

Determining the rotational alignment of the tibial component at total knee replacement

A COMPARISON OF TWO TECHNIQUES

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We prospectively assessed the benefits of using either a range-of-movement technique or an anatomical landmark method to determine the rotational alignment of the tibial component during total knee replacement. We analysed the cut proximal tibia intraoperatively, determining anteroposterior axes by the range-of-movement technique and comparing them with the anatomical anteroposterior axis.

We found that the range-of-movement technique tended to leave the tibial component more internally rotated than when anatomical landmarks were used. In addition, it gave widely variable results (mean 7.5°; 2° to 17°), determined to some extent by which posterior reference point was used. Because of the wide variability and the possibilities for error, we consider that it is inappropriate to use the range-of-movement technique as the sole method of determining alignment of the tibial component during total knee replacement.

The importance of correct rotational alignment in total knee replacement (TKR) is well established. Rotational malalignment causes several complications, including anterior knee pain,¹ patellofemoral instability,^{2,3} and excessive wear of polyethylene.⁴⁻⁶ The rotational alignment of the femoral component has been extensively studied.^{1,3,7-14} Useful reference axes for setting proper femoral rotation include the posterior condylar axis,⁷ the midtrochlear line (Whiteside's line⁸) and the transepicondylar axis.^{10,13,14} Less attention has been given to the rotational alignment of the tibial component.

Currently, two techniques are widely used to determine the rotational alignment of the tibial component in TKR.¹⁵ The first uses anatomical landmarks such as the tibial tuberosity, the posterior condylar line of the tibia and the malleolar axis of the ankle. The second, which avoids reference to anatomical landmarks, is the range-of-movement (ROM) technique, in which the knee is put through a full range of flexion and extension, allowing the tibial trial to orientate itself in the best position relative to the femoral component. This orientation is marked on the anterior tibial cortex and the definitive tibial component is then implanted to match this mark.¹⁶

The anatomical landmark technique has been reported to be reliable and reproducible^{17,18} but the ROM technique has not been well evaluated and our aim was to assess its benefits.

The cut proximal tibia was analysed intraoperatively, and the anteroposterior (AP) tibial axes determined by the ROM technique were compared with the anatomical AP axis described by Akagi et al.¹⁸

Patients and Methods

Between January 2004 and July 2005, 40 consecutive primary TKRs in 38 patients were performed by one surgeon (MI). The pre-operative diagnosis was osteoarthritis in 31 patients and rheumatoid arthritis in seven. There were 32 women and six men with a mean age at the time of surgery of 72 years (48 to 86). The mean pre-operative femorotibial lateral angle was 181° (161° to 197°), measured on a weight-bearing long-leg anteroposterior radiograph.

Through a standard midline incision and medial parapatellar arthrotomy, we implanted a posterior-cruciate-ligament (PCL)-retaining prosthesis (TC-PLUS solution; Plus Orthopaedics, Rotkreuz, Switzerland) in all patients. Distal femoral preparation was performed in a standard fashion using the transepicondylar axis (a line connecting the sulcus of the medial epicondyle and the bony prominence lateral epicondyle) to establish rotational alignment of the femoral component. When the epicondyles could not be accurately identified, we referred to the posterior condylar axis of the femur. The variation between the transepicondylar axis and the posterior condylar axis

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©2007 British Editorial Society
of Bone and Joint Surgery
doi:10.1302/0301-620X.89B1.
17728 \$2.00

J Bone Joint Surg [Br]
2007;89-B:45-9.

