How Frequent Is Rotational Mismatch Within 0°±10° in Kinematically Aligned Total Knee Arthroplasty?

Alexander J. Nedopil, MD; Stephen M. Howell, MD; Maximilian Rudert, MD; Josh Roth, BS; Maury L. Hull, PhD

abstract

Full article available online at Healio.com/Orthopedics. Search: 20131120-15

Rotational mismatch of the tibial component on the femoral component within 0°±10° is associated with better function after mechanically aligned total knee arthroplasty (TKA). Kinematically aligned TKA has gained interest; however, the percentage of kinematically aligned TKA within 0°±10° is unknown. The authors prospectively followed all patients who underwent TKA for primary osteoarthritis between December 2011 and April 2012 (194 patients, 195 knees). Each underwent kinematically aligned TKA with manual instruments. Aligning the anteroposterior axis of the tibial component parallel to the line that bisects the oval boundary of the lateral tibial condyle set internal/external rotation. Removing bone from the posterior femoral condyles equal in thickness to the femoral component after correction for cartilage wear set internal/external rotation and anteroposterior translation of the femoral component. Rotational mismatch of the tibial component on the femoral component was determined from a computed tomography scan of the knee. Ninety-seven percent of kinematically aligned TKA with fixed-bearing components had a rotational mismatch within 0°±10° (overall range, -11° to 11°). This percentage was higher and the range narrower than the 85% of TKA within 0°±10° and the -14° to 16° range reported for mechanically aligned TKA. The use of manual instruments to kinematically aligned TKA reliably limited rotational mismatch to within 0°±10°, which has been associated with better function.

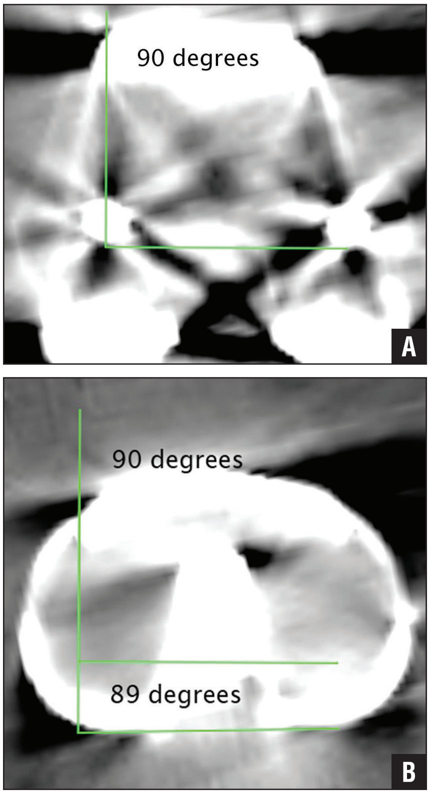

Figure: Computed tomography scan of a right knee that best shows the femoral fixation lugs. A right angle was drawn with the vertical arm through the midpoint of the lateral lug and the transverse arm parallel to the posterior border of the 2 lugs. The angle was propagated through all slices (A). Computed tomography scan of a right knee that best shows the posterior border of the tibial component. The right angle was copied, pasted, and translated posteriorly, and the transverse arm was adjusted until parallel to the posterior border of the tibial component. The tibial component was externally rotated 1° on the femoral component (B).

The authors are from the Orthopaedic Center for Musculoskeletal Research (AJN, MR), Orthopädische Klinik König-Ludwig-Haus, Würzburg, Germany; the Biomedical Engineering Graduate Group (SMH, JR, MLH), and the Department of Mechanical Engineering (MLH), University of California at Davis, Davis, California.

Drs Nedopil and Rudert and Mr Roth have no relevant financial relationships to disclose. Dr Howell is a paid consultant for Biomet Sports Medicine and Stryker and receives research support from Stryker. Dr Hull receives research support from Stryker.

The authors thank the imaging technicians at Methodist Hospital, Sacramento, California, for performing the axial computed tomography scans.

