Aligning the tibial component with medial border of the tibial tubercle— is it always right?¹

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Introduction: Correct rotational alignment of the tibial component is crucial for total knee arthroplasty (TKA). Several studies have indicated that the best rotational orientation of the tibial component is close to the medial border of the tibial tubercle. However, it remains obscure whether it is always right. Thus, the objective of current study was to quantify tibial rotational alignment in 120 primary rotating platform TKAs using the medial border of tibial tubercle as a landmark between July 2008 and June 2010.

Methods: The femoral component was positioned parallel to the transepicondylar axis, and a rotating platform trial insert was used to determine tibial insert rotational alignment relative to the most medial aspect of the tibial tubercle with the knee in full extension. Rotational alignment of the components was detected based on radiograph and CT scan. This investigation is based on the premise that all neutral points would lie within 10° of the mean.

Results: The mean divergence external to the medial border of the tibial tubercle was 2.3° ± 3.5°. However, six of the knees (5%) had neutral points ≥ 10° from the mean, including two valgus knees measured 10° of internal rotation and four varus knees measured 10° of external rotation.

Conclusion: Using the medial border of tibial tubercle as a landmark does not always result in a good femorotibial rotational alignment. Surgeons using fixed bearings component should be aware of this effect to avoid suboptimal outcomes resulting from tibiofemoral rotational malalignment in full extension.

Level of evidence: Diagnostic study, Level II-3.

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1. Introduction

Correct rotational alignment of the femoral and tibial component has been suggested as an important factor for total knee arthroplasty (TKA) in multiple studies. Rotational malalignment may lead to various forms of patellofemoral problems, aseptic loosening, premature polyethylene wear, flexion instability, and abnormal gait [1–3]. At present, at least four rotational reference axes have been recommended for alignment of the femoral component: 1) the posterior condylar axis [4]; 2) the tibial cut or shaft axis [5]; 3) the transepicondylar axis (surgical epicondylar axis, SEA) [6]; and 4) the midtrochlear line (Whiteside anteroposterior (AP) axis) [7]. Of these, the transepicondylar axis has been shown to be not only a useful anatomic reference axis, but also a functional flexion-extension axis [6,8]. Furthermore, it has been reported that aligning the femoral component parallel to the transepicondylar axis results in optimum patellofemoral tracking and minimized femorotibial wear motion and instability [8]. Therefore, the transepicondylar axis has been established as the mediolateral axis of the femur for TKA.

Several methods also have been described to achieve proper tibial component rotation. One of the most widely used methods is to align the tibial component with the medial third of the tibial tubercle, which has been stated to maximize function [9]. However, no literature has been published on the theoretical background of this technique, which seems to be established empirically. Importantly, some studies have mentioned that aligning the tibial component with the medial third of the tibial tubercle will result in excessive external rotation of the tibial component in some cases [10–12].

As the femoral component is set parallel to the transepicondylar axis, Akagi et al. described a new AP axis for the tibial component which is defined as a line perpendicular to the SEA and passing through the center of the knee [10]. Using preoperative computed tomography (CT) scans, the medial edge of the patellar tendon was found as the anterior landmark instead of the medial third of the tibial tubercle [10]. They also showed that the tibial component would have approximately 10° excessive external rotation relative to the femoral component in an extended knee position if the medial third method was used [10]. Another widely accepted method to determine the tibial component rotation is the range-of-movement (ROM) technique, which avoids reference to anatomical landmarks and calls for rotating the tibial tray
into neutrality with the established rotation of the femoral component in extension [13]. Using this technique, Ikeuchi et al. suggested that the best rotational orientation of the tibial component is close to the medial border of the patellar tendon, which is in accordance with the result of Akagi’s [12].

The purpose of this study was to quantify rotational alignment of the tibial component using the medial border of tibial tubercle as a landmark. As the femoral component is set parallel to the transepicondylar axis (perpendicular to the Whiteside line), the AP axis of the tibial component should be set parallel to the Whiteside line (perpendicular to the SEA) and passing through the center of the knee. If the tibial component is internally (or externally) set to the Whiteside line, it is considered as internal (or external) rotation. This investigation is based on the premise that all neutral points would lie within 10° of the mean.