Received 6 February 2006;
Accepted after revision 12
September 2006

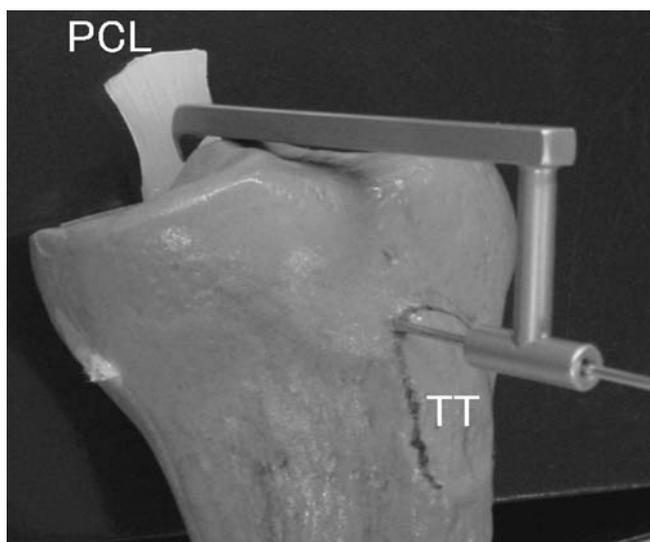


Fig. 1

Photograph showing the insertion device used to connect the medial border of the patellar tendon attachment and the middle of the posterior cruciate ligament (PCL) at the level of its tibial attachment (TT, tibial tuberosity).

was measured pre-operatively by CT in all patients. The femoral component was placed externally rotated relative to the posterior condylar axis based on the result of the CT measurement.

Before retracting the proximal tibia anteriorly for the first proximal tibial osteotomy, a 1.8 mm Kirschner (K)-wire was inserted at the medial border of the insertion of the patellar tendon and directed towards the middle of the PCL at the level of the tibial attachment, using an insertion device. The direction of this K-wire indicated the anatomical AP axis of the tibia as reported by Akagi et al.¹⁸ They investigated the AP axis of the tibia using CT in healthy knees, and reported that this line was reliable and reproducible as the AP axis of the tibia. The insertion device was originally developed to connect the two points located at different levels in the axial planes (Fig. 1). The proximal tibial osteotomy was cut with a 5° posterior slope having defined the rotation of the proximal cutting jig by referencing the K-wire and defining the long axis of the tibia by extramedullary jigs. The posterior tibial osteophytes were removed.

Measurement of soft-tissue balancing was assessed using a balancer supplied by the manufacturer (Plus Orthopaedics). The joint space was expanded by the balancer, applying a force of 50 N. The gap created between the tibia and femur was measured in millimetres. Differences in measurements of the flexion and extension, and medial and lateral gaps were within 4 mm for all patients. After soft-tissue balancing, the ROM technique was performed. The tibial trial tray with the appropriately-sized insert was placed on the cut proximal tibia before preparation of the tibia to accept the keel of the tibial component. The femoral tray was placed on the prepared femur, the patella was

relocated, and the medial arthrotomy was held approximated by three tissue clamps. The knee was fully flexed and extended five times, allowing the unsecured tibial trial to seek its own rotation which occurred between the under surface of the unsecured tibial trial and the cut surface of the proximal tibia. The rotational orientation of the tibial trial determined by the ROM technique was marked on the anterior tibial cortex by electrocautery (anterior ROM mark). The distance between the medial border of the attachment of the patellar tendon, which had already been marked by a K-wire, and the anterior ROM mark was measured using a ruler marked at intervals of 1 mm. When the anterior ROM mark was located lateral to the medial border of the attachment of the patellar tendon, the measurement was expressed as a negative value.

Next, a digital camera (Sony DSC-F505V, Tokyo, Japan) was placed perpendicular to the cut proximal tibia and digital images of the cut surface were recorded. During this procedure, two observers besides the surgeon (NY, YO, EU) controlled the position of the camera so that it was perpendicular to the cut surface, indicated by the extramedullary tibial jig. Finally, the proximal tibial preparation was completed by aligning the tibial trial to the anatomical AP axis in order to create the recess for the keel. The patella was resurfaced in all patients. All three components were implanted with cement, after which the tracking of the patella was checked. No lateral retinacular releases were required.

