Total knee arthroplasty (TKA) is considered as the definitive treatment for pain, disability, and loss of motion associated with end-stage joint disease. The number of TKAs is following a continuous growth trend as currently an estimated 600,000 procedures are performed annually in the United States with projection to reach up to 3.48 million procedures yearly by 2030. Although the procedure is considered among the most cost-effective interventions in medicine by restoring function and quality of life, multiple undesired outcomes occur, ranging from persistent pain to failure leading to revision surgery. As such, it was expected that with the increase in number of TKAs, a concomitant associated rise in revision TKA would be noted. The main aseptic etiologies that lead to failure of TKA are instability, tibial and femoral aseptic loosening, and polyethylene wear.

Many modifiable factors affect the outcomes and functionality following TKA, including the proper alignment of the components. Component malalignment leads to alteration of joint kinematics, patellar maltracking and anterior knee pain, premature polyethylene wear, and knee instability.

The transepicondylar axis and the anteroposterior axis (AP), which are assumed to be closely associated with the flexion-extension axis of the knee, are considered as the gold standard to guide and achieve optimal transverse Tibial anatomical landmarks for transverse plane rotation of the tibial tray have not been validated. The current authors propose aligning the tibial tray with both the anterior tibial center point of rotation (ATCPR) and the femoral trochlear groove (FTG) to establish the ideal tibial tray rotation in total knee arthroplasty (TKA). When the tibial tray centerline was aligned with ATCPR and FTG lines, the mean range of motion (ROM) was 144.3° (preoperatively 145°) and tibial rotation range was 22.8 mm (preoperatively, 24.9 mm). When the tibial component was rotated 5 mm medially to the ATCPR, the knee ROM decreased in flexion with patellar subluxation, while it decreased in extension when rotated 5 mm laterally. This method identifies the ideal tibial tray rotation in TKA, at which maximal range of tibial rotation and knee ROM are achieved without obvious overriding of components. [Orthopedics, 2016; 39(3):S67-S71.]
The current gold standard for the tibia in full extension is then marked with a pen. Points making the FTG plane intersected line may be square), and the line the FTG plane makes on the anterior-most point is then taken as point P1 (black color line on tibia). The 2 points making the FTG plane intersected line may be marked with a pen. The ideal tibia tray rotation (ITTR) is the degree at which the tibial baseplate is rotated in a fixed-bearing TKA that allows the optimal flexion and extension arc. The current authors suggest a new anatomic landmark that will aid in achieving the ITTR position in TKA. The aim, in addition to identifying the ITTR, is to assess the intra- and interobserver reliability in the establishment of the tibia center of rotation registration points used in imageless computer-assisted navigation of TKA. This method will be compared with similar intra- and inter-observer reliability of mechanical tibia rotation measurement using goniometers before and after TKA. The current authors hypothesized that this approach will achieve optimal tibial rotation with minimal variability. This method was tested on 9 cadavers at 2 different sessions.

The Ideal Tibial Tray Rotation (ITTR) Line
The midpoint between the 2 anterior-most points of the tibia where the FTG intersect the tibia under maximum internal and external rotation defined above is then established (Figure 3). The line created by this point (P3 in Figure 3) and the ATCLR is then labeled the ITTR and used for rotational alignment of the tibial tray in the transverse plane.

Cadaveric Protocol
For 9 cadaveric knees, the subvastus approach was utilized in all cases by a fellowship-trained surgeon (SH). Following skin and subcutaneous incisions, the joint was exposed, and computer-navigated measurements were made for the kinematics and range of motion (ROM) of the knee before the removal of any intra-articular structures. The data from the computer were collected to quantitate and calculate the mid points and the planes from 3 points. Then the FTG plane was determined by registering the 3 points along the AP axis as described above by the surgeon and 2 novice untrained collaborators. Then the leg was put in full extension, with the tibia placed in maximal external rotation. This point was registered and marked with a surgical pen. Next, the leg was positioned

