer variation.3,12,22,23 The AP axis is easily identified in an exposed knee during surgery,11,12 but in valgus/varus knees it may lead to...
excessive external/internal rotation of the femoral component due to erosion of the anterior part of the lateral/medial femoral condyle.\textsuperscript{4,24} Therefore, rotation of the femoral component should be verified using all available axes.\textsuperscript{8,15,24–26}

There are geographic and racial differences in the angular relationships between these axes,\textsuperscript{25,27} and these have been studied using cadaveric bones,\textsuperscript{3,10,11,18,26,27} intra-operative measurements,\textsuperscript{4,12,14,15,19} or computer tomography (CT).\textsuperscript{13,19,24,25,28,29} Most CT studies were performed on arthritic knees; only a small number involved normal knees.\textsuperscript{24,28} We measured the angular relationships of distal femoral rotational axes in 100 normal Indian knees using CT.

MATERIALS AND METHODS

Between August 2005 and July 2006, 42 men and 8 women aged 26 to 40 (mean, 31; standard deviation [SD], 3) years with 100 normal knees were recruited. Subjects with clinical or radiographic features of arthritic knees were excluded, as were those with knee pain, previous fracture, ligamentous injury or laxity around the knee, and any surgery in and around the knee. Each subject gave the informed consent, and our hospital ethics committee approved the study.

Long-leg, standing AP radiographs were taken; mechanical axes of the femur and tibia were drawn and the femorotibial alignment determined. The subjects were then placed in a supine position, with the legs stabilised using a plastic boot and bar. Sequential CT cuts at 3 mm distance were taken from the level of the superior pole of the patella to the tibial tuberosity. In most cases, all anatomic landmarks were defined on one CT scan (Fig.).

The posterior condylar axis was a tangent joining the most posterior point of the medial and lateral femoral condyles. The transepicondylar axis was a line joining the most prominent point of the medial and lateral epicondyles. The AP axis (Whiteside’s line) was drawn from the apex of the intercondylar notch to the deepest point of the patellar groove. The posterior condylar angle (PCA) was the angle between the posterior condylar axis and the transepicondylar axis. The Whiteside-epicondylar angle (W-EP) was the angle between Whiteside’s line and the transepicondylar axis. The Whiteside-posterior condylar angle (W-PC) was the angle between Whiteside’s line and the posterior condylar axis.

Differences between genders and between sides were compared using Student’s \textit{t}-test and paired \textit{t}-test, respectively. A \textit{p} value of <0.05 was considered statistically significant. 20 limbs were measured by a single observer 3 times at weekly intervals as well as by 3 different observers in order to assess intra- and inter-observer variability.

RESULTS

The mean PCA, W-EP, and W-PC were 5° (SD, 1.7°; range, 1.3°–9.1°), 90.8° (SD, 3.7°; range, 83.2–98.8°), and 95.8° (SD, 3.5°; range, 89–104.2°), respectively. The mean femorotibial alignment was 179.6° (SD, 2.1°; range, 176°–185°). The difference between the left and right sides was significant for the W-EP and W-PC only (\textit{p}<0.001, paired \textit{t}-test, Table 1). Only the PCA and W-EP were weakly correlated (\textit{r}=0.338, \textit{p}=0.001). The difference between genders was not significant for the PCA, W-EP and W-PC, but the number of female samples was too small to be conclusive.

Respectively for PCA, W-EP, and W-PC, intra-observer variability was 0.1° (SD, 0.3°), 0.2° (SD, 0.4°), and 0.2° (SD, 0.3°), whereas inter-observer variability was 0.5° (SD, 0.7°), 0.8° (SD, 0.9°), and 0.7° (SD, 0.5°).

DISCUSSION

There is no consensus regarding the use of the transepicondylar axis for measuring the rotation of the femoral component.\textsuperscript{21,25} Regarding the most prominent point of the medial epicondyle, intra- and inter-observer variation is wide. The sulcus of the medial epicondyle is a more reliable and reproducible
landmark, and is commonly used. However, the sulcus may be difficult to define on CT or intraoperatively, especially in arthritic knees. Instead, the most prominent point of the medial epicondyle is easily demarcated and has been used to draw the transepicondylar axis.