The patients were followed up for a mean of 14.2 months (6 to 24) after surgery. Record was made of any post-operative complications, including infection, nerve palsy, symptomatic deep-vein thrombosis or pulmonary embolism. Measurements were made of the post-operative femorotibial lateral angle from the weight-bearing long-leg anteroposterior radiograph and the post-operative posterior tibial slope from the lateral knee radiograph. This latter measurement was the angle between a line drawn anteroposteriorly across the tibial component and a line drawn perpendicular to the midline axis of the tibia. The skyline view showed no subluxation or dislocation of the patella. In order to check the rotational alignment of the components, we obtained axial CT scans (3 mm thickness) in addition to conventional radiographs one month post-operatively.

The variation between the posterior condylar axis of the femoral component and the transepicondylar axis was also measured, a negative value being applied when the femoral component was externally rotated compared with the transepicondylar axis. The femorotibial rotational mismatch was evaluated by superimposition of the axial views of each component with the knees in extension.¹⁹ Because the tibial component used in this series was asymmetrical we were unable to draw a line corresponding to the posterior condylar axis of the femoral component.²⁰ As an alternative we used the symmetrical posterior margin of the polyethylene tibial insert for evaluation. The mean differen-

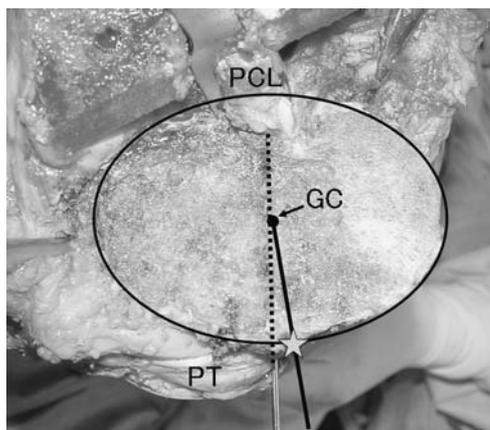


Fig. 2a

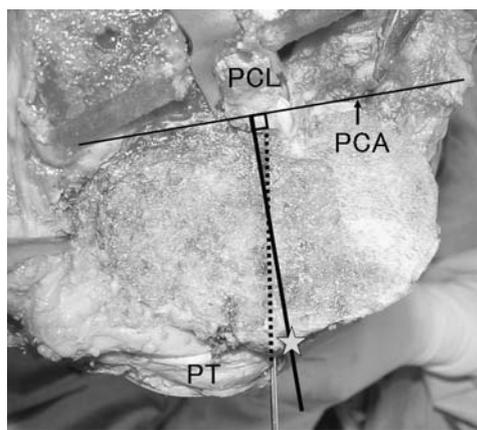


Fig. 2b

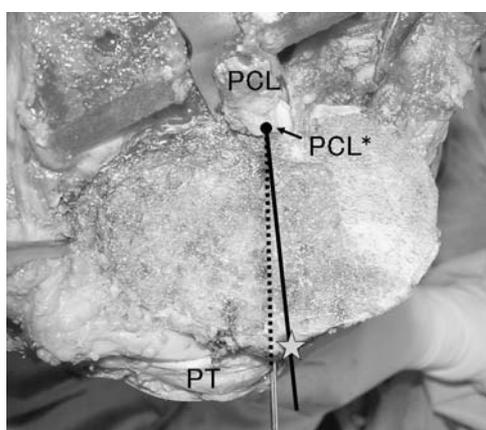


Fig. 2c

Photographs showing a) geometrical centre (GC)-range of movement (ROM); b) the posterior condylar axis (PCA)-ROM and c) the posterior cruciate ligament (PCL)-ROM axes. The star indicates the anterior reference point (anterior ROM mark) which is determined by the ROM technique. The dotted line indicates the anatomical anteroposterior axis. See text for explanation (PT, patellar tendon; PCL*, intersection between the anatomical anteroposterior axis and the posterior tibial rim).

tial angle between the posterior condylar axis of the femoral component and that of the polyethylene insert was 1.1° (-5° to 8°) where a negative value indicated that the femoral component was externally rotated compared with the polyethylene insert.

