Femoral and tibial component rotation in total knee arthroplasty

METHODS AND CONSEQUENCES

At least four ways have been described to determine femoral component rotation, and three ways to determine tibial component rotation in total knee replacement (TKR). Each method has its advocates and each has an influence on knee kinematics and the ultimate short and long term success of TKR. Of the four femoral component methods, the author prefers rotating the femoral component in flexion to that amount that establishes a stable symmetrical flexion gap. This judgement is made after the soft tissues of the knee have been balanced in extension.

Of the three tibial component methods, the author prefers rotating the tibial component into congruency with the established femoral component rotation with the knee is in extension. This yields a rotationally congruent articulation during weight-bearing and should minimise the torsional forces being transferred through a conforming tibial insert, which could lead to wear to the underside of the tibial polyethylene. Rotating platform components will compensate for any mal-rotation, but can still lead to pain if excessive tibial insert rotation causes soft-tissue impingement.

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The determination of proper rotation of the femoral and tibial component during total knee replacement (TKR) has been controversial for decades. Each method has its advocates and often all the methods yield similar results. At times however any method can be inappropriate, with some leading to deleterious effects on both the kinematics and results of TKR. Surgeons should be aware of the various methods available, and should be knowledgeable enough to vary their standard technique in order to benefit their patient.

Determining femoral component rotation

At least four ways have been described for surgeons to determine proper femoral component rotation:

The trans-sulcus axis. A line is drawn down the deepest part of the trochlear sulcus (The Whiteside Line) and femoral component rotation is oriented perpendicular to it (Fig. 1).

The transepicondylar axis. The surgeon palpates the medial and lateral epicondyles and draws a line connecting them. The lateral epicondyle is prominent and easy to locate, however the medial epicondyle is broader and not as well defined. Some surgeons locate it by palping for a sulcus or dimple in its centre.

The posterior condylar axis. This method uses a fixed number of degrees of external rotation (usually between 3° and 5°) referenced off the posterior condylar axis. Most systems have an antero-posterior sizing guide with ‘feet’ that slide under the medial and lateral posterior condyles. Left and right handed pin holes are usually provided in order to mark the desired amount of external rotation of the femur relative to the posterior condyles (Fig. 3). The rationale for this method derives from the observation that the normal tibial joint line is in between 3° and 5° of varus relative to the long axis of the tibia. For example, if the tibial resection is made in 3° of varus, an equal symmetrical posterior condylar resection will result in a rectangular flexion gap. If the tibial resection is 90° to the long axis of the tibia, 3° to 5° of external rotation will be necessary in order to recreate a rectangular gap.

Gap balancing. This method determines the rotation that will establish a symmetrical and rectangular flexion gap likely to produce optimal knee stability and effective kinematic function. The extension gap is balanced first by an appropriate medial release in varus knees. Most valgus knees are balanced without any major degree of lateral collateral ligament...
After balancing with the knee in extension, it is placed in 90° of flexion, and some form of tension measuring device is applied across the medial and lateral compartments. The femoral component is then rotated in order to achieve flexion gap symmetry: laminar spreaders can be used for this purpose (Fig. 4). The spreader will open up the medial gap a finite amount regardless of the tension applied unless the anterior aspect of the medial collateral ligament is abnormal or injured. It must be noted however that the lateral compartment is more pliable in flexion than the medial side. It is probably helpful therefore to use a calibrated spreader on the lateral side, despite the tension amount not having been established. (The author has used 20 pounds of tension over the past ten years with good results.) When using this method, well over 90% of knees end up in 5° of external rotation relative to the posterior femoral condylar line.

There are two exceptions to this. One occurs in the severe valgus knee with a hypoplastic posterior lateral femoral condyle where 7° or 8° may be required (Fig. 5). The second is seen in the severely varus knee where the medial posterior femoral condyle is ‘hyperplastic’ and as much as 7° may be needed in order to restore a rectangular gap.