Correspondence should be addressed to: Alexander J. Nedophil, MD, Orthopaedic Center for Musculoskeletal Research, Orthopädische Klinik König-Ludwig-Haus, Brettreichstraße 11, 97074 Würzburg, Germany (a-nedopil.klh@uni-wuerzburg.de).

Received: July 9, 2013; Accepted: July 25, 2013; Posted: December 13, 2013.
doi: 10.3928/01477447-20131120-15

The success of total knee arthroplasty (TKA) depends on many factors, including rotational alignment of the tibial and femoral components.[1] Rotational malalignment of the tibial component on the femoral component can lead to pain, stiffness, instability, polyethylene wear, patellar maltracking, and a high revision rate.[2-6] A study of mechanically aligned TKA with a mobile-bearing cruciate-retaining implant that adjusts for component malrotation reported that 15% had rotational mismatch with the knee in full extension outside 0°±10°, and that TKA with rotational mismatch outside this range had lower function scores and more undesirable contact kinematics of external rotation of the tibia on the femur with flexion than TKA with rotational mismatch within this range.[1,7] Accordingly, Lützner et al[1,7] proposed that surgical techniques that narrow the range of rotational mismatch within 0°±10° could provide better function and more normal kinematics.

Recently, the concept of kinematically aligned TKA has gained interest among knee surgeons because randomized trials and case series of kinematically aligned TKA implanted with patient-specific guides have reported better patient satisfaction, function, and flexion, lower failure, and more desirable contact kinematics than mechanically aligned TKA.[8-11] In October 2009, a technique was developed to perform kinematically aligned TKA with manual instruments to eliminate the added cost of patient-specific guides.[12-14] In manual kinematically aligned TKA, the internal/external rotational position of the tibial component is set by aligning the anteroposterior (AP) axis of the tibial component parallel to a line drawn on the AP axis that bisects the oval boundary of the lateral tibial condyle. The goal of this method for aligning the tibial component is to orient the AP axis of the tibial component perpendicular to the transverse axis in the femur and femoral component about which the tibia flexes and extends.[8,12,13,15] The internal/external rotation of the femoral component is set by removing bone from the posterior femoral condyles equal in thickness to the femoral component after correcting for cartilage wear and kerf with the intent of aligning the transverse axis in the femur about which the tibia flexes and extends with the axis of the femoral component.[12,13,15,16] However, the current authors are unaware of any studies that have reported rotational mismatch when kinematically aligned TKA is performed with manual instruments and a fixed-bearing tibial component that can not adjust for component malrotation.

Accordingly, the authors determined the percentage of rotational mismatch within the high function range of 0°±10° in kinematically aligned TKA performed with manual instruments and a fixed-bearing tibial component by a single surgeon. They then determined whether the percentage of TKA within this range is higher than a report[1] of mechanically aligned TKA performed with mobile-bearing cruciate-retaining components.

Table

Preoperative Demographics and Clinical Characteristics

Variable	Mean±SD (Range)
Age, y	67±9.8 (48 to 95)
Male sex, %	42
BMI, kg/m^2	30±6.1 (19 to 44)
Extension, deg	11±8.8 (-5 to 30)
Flexion, deg	112±11.3 (65 to 135)
Varus (+)/valgus (-) deformity, deg	0±11.2 (-30 to 22)
Oxford Score	21±7.1 (1 to 42)
Knee Society Score	40±20.9 (4 to 100)
Knee Function Score	49±19.3 (0 to 100)

Abbreviations: BMI, body mass index; deg, degrees.

Materials and Methods

The authors prospectively followed 194 patients (195 knees) undergoing kinematically aligned TKA implanted using manual instruments between November 2011 and April 2012. During the study period, no other method of performing primary TKA was used. The indications for performing TKA were (1) disabling knee pain and functional loss unresolved with customary nonoperative treatment modalities; (2) radiographic evidence of advanced arthritic change; and (3) all severities of varus, valgus, and flexion contracture deformities. Contraindications were infection and knees with Charcot changes. Eight patients were excluded: 1 with a high tibial osteotomy, 1 with internal fixation of a tibial plateau fracture, 3 with incomplete imaging of the tibial tubercle, and 3 without computed tomography (CT) scans because the scanner was either in use with emergency cases or inoperable due to maintenance. Therefore, the study group comprised 188 TKA in 187 consecutive patients (109 women and 87 men; mean age, 67±9 years). Patient preoperative demographics, motion, and function scores are shown in the **Table**. An institutional review board approved the study (Dignity Health, Sacramento, California; protocol number 00006573).