Materials and Methods
ATCLR Calculation
The current authors propose aligning the tibial tray along the anterior tibia center line of rotation (ATCLR). This line is calculated by referencing the femoral trochlear groove (FTG) with 3 points (1 at the superior-most point, another at the base at the lateral border of the posterior cruciate ligament, and a third equidistant along the groove (or AP axis)°). The tibia in full extension is then externally rotated to its maximum, and the point where the FTG line meets the tibia is drawn (Figure 1). With the knee in 90° of flexion, the tibia is placed under maximal internal rotation, and the anterior point on the tibia where the FTG meets is drawn out again (Figure 2). The intersection point of these 2 lines created on the tibia then represents the ATCLR. The ATCLR is then used as the point to align the center of the tibial tray in the sagittal plane.
in full flexion, and the surgeons internally rotated the tibia, and the plane registered on the navigation system as well as manually marked with a surgical pen.

The computer then automatically identified P3 and the bisecting line. This can also be identified manually by marking the midpoint between P1 and P2, labeled as P3 (Figure 3), then drawing a line (another yellow) from P3 to the blue dot, which is the intersection of lines from P1 and P2 in the plane of FTG in full extension and full flexion, successively. A large bore drill hole in the blue dot was made to the depth of the tibia of at least 12 mm, a point beyond which the tibia resection was made. This approach manually identifies 2 points and a line on the top and on the anterior surface of the tibia. As such, the ITTR can be manually located without the guidance of the computer.

Extreme internal and external rotation of the tibia and tibia component in extension, and in 90° of flexion and in full flexion were measured and documented by all 3 operators. The measurements were performed using a goniometer and a computer navigation system (Ortho Pilot Software, Aesculap, Tuttlingen, Germany). The current authors compared the variation from multiple measurements of tibia rotation by a single operator to multiple palpation points by other 2 inexperienced operators (inter-observer variation). Also, the variation of multiple measurements by each operator was compared (intra-observer variation). The data were collected and repeated 3 times before and after navigated TKA in 9 cadavers to assess the intra- and inter-observer reliability.

Three operators determined the tibia center of rotation by averaging the extreme internal and external rotation of the tibia. The effects on ROM of the knee were also measured by the computer and documented to further confirm the ideal tibia rotation necessary for best ROM.

After a 10-mm matched resection of the tibia, the tibia tray was placed at approximate equidistance from medial and lateral tibial borders at 90°, tibia tray AP centerline was aligned with ATCLR. This was done visually and compared with computer navigation to quantify the difference. Tibia range of internal and external rotation and knee ROM were then recorded. These measurements were then recorded with the tibial component rotated internally to a point 5 mm medial to the ACTLR and then externally at a point 5 mm lateral to the ACTLR. The femoral component in all cases was placed using routine computer navigation placed along the AP axis. All knees were either normal or had osteoarthritis of grade II-III with no exposed bones.

**Statistical Analysis**

Descriptive statistical analyses were undertaken to assess the collected data, in terms of means. Statistical significance was defined at the level of P value with 0.05 considered as significant.

**RESULTS**

ATCLR was at a mean of 11.4 mm lateral to the intersection of the FTG and the anterior border of the tibia in full extension (P1 point). When the tibia tray centerline was aligned with the ATCLR, the mean ROM was 144.3° (compared with 145° preoperatively) and mean range of tibial rotation was 22.8 mm (compared with 24.9 mm preoperatively).

When the tibial component was rotated 5 mm medially in relation to the ATCLR (internally rotated), the ROM of the knee decreased by a mean of 16° of flexion in addition to patellar tilting or subluxation. When the tibial component was placed 5 mm lateral to the ATCLR (externally rotated), the knee ROM decreased by 8° of full extension with component overriding and loss of equivalent tibial rotation range.

The current authors also assessed the relation of the ITTR with the known medial third of the tibial tubercle rule. The current authors found that the ITTR is at the medial third of the patella insertion 82% of the time for 3 observers that were recorded in this study (22/27 recorded trials from 3 observers). In the other 5/27 recorded trials, the ITTR lateral in 1 and medial in 4 specimens.