The mean PCA was smaller in Indian than Japanese knees (5º vs 5.8º and 6.3º, Table 2). In Japanese knees, the mean W-PC and W-EP were 93.5º (externally rotated) and 87.7º (internally rotated), respectively. In our Indian knees, the corresponding angles were 95.8º and 90.8º (externally rotated), respectively. However, the Japanese subjects were older than ours (50.2 and 63.5 vs 31.3 years). In Caucasian cadaveric knees, the mean W-PC was 93.1º or 93.4º (externally rotated) and the mean W-EP was <90º (internally rotated). The W-PC was about 3º more externally rotated in Indian than Caucasian and Japanese knees (Table 2). Similarly, the W-EP was >90º in Indian knees, compared to <90º in Caucasian and Japanese knees. Using the posterior condylar axis as a reference for femoral rotation may lead to internal rotation of the femoral component by 2º to 3º if a 3º fixed angle is used in Indian knees. A larger sample of non-arthritic knees in similar age groups is required from Caucasian and Japanese subjects for more reliable comparisons.

Gender differences in PCA, W-EP, and W-PC were either not significant or could not be determined because of the small number of female subjects. Our study was limited by the small number of female subjects. In addition, CT cannot assess cartilaginous joint surfaces, for which magnetic resonance imaging appears to be a better imaging modality. There are differences in distal femoral rotational axes among Indian, Caucasian, and Japanese knees. Our data can be used to evaluate changes in those axes in ageing or arthritic patients.

### Table 1
Comparison of left and right knees

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Left side</th>
<th>Right side</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femorotibial alignment</td>
<td>179.5º (2.0º)</td>
<td>179.8º (2.1º)</td>
<td>0.20</td>
</tr>
<tr>
<td>Posterior condylar angle</td>
<td>4.8º (1.7º)</td>
<td>5.2º (1.7º)</td>
<td>0.07</td>
</tr>
<tr>
<td>Whiteside-epicondylar angle</td>
<td>89.8º (3.4º)</td>
<td>91.8º (3.7º)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Whiteside-posterior condylar angle</td>
<td>94.6º (3.2º)</td>
<td>97.0º (3.4º)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Data are presented as mean (SD)

### Table 2
Distal femoral rotational axes reported in various studies

<table>
<thead>
<tr>
<th>Studies</th>
<th>No. of samples</th>
<th>Mean±SD (range) patient age (years)</th>
<th>Mean (SD) posterior condylar angle</th>
<th>Mean (SD) Whiteside-posterior condylar angle</th>
<th>Mean (SD) Whiteside-epicondylar angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computed tomography</td>
<td></td>
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</tr>
<tr>
<td>Present study</td>
<td>100 knees (42 men and 8 women)</td>
<td>31.3 (26–40)</td>
<td>5º (1.7º)</td>
<td>95.8º (3.5º)</td>
<td>90.8º (3.7º)</td>
</tr>
<tr>
<td>Nagamine et al.24</td>
<td>40 knees (all women)</td>
<td>50.2±12.5</td>
<td>5.8º (2.7º)</td>
<td>93.5º (4.0º)</td>
<td>87.7º (3.9º)</td>
</tr>
<tr>
<td>Takai et al.28</td>
<td>19 knees (3 men and 8 women)</td>
<td>63.5 (51–81)</td>
<td>6.3º (1.5º)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cadaveric</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arima et al.11</td>
<td>30 normal femurs</td>
<td>Not specified</td>
<td>5.7º (1.7º)</td>
<td>93.1º (1.7º)</td>
<td>&lt;90º</td>
</tr>
<tr>
<td>Berger et al.3</td>
<td>75 embalmed femurs (20 men, 15 women, and 40 unknown)</td>
<td>Not specified</td>
<td>Male: 4º (3.5º)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Male: 5.2º (4.1º)</td>
<td>Female: 5.2º (4.1º)</td>
<td></td>
<td></td>
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<tr>
<td>Katz et al.18</td>
<td>8 fresh frozen knees</td>
<td>Not specified</td>
<td>6.1º (3.3º)</td>
<td>93.4º (2.1º)</td>
<td>&lt;90º</td>
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<tr>
<td>Mantas et al.30</td>
<td>14 men and 5 women</td>
<td>43±19 (17–89)</td>
<td>Male: 4.4º (2º)</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Female: 6.6º (2.2º)</td>
<td></td>
<td>Female: 6.6º (2.2º)</td>
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<tr>
<td>Yoshioka et al.10</td>
<td>16 male and 16 female embalmed normal femurs</td>
<td>73.4</td>
<td>Male: 5º (1.8º)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Female: 6º (2.4º)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### REFERENCES
2. Anouchi YS, Whiteside LA, Kaiser AD, Milliano MT. The effects of axial rotational alignment of the femoral component on