Surgical Technique

Setting Rotation of the Femoral and Tibial Components

The senior author (S.M.H.) performed all kinematically aligned TKA with manual instruments under a general anesthetic with use of a fixed-bearing cruciate-retaining component (Triathlon; Stryker, Inc, Mahwah, New Jersey) and tourniquet control as previously described.[12,13] The following is an abridged description of the surgical technique.

Two pads on the distal surface of the distal femoral cutting guide were adjust-

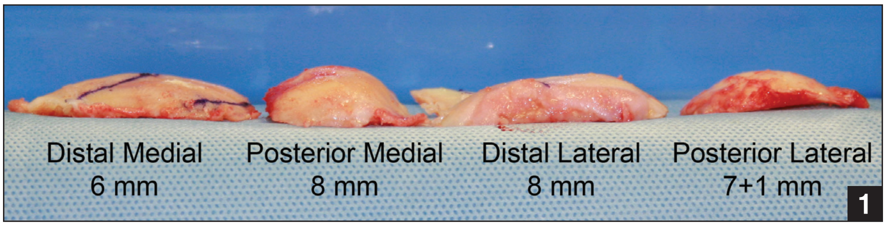

Figure 1: Photograph showing the measured thicknesses of the bone resected from the posterior femoral condyles used to rotationally align the femoral component. The 8-mm posterior medial resection matched the thickness of the condyle of the femoral component (8 mm). The 7+1-mm posterior lateral resection indicates that the initial resection of 7 mm was increased 1 mm to match the thickness of the femoral component. In this varus knee, the distal medial resection was 2 mm thinner than the other resections to compensate for 2 mm of cartilage wear.