All the digital images of the cut proximal tibia were transferred to computer-measuring software (CIS-Image; IBM, Tokyo, Japan), and angular measurements performed semi-automatically using a computer mouse. The anatomical AP axis and three tibial axes determined by the ROM technique (ROM-dependent axes) were drawn on the cut proximal tibia on the computer monitor. These three ROM-dependent axes were defined as follows: 1) The GC-ROM axis, a line connecting the anterior ROM mark and the geometrical centre (GC)³ of the cut tibial surface (Fig. 2a); 2) The PCA-ROM axis, a perpendicular line to the posterior tibial condylar axis¹⁶ (a line connecting the two most posterior points of medial and lateral tibial condyles) passing through the anterior ROM mark (Fig. 2b); 3) The PCL-ROM axis, a line connecting the anterior ROM mark and the intersection between the anatomical AP axis and the posterior tibial rim (Fig. 2c). The angles between the anatomical AP axis and each of the three ROM-dependent axes were measured at intervals of 1° .

Statistical analysis. The results were analysed by analysis of variance followed by the Fisher protected least significant difference,²¹ with $p < 0.05$ indicating statistical significance. The maximum differential angles for the three ROM-dependent axes were also measured in individual knees. All angular measurements were repeated by two independent observers (MI, YO) and the mean value was used for analysis. The interobserver error for all angular measurements was $< 2^\circ$.

Results

The anterior ROM mark was located close, but slightly medial to, the medial border of the attachment of the patellar tendon in most patients. The mean distance between the anterior ROM mark and the medial border of the insertion of the patellar ligament was -0.6 mm (-10 to 9). The mean post-operative femorotibial lateral angle was 174° (170° to 179°). The mean post-operative posterior tibial slope was 5.7° (2° to 8°) and the mean variation between the posterior condylar axis of the femoral component and the transcondylar axis was 1.1° (-3° to 3°).

The mean angles between the anatomical AP axis and each of the three ROM-dependent axes (GC-ROM, PCA-ROM, PCL-ROM) were 5.2° (-12° to 22°), 3.7° (-10° to

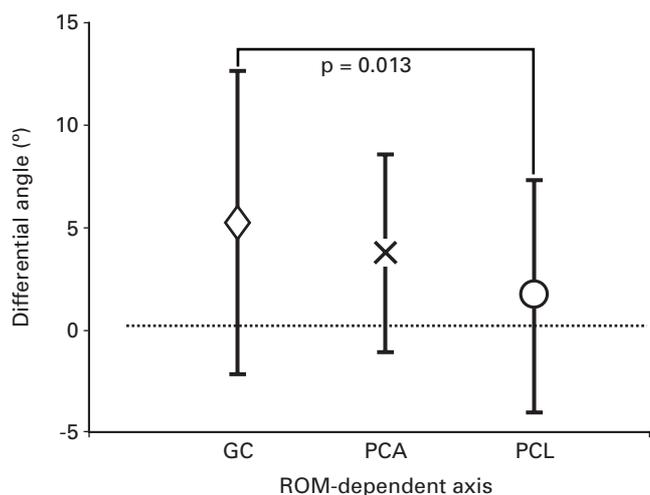


Fig. 3

Chart showing the differential angles between the anatomical antero-posterior axis and each of the three range of movement (ROM)-dependent axes (geometrical centre (GC) ROM; posterior condylar axis (PCA) ROM axis; posterior cruciate ligament (PCL) ROM axis). The dotted line indicates no rotational mismatch. A negative value means that the ROM-dependent axis is externally rotated compared with the anatomical anteroposterior axis.

16°), and 1.6° (-10° to 14°), respectively. The ROM-dependent axes were internally rotated compared with the anatomical AP axis in most patients. The amount of internal rotation of the GC-ROM axis was the largest of the three ROM-dependent axes, and a significant difference was found between the GC-ROM and PCL-ROM axes (Fisher protected least significant difference, $p = 0.013$) (Fig. 3). The mean maximum differential angle for the three ROM-dependent axes was 7.8° (2° to 17°). CT scans showed neither excessive rotational malposition of the femoral component nor femorotibial rotational mismatch in any patient.