2. Materials and methods

Between July 2008 and June 2010, a prospective, observational study was conducted in 120 consecutive primary rotating-platform TKAs (PFC Sigma Rotating Platform, DePuy/Johnson & Johnson, Warsaw, IN) done by one surgeon in one hospital. Preoperative range of motion was assessed just prior to inflation of the tourniquet. Final range of motion was determined after closure of the arthrotomy. The amount of rotation of the trial tibial insert relative to the midline of the trial tibial tray (aligned with the medial border of the tibial tubercle) was collected for each knee.

There were 84 women and 36 men enrolled in the study. Their average age at the time of surgery was 67 ± 6.6 years (range, 56–81 years). The pathological diagnoses included 103 cases of osteoarthritis and 17 cases of rheumatoid arthritis. Evaluation of preoperative standing 3-foot long roentgenograms revealed 76 varus deformities (defined for our study as anatomic tibiofemoral alignment <0°) and 44 valgus deformities. The mean preoperative osseous coronal alignment was 2.7° ± 3.3° of anatomic varus (range, 12° of varus to 17° of valgus). Mean preoperative flexion was 105° ± 12° (range, 45°–125°). Intra-operatively, full extension was achieved in all patients. Flexion against gravity after closure of the medial parapatellar arthrotomy had a mean value of 112° ± 9° (range, 90°–125°).

Through a standard midline incision and medial parapatellar arthrotomy, the anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) were excised. A medial soft tissue sleeve, including the deep medial collateral ligament (MCL), was elevated from the proximal medial tibia, allowing the tibial plateau to be delivered anteriorly relative to the distal femur. The distal femoral and proximal tibial resections were then done. Long-leg weight-bearing anteroposterior radiographs, obtained preoperatively in all patients, were used to evaluate osseous coronal alignment and assist in the determination of the appropriate valgus angulation of the distal femoral cut and the relative amount of medial and lateral resection from the proximal tibia. Intramedullary femoral and extramedullary tibial instrumentation were used in all cases. The proximal tibial osteotomy was cut with a 3° posterior slope.

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 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.

Soft tissue balancing, based on preoperative deformity, was performed to get a rectangular flexion and extension gap. The shift and resection technique was an additional release used in some varus knees. Knees with substantial valgus deformity were balanced using a lateral cruciform retinacular release. Spacer blocks supplied by the manufacturer were used to confirm the effect of soft tissue release.

After soft-tissue balancing, the medial border of the tibial tubercle was palatted, cleared of any overlying soft tissues, and marked with electrocautery. A line connecting this maker to the middle of the PCL was marked at the cut surface of the tibia. This line indicated the anatomical AP axis of the tibia as reported by Akagi et al. [10]. They investigated the AP axis of the tibia using preoperative CT, and reported that this line was reliable and reproducible [10]. An appropriately sized trial rotating platform tray was subsequently inserted and centered on this line. The femoral tray was placed on the prepared femur and the patella was relocated. The knee was placed through a range of motion and tested for patellofemoral tracking as well as for stability in the sagittal and coronal planes. Adjustments were made until the construction was determined to be satisfactory by the attending surgeons.

The trial inserts had a series of marks along their anterior surfaces. These marks extended, in 5° increments, 15° from the midline in either direction, delineating a total arc of 30°. The angles were calibrated to accommodate for changes in the radius of each size of tray/insert combination (Fig. 1). A measurement was taken after the knee was fully flexed and extended five times, allowing the tibial trial to seek its own rotation with the established rotation of the femoral component in extension (Fig. 2). With the knee in full extension and the patella everted, the direction of rotation (internal versus external rotation) and the magnitude of the angle subtended between the line on the midpoint of the tibial tray and the midline of the trial insert were recorded to the nearest 5-degree increment. The knee was then prepared for implantation of the real components which were inserted using standard techniques. The final rotational alignment of the tibial tray was changed, if necessary, toward the neutral rotatory alignment of the trial insert.