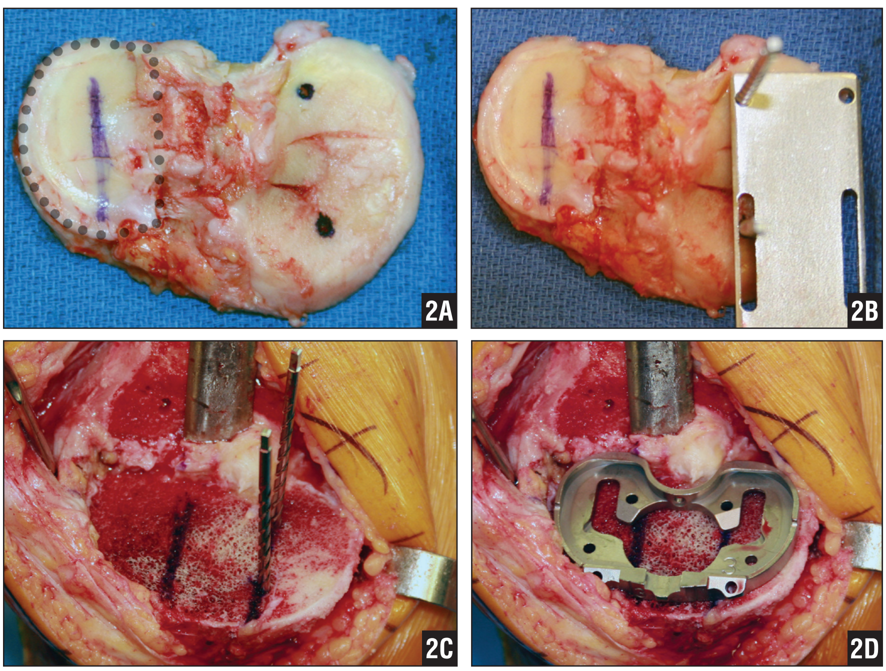

Figure 2: Photographs of a right knee showing the steps for aligning the rotation of the tibial component on the tibia. On the articular surface of the tibial plateau (after resecting the tibia), the boundary of the oval-shaped lateral femoral condyle was outlined with a series of partially opaque black dots (A). A vertical blue line was drawn on the perceived location of the anteroposterior (AP) axis that bisects the oval shape of the lateral tibial condyle. Two pins were drilled parallel to the AP line through the articular surface of the medial tibial condyle 15 to 10 mm into the medial plateau with a homemade guide (B). On the cut surface of the tibial plateau, 2 AP lines were drawn parallel to the 2 drill holes, into which pins were placed to clarify their location (C). The AP axis of the trial tibial component was aligned parallel to these 2 AP lines (D).

ed in prominence to account for cartilage wear on the distal femur. The guide was pinned to the distal femoral condyle just posterior to the apex of the intercondylar notch. The distal femoral cut was performed, and the thickness of the resections was measured with calipers. When necessary, the thickness of the distal femoral cut was adjusted so the bone resections matched the thickness of the condyles of the femoral component after correcting for cartilage wear and kerf of the saw (**Figure 1**). This step set the varus/valgus rotational and proximal/distal translational alignments of the femoral component and restored the angle and level of the normal distal joint line.

The 2 pads on a 0° posterior referencing femoral cutting guide were adjusted to account for cartilage wear, and the guide was pinned to the femur. The conventional 4-in-1 cutting block that matched the planned size of the femoral component was pinned. The posterior femoral cut was performed, and the thickness of the resections was measured with calipers. When necessary, the thickness of the posterior femoral cut was adjusted so the resection of the bone and cartilage matched the thickness of the condyles of the femoral component after correcting for wear and kerf. This step set the internal/external rotational and the AP translational alignments of the femoral component and restored the angle and level of the normal posterior joint line.

The anterior and chamfer resections were performed. The tibia was dislocated anteriorly, preserving the posterior cruciate ligament. On the articular surface of the tibia, the oval boundary of the lateral tibial condyle was visualized, and the AP axis bisecting the oval was marked (**Figure 2**). A parallel drill guide was used to drill 2 holes parallel to this line through the articular surface on the medial condyle. Osteophytes were removed to restore collateral ligament length, and the gap-balancing method was used to perform a conservative tibial resection, leaving the posterior cruciate ligament intact. Posterior osteophytes were removed, and a posterior capsular release was performed when a flexion contracture required correction. The AP axis of the tibial trial was aligned parallel to 2 AP lines drawn parallel to the drill holes in the tibia. The patella was resurfaced. Trial components were inserted, and balance of the knee and patella tracking were qualitatively determined by manual examination. Knee balance was fine-tuned by adjusting the angle and depth of the tibial cut. All components were cemented.

Determining Rotational Mismatch of the Components

The rotational mismatch of the tibial component on the femoral component was determined by analyzing axial computed tomography (CT) scans of the knee with a 1.25-mm slice thickness (Lightspeed 16; General Electric Healthcare, Little Chalfont, United Kingdom), which were acquired on the day of discharge for each patient. These images were analyzed using free image analysis software (OsiriX; www.osirix-viewer.com, Geneva, Switzerland) on a personal computer (PowerBook; Apple Computer, Cuppertino, California) with the following technique (**Figure 3**). The rotational mismatch of the tibial component relative to the femoral component was defined by the angle between a line tangent to the posterior borders of the femoral fixation lugs and a line tangent to the posterior border of the tibial liner. These lines were created from the 2 CT slices that best showed these features and then projected to the same slice. A positive angle indicated external rotation of the tibial component on the femoral component, and a negative angle indicated internal rotation.