Discussion

The tibial component is typically aligned with a point between the medial one-third and lateral two-thirds of the tibial tuberosity when the anatomical technique is used. However, several studies have suggested that this technique may cause the tibial component to be in external rotation relative to the femoral component.^{17,18,22,23} Our findings have also indicated that the best rotational orientation of the tibial component is close to the medial border of the attachment of the patellar tendon. We suggest therefore that the anterior reference point of the proximal tibia should be close to this point rather than being aligned between the medial one-third and lateral two-thirds of the tibial tuberosity, if anatomical landmarks are used.

We found that relying only on the anterior ROM mark, the rotational orientation of the tibial component varied widely (mean 7.8°; 2° to 17°), depending on the posterior reference point. We consider that the posterior reference point, where the differential angle between the ROM-

dependent and anatomical AP axes is minimal, should be used in the ROM technique. Although the range of variation for all the ROM-dependent axes was so large that a small difference was difficult to interpret, the PCL-ROM axis was significantly closer to the anatomical AP axis than the GC-ROM axis. Furthermore, a small error in selection of the reference point could cause a large rotational error when a short axis was used. We consider that the distance between two reference points should be as great as possible and recommend the centre of the PCL at the level of its tibial attachment as the posterior reference point in the ROM technique.

Other than the variability of the ROM-dependent axis with the posterior reference point, the ROM technique is theoretically dependent on the rotational orientation of the femoral component and the soft-tissue balancing. In our study, post-operative CT scans showed no malrotation of the femoral component and minimal soft-tissue imbalance, checked by a balancer in all knees. Consequently, we do not believe that these factors affected our results.

Some surgeons prefer an alternative method of determining rotational alignment of the tibial component, which uses an asymmetrical component and maximises tibial cover in order to provide the best stability and load transfer.^{24,25} We did not evaluate this method in our study, because a reproducible and reliable AP axis could not be determined in this way. We aim to achieve optimal patellar tracking, femorotibial kinematics and tibial cover simultaneously during TKR. Although we agree that maximising tibial cover is an important technique, we believe that tibial cover itself is not the only factor to consider when determining rotational alignment of the tibial component.

However, our study has some limitations. First, there were potential errors in determining the anatomical AP axis intra-operatively, which affected the reliability of the measurements. In order to minimise these errors, we chose the anatomical landmarks (patellar tendon and PCL) which were not directly affected by osteoarthritic change. We also used the insertion device which originally had been developed for connecting these landmarks which are located at different levels in axial planes. Secondly, we used one type of PCL-retaining prosthesis in all patients, with a femur-first technique, referencing the transepicondylar axis for the femoral rotation, and resurfacing of the patella. Consequently, the effects of other prostheses or techniques on rotational alignment of the component could not be established from our study alone. Other limitations included the small number of subjects and the lack of any major malalignment in most knees (mean pre-operative femorotibial lateral angle 181° (161° to 197°)). The results of our study may not apply to the severely deformed knee. Regardless of these limitations, we believe that our study has revealed clinically important information about the rotational alignment of the tibial component in TKR.

The rotational incongruity of the femorotibial joint in a TKR generates an abnormal distribution of stress at the

polyethylene surface,⁶ which in turn results in excessive wear of polyethylene.^{4,5} The design of the implant also affects the severity of this complication. The more conforming a surface is, the more severe the polyethylene wear in the presence of rotational malposition. When a PCL-substituting design is used, the rotational malposition generates high contact stress at the post-cam mechanism,²⁶ which results in disruption of the posterior stabilising mechanism. For a highly conforming design and posterior stabilising mechanism, which is currently popular, rotational alignment is more important than for less conforming designs. The use of a rotating platform implant may circumvent these issues.^{26,27}

In conclusion, we found unacceptably large differences in the rotational alignment of the tibial component when using the alignment techniques described. The ROM technique tended to leave the tibial component more internally rotated than if anatomical landmarks had been used, and gave widely variable results, determined to some extent by which posterior reference point was used. Because of such wide variability and the several possibilities for error, it is perhaps inappropriate to use the ROM technique as the sole method of determining alignment.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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