The patients were followed up for a mean of 14.2 months (range, 6 to 30) after surgery. Record was made of any post-operative complications. No patients suffered from infection, nerve palsy, symptomatic deep-vein thrombosis or pulmonary embolism.

Measurements were made of the post-operative femorotibial lateral angle from the long-leg weight-bearing anteroposterior radiograph and the post-operative posterior tibial slope from the lateral knee radiograph. The skyline view showed no subluxation or dislocation of the patella.

Fig. 1. The rotating platform trial inserts have a series of marks in 5° increments along their anterior surface. The angles are calibrated to account for different trial insert and/or tray sizes.
Fig. 2. The trial tibial insert has the freedom to rotate into congruency with the femoral component.

In order to check the rotational alignment of the components, we obtained axial CT scans in addition to conventional radiographs 1 month postoperatively. The variation between the posterior condylar axis of the femoral component and the transepicondylar axis was measured, a negative value being applied when the femoral component was externally rotated compared with the transepicondylar axis. CT scans showed no excessive rotational malposition of the femoral component in any patients.

3. Statistical methods

Statistical analysis was done with the assistance of a biostatistician using the SAS 9.0 software (SAS Institute Inc., Cary, NC, USA). A student’s t-test was used to compare mean rotation for the male and female as well as the varus and valgus subgroups.

4. Results

With the knee in extension, we observed that the mean rotation of trial tibial insert from the midline of the trial tibial tray (the medial border of the tibial tubercle) was $2.3°\pm3.5°$ of external rotation (range, $10°$ of internal rotation to $15°$ of external rotation) for all knees (Table 1). Six of the knees (5%) studied had neutral points greater than or equal to $10°$ from the mean, which seemed to violate our original hypothesis that all neutral points would lie within $10°$ of the mean.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>All knees</th>
<th>Male</th>
<th>Female</th>
<th>Valgus</th>
<th>Varus</th>
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<tr>
<td>Tibial insert</td>
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Negative angle indicates that the rotation of trial tibial insert from the midline of the trial tibial tray is internal.

Varus knees had greater external rotation ($p = 0.015$). Varus knees had a mean of $2.8°\pm3.4°$ of external rotation (range, $5°$ of internal rotation to $15°$ of external rotation). Valgus knees had a mean of $1.4°\pm3.5°$ (range, $10°$ of internal rotation to $10°$ of external rotation).

5. Discussion

Several studies have demonstrated that TKA can generate reliable, reproducible, and lasting positive clinical results, when used for the accepted indications in an appropriate population of patients. Despite improvements in surgical technique, instrumentation, and implant design, technical failures still emerge. Rotational malalignment has been associated with patellofemoral problems as well as accelerated topside wear of the tibial polyethylene, medial and/or lateral wear on the post of posterior-stabilized designs, backside wear in any conforming modular system, premature component loosening, and even total knee dislocation [1–3,14,15]. In this cohort of 120 primary TKAs, we found that the average tibial rotation from the most medial aspect of the tibial tubercle was $2.3°\pm3.5°$ of external rotation (range, $10°$ of internal rotation to $15°$ of external rotation). Nevertheless, six knees (5%, two valgus and four varus) had neutral points greater than or equal to $10°$ from the mean, which seemed to violate our original hypothesis that all neutral points would lie within $10°$ of the mean.

The tibial component is typically aligned with medial third of the tibial tubercle when the anatomical technique is used [9]. However, several studies have suggested that this technique may cause the tibial component to be in external rotation relative to the femoral component [10–12]. In the study reported by Akagi et al., which has been done by preoperative CT scans to identify an extrarticular anatomic landmark, the medial edge of the patellar tendon has been implicated to a reliable anterior anatomic landmark [10]. Ikeuchi et al. compared the anterior reference point determined by the ROM technique with medial third of the tibial tubercle during TKA and found that the best rotational orientation of the tibial component is close to the medial border of the attachment of the patellar tendon [12]. Our findings have also indicated nearly the same conclusion. The mean angle between the tibial AP axis and a line connecting the middle of the PCL to the medial third of the patellar tendon attachment at the tibial cutting level is within $10°$ in the majority of uncomplicated cases [10,16].