Statistical Analyses

The mean±SD, range, and percentage of TKA within and outside 0°±10° rotational mismatch of the tibial component on the femoral component were determined using JMP version 10.0.0 statistical software (SAS Institute, Inc, Cary, North Carolina). The authors also determined the percentage of TKA within the 0°±10° range that surpassed the percentage reported in a study of mechanically aligned TKA performed with mobile-bearing cruciate-retaining components.[1]

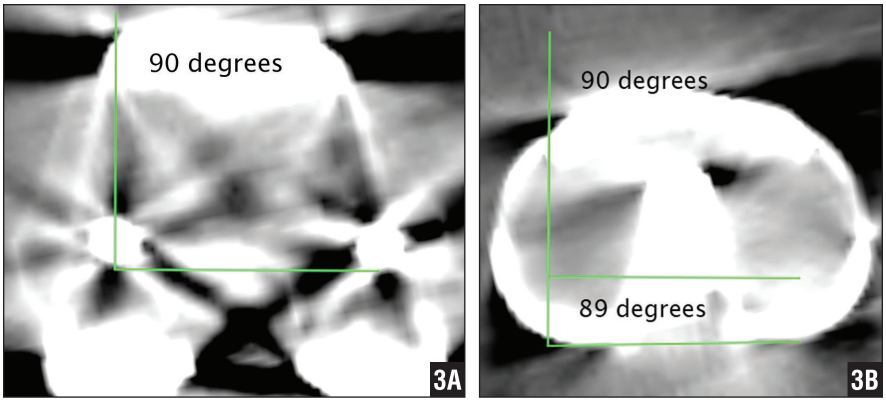

Figure 3: Computed tomography scan of a right knee that best shows the femoral fixation lugs. A right angle was drawn with the vertical arm through the midpoint of the lateral lug and the transverse arm parallel to the posterior border of the 2 lugs. The angle was propagated through all slices (A). Computed tomography scan of a right knee that best shows the posterior border of the tibial component. The right angle was copied, pasted, and translated posteriorly, and the transverse arm was adjusted until parallel to the posterior border of the tibial component. The tibial component was externally rotated 1° on the femoral component (B).

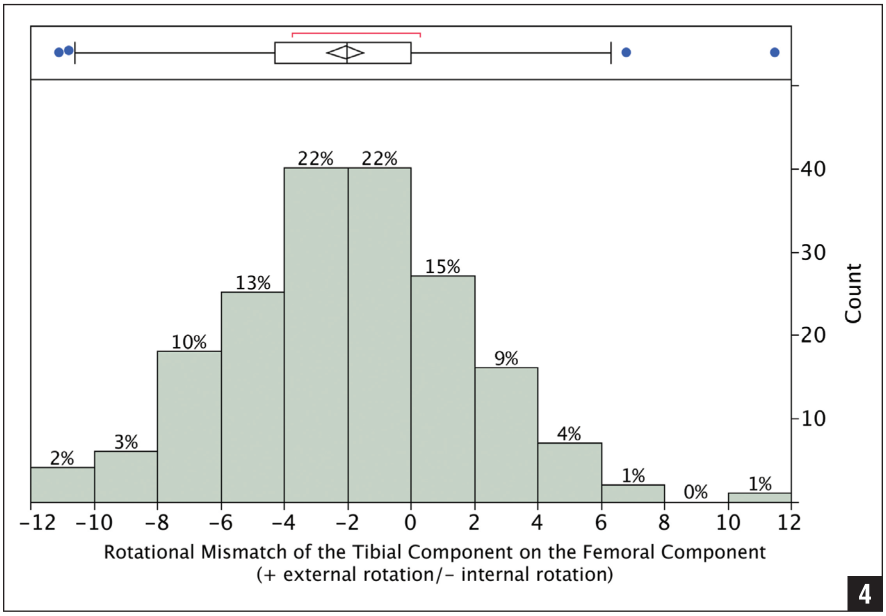

Figure 4: Frequency distribution and quantile plot showing the percentage and count of kinematically aligned total knee arthroplasties with rotational mismatch of the tibial component on the femoral component in 2° intervals from -12° to 12°. Ninety-seven percent of the total knee arthroplasties were within 0°±10° of malrotation, which is the range associated with better function and kinematics.