The knee may in rare cases require no external rotation relative to the posterior femoral condyles, or perhaps there will be a need for intentional internal rotation. This can be the case in a knee with laxity of the anterior aspect of the medial collateral ligament. Rotating the femoral
component internally will close down the medial flexion gap, and restore medial stability in flexion. It can also occur when converting a patient with a proximal tibial osteotomy that has healed in excessive valgus with a valgus tibial joint line. Thus, when the knee is flexed to 90°, the femoral condyles rest in marked external rotation on the valgus tibial joint line (Fig. 6).

If a method other than gap balancing is used to determine femoral component rotation, more flexion gap asymmetry will be created, and an extensive lateral collateral release will be required to balance the flexion gap. Most surgeons are concerned that purposeful femoral component internal rotation will compromise patellar tracking (see Discussion below).

Some surgeons are wedded to just one of the four methods, while others initially use one or more of the first three techniques as guidelines, but rely on gap balancing to ensure knee stability in flexion. There is universal agreement that femoral mal-rotation (defined as internal or external rotation deviating more than 3° from the trans-sulcus or transepicondylar axis) should be avoided as it can be a source of patellar instability, especially if the femoral component is mistakenly rotated internally. It is of interest to note however that mathematical calculation of the actual effect of rotation on the displacement of the trochlear groove shows that for every 4° of femoral component rotation, the groove is displaced by about 2 mm. This relatively small amount can be compensated by under-sizing the patellar component by one size and shifting it medially, beveling the uncapped patellar surface to prevent impingement. There are also reports that suggest that femoral or tibial component mal-rotation can cause pain, stiffness and subsequent failure of the TKR.

Determining tibial component rotation
There are three ways of determining tibial component rotation. Firstly, it is placed anatomically on the cut surface of the tibia using an asymmetrical tibial tray. Secondly, the tibial component is rotated relative to the location of the tibial tubercle, usually at the junction of the medial and central thirds of the tubercle. The third is to rotate the tibial component into alignment with the chosen femoral component rotation when the knee is moved into full extension.

Each of these methods has its advantages. Advocates of the anatomical method emphasise the advantage of maximally covering the cut tibial surface to facilitate component fixation, while avoiding the potential of component overhang and soft tissue impingement.

According to advocates of the second method, the tibial tubercle can easily be identified. The third method would appear to be the most logical and appropriate in order to avoid mal-rotation of the femoral/tibial articulation during weight-bearing.

Tibial insert topside morphology has evolved from being relatively flat to curved in the last 20 years, in order to increase articular conformity and to minimise topside wear. Wear on the tibial component under-surface and subsequent osteolysis was relatively rare beneath these flat inserts, but became an issue after the more curved and conforming tibial articultations were introduced. The hypothesis was formed that torsional forces normally dissipated on the topside of relatively flat inserts were now being transferred through the curved, and conforming insert morphology to the under-surface, leading to increased relative movement between modular tibial components and resulting production of wear debris and osteolysis. Rotating platform articulations have to some extent addressed this issue by allowing the movement beneath conforming articulations to occur on
Rotating platform components will compensate to some degree transferred through a conforming tibial surface during weight-bearing and minimises the torsional forces extension. This yields a rotationally congruent articulation established femoral component rotation when the knee is in full extension. This results in a polished flat-on-flat surface. An intra-operative study using rotating platform trials revealed that using a fixed tibial anatomical landmark could lead to significant femoral/tibial articular malrotation in 5% of cases studied. Stabilised systems with posted tibial components that have rotational constraint are more vulnerable than minimally constrained cruciate retaining articulations (Fig. 7).

Summary

There are at least four ways for surgeons to determine femoral component rotation, and three to determine tibial component rotation. Each method has its advocates and each has an influence on knee kinematics and the ultimate short and long-term success of TKR. Of the four femoral component methods, the author prefers rotating the femoral component to the amount that establishes a stable symmetrical flexion gap in flexion.

Of the three tibial component methods, the author prefers rotating the tibial component into congruency with the established femoral component rotation when the knee is in extension. This yields a rotationally congruent articulation during weight-bearing and minimises the torsional forces being transferred through a conforming tibial surface. Rotating platform components will compensate to some degree for any mal-rotation, but can still lead to pain if there is soft-tissue impingement.

References