The rotational incongruity of the femorotibial joint has been shown to cause morbidity. In a CT study of patients with isolated patellofemoral complications awaiting revision TKA, the authors concluded that internal rotation of the femoral and/or tibial components in a TKA with proper coronal alignment may be the predominant cause of patellofemoral complications after TKA [14]. They reported that mild combined internal rotation (1°–4°) was correlated with lateral patellar tracking and patellar tilting; moderate combined internal rotation (5°–8°) correlated with patellar subluxation; and severe combined internal rotation (7°–17°) might cause patellar dislocation or late component failure.

Excessive external rotation of the tibial component is associated with complications as well. In a study using cadavers, Eckhoff et al. evaluated six commonly used methods of identifying the appropriate amount of external rotation of the tibial tray [17]. The authors confirmed that none of the methods accurately and reproducibly positioned the tibial component, relative to the femoral component. A tendency toward overly externally rotating the tibial tray relative to the femoral component was also identified by the authors.

Authors of tibial polyethylene retrieval studies have identified that most failed inserts have asymmetric wear [18,19]. The most common of these asymmetrical wear patterns is a postero medial to antero lateral orientation. One explanation for this is an uncoupled alignment of the femoral and tibial components. In addition, authors of a study of tibial post wear in posterior-stabilized knees point to rotationally malaligned components as a cause of medial and lateral cam wear as well as backside wear in any conforming modular system [20].
It is clear from our study and others that there is a narrow range of optimal rotation of the tibial component relative to the medial border of the tibial tubercle. In our cohort, external rotation of the trial insert had a mean value of 2.3°±3.5° from the most medial aspect of the tibial tubercle. In the majority of uncomplicated cases, this point is much closer to the medial aspect of the tibial tubercle. However, 5% of knees implanted by referencing only the tibial tubercle will have neutral points plus or minus 10° from the mean. Based on previous investigations, it is likely that TKAs with greater than 10° of rotational malalignment will have complications [14,21]. Because of the large number of primary TKAs done worldwide each year, the ramifications of such malalignment are substantial.

Although rotating-bearing TKA can accommodate tibial component malrotation, fixed-bearing TKA designs are less forgiving. Surgeons using fixed-bearing modular components with any rotational constraint must be cautious in choosing a fixed anatomic tibial landmark to determine the rotational alignment of the tibial component. Tibiofemoral rotational malalignment may be created in full extension to lead to patellofemoral problems, aseptic loosening, polyethylene wear, flexion instability, and abnormal gait in any conforming modular system. We believe that once femoral component rotation has been established in a fixed-bearing design, the tibial tray should be rotated in such a way that it is rotationally congruent with the femoral component with the knee in full extension. Even doing so may not accommodate dynamic rotational forces applied during gait.

This investigation has several limitations. First, the number of subjects was limited (total number of subjects was 120, 36 males and 84 females), and the study population was confined to Chinese subjects. The data included in this current study may be typical for knees of Asian subjects and there may be anatomic differences in the Caucasian population or other groups. Therefore, the results of this study should be interpreted cautiously. Second, intraoperative measurements, regardless of how they are taken, often are less accurate than those taken in a controlled setting in which more sophisticated equipment can be used. We estimated the amount of trial insert rotation to the nearest 5° increment. Though it would have been ideal to measure the angles of rotation continuously, this was not possible because the inserts only had marks in 5° intervals. We could have estimated to the nearest degree, but doing so would be less accurate. Regardless of these limitations, we believe that our study has revealed clinically important information about the rotational alignment of the tibial component in TKAs.

In conclusion, we represent that there is a narrow range of optimal rotation of the tibial component relative to the medial border of the tibial tubercle. Surgeons who use the anatomical technique must be cautious in choosing a fixed anatomic tibial landmark to determine the rotational alignment of the tibial component. Doing so may create tibiofemoral rotational malalignment in full extension that may lead to suboptimal outcomes.

6. Conflict of interest statement

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. We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work. There is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

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