Results

The reproducibility of measuring rotational mismatch was assessed on the first 19 patients undergoing TKA by computing the intraclass correlation coefficient of measurements made by 2 observers (A.J.N., S.M.H.). The high intraclass correlation coefficient of 0.9367 confirms strong agreement between the readings of the 2 observers.

Ninety-seven percent of the kinematically aligned TKA with fixed-bearing components had a rotational mismatch within the 0°±10° range and the overall range was from -11° to 11° (**Figure 4**). This percentage was higher and the range was narrower than the 89% of TKA within 0°±10° and the -14° to 16° range reported[1] for mechanically aligned TKA with a mobile-bearing tibial component.

Discussion

Narrowing the range of rotational mismatch of the tibial component on the femoral component to within 0°±10° has been reported to be associated with improved function and more desirable contact kinematics after mechanically aligned TKA with a cruciate-retaining mobile-bearing tibial component that adjusts for malrotation.[7] The current study measured rotational mismatch for kinematically aligned TKA performed with manual instruments and a cruciate-retaining fixed-bearing tibial component that does not adjust for malrotation. The rotation of the AP axis of the tibial component was aligned parallel to a line drawn on the perceived location of the AP axis that bisects the oval shape of the lateral tibial condyle, and the rotation of the femoral component was aligned by resecting bone from the posterior condyles that matched the thickness of the posterior condyles of the femoral component after correcting for wear.

Two limitations of this study must be discussed before interpreting the results. First, 8 (4%) of 196 knees had no rotational measurements because either the landmarks were unclear on the CT scan or a scan was not performed because the scanner was unavailable. Because random events caused a small percentage of TKA to not have rotational measurements, the interpretation of the results should not be biased. Second, the results require independent confirmation because they reflect the experience of 1 surgeon.

The most important finding of the current study is that 97% of kinematically aligned TKA treated with manual instruments and a fixed-bearing tibial component were within the high function 0°±10° range and had a narrow range of -11° to 11°. This percentage of TKA within the high function range is higher than the reported 85% and 88% for mechanically aligned TKA with a cruciate-retaining mobile-bearing component.[1,7] The -11° to 11° range of malrotation is narrower than the reported range of -14° to 16° for mechanically aligned TKA with a cruciate-retaining mobile-bearing component.[1,7] The high percentage of kinematically aligned TKA within the high function range can be explained by the intraoperative verification of the rotation of the femoral component by measuring the resection of bone and cartilage from the posterior condyles and adjusting the position of the femoral component so that the thickness of the resections equaled the thicknesses of the posterior condyles of the femoral component after correcting for kerf and wear. Because of the intraoperative verification of the rotation of the femoral component, the primary cause of the rotational mismatch was likely an error between the line drawn on the perceived location of the AP axis of the lateral tibial condyle and the actual AP axis of the lateral plateau, an error between drawing the 2 lines on the resected surface of the tibia and the actual AP axis of the lateral plateau, and an error aligning the AP axis of the tibial component parallel to the 2 lines drawn on the resected surface of the tibia.

The method of aligning the AP axis of the tibial component parallel to a line drawn on the AP axis that bisects the oval shape of the lateral tibial condyle may seem unconventional based on 4 other axes that are more commonly used, such as the medial border and the medial one-third of the tibial tubercle, the posterior condylar line of the tibial plateau, and the transcondylar line of the tibia. However, the reliability of each of these landmarks in setting the rotation of the tibial component has been questioned and debated,[17-22] especially the use of the tibial tubercle because its location is variable.[20] The current authors' method of aligning the AP axis of the tibial component parallel to the AP axis that bisects the oval shape of the lateral tibial condyle was effective at limiting malrotation and justifies further study to determine the relative reliability of all of these methods.

Conclusion

Kinematically aligned TKA with manual instruments with a cruciate-retaining fixed-bearing tibial component that can not adjust for malrotation reliably limited rotational mismatch to within the 0°±10° range, which has been associated with better function and kinematics. Further reduction of the range of malrotation in the kinematically aligned TKA with manual instruments will require a more reliable way to set the rotation of the tibial component on the tibia.

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