No significant inter-observer and intra-observer variation were noted whether by
and ROM following TKA. The soft tissue envelops the knee, which includes the collaterals, popliteus, posterior cruciate, and capsule working together throughout the knee ROM. Any interference by tightening 1 and loosening the other may substantially affect the kinematics of the knee resulting in decrease in the knee’s ROM, knee pain at specific points in the ROM, fatigue and pain by the end of the day, or a combination of these symptoms. In a retrospective study based on computed tomography (CT) analysis, the authors determined the rotational alignment of 39 painful and 26 painless knees from a cohort of 740 fixed-bearing TKAs.27 They noted that, in relation to the anterior tibial tuberosity, external rotation of tibial component was not associated with pain, while internal rotation by over 9° was the major etiology of pain in 17 TKAs.27 Barrack et al prospectively collected clinical and radiographic data for 102 cruciate-retaining TKA in 73 patients, over a minimum follow-up period of 5 years.11 The study included 11 patients with 14 painful knees that were matched and compared with a control group of 11 patients with 14 pain-free knees.11 Using the anterior tibial tubercle axis as reference, the authors noted a significant difference in tibial component rotation between the 2 cohorts, with the painful group averaging 6.2° of internal rotation, vs 0.4° of external rotation in the control group.11 In a study of 52 patients receiving revision surgery for stiffness, Bedard et al assessed the components’ rotation in 34 TKAs.28 The authors reported an average of 3.1° of internal rotation in 24 out of the 34 femoral components and a mean of 13.7° of internal rotation in 33 out of the 34 tibial components.28 Bell et al compared the components’ rotational alignment with CT images in 56 patients with pain following TKA with a matched control cohort of 56 pain-free patients.29 The authors noted that an excessive internal rotation of the tibial component was significantly \( P = .0003 \) associated with pain following TKA, while external rotation did not correlate with painful TKA.29 In another retrospective analysis of radiographic and CT images, Kim et al reviewed 3048 knees in 1696 patients with an average follow-up of 15.8 years.30 Although the authors reported only 30 cases of revision not related to infection or periprosthetic fracture, they recommended the tibial component to be aligned within 2° to 5° of external rotation in relation to the posterior tibial plateau margins to avoid increase in failure rates following TKA.30 The findings of these studies highlight the significance of achieving proper tibial component alignment and its impact on postoperative long-term outcomes and survivorship of the implant following TKA.

This study proposed a new landmark that can be applied to guide the tibial tray rotation in TKA. This method was validated by comparing the results achieved by placing the component visually and with computer-assisted navigation, with no significant intra- or intra-observer variation. The current authors’ method obtained maximum range of tibia rotation and knee ROM without apparent components override. It is also noted that rotating the tibial tray by 5 mm or more outside of the ITTR showed significant loss of tibia rotation and knee ROM (\( P = .2 \)) with possible components override.

However, there are several limitations to the current authors’ study. First, the procedures were performed by a single, experienced surgeon, using a cruciate-retaining prosthesis on 9 cadavers with 2 novice individuals with no medical training. Different surgeons with different skills and different implants and different tibial morphology may experience different results. Second, the knee samples used in this study were all either normal or had osteoarthritis of grade II-III. This might be relatively different from patients in the clinical setting, where the degree of osteoarthritis might be more extensive with associated soft tissue contractures,
which might lead to different results. The technique may also yield different results if a significant amount of soft tissue balancing is performed during the TKA, which was not the case in these cadaveric specimens. Finally, this is a cadaveric study conducted to establish an anatomic landmark that will be helpful in improving the tibial tray rotation. As such, and due to the nature of the study, the current authors could not correlate these new findings to the actual clinical setting, where various factors and forces can affect the component’s positioning. Further, intraoperative investigations are now necessary to investigate the robustness of this method. It also should be pointed out that this technique as measured by 3 individuals, correlated should be pointed out that this technique of the medial third of the tibia tubercle more than 80% of the time and may further justify the use of this landmark as well.

In summary, to improve the tibial tray rotation in TKA, the current authors believe that the ITTR may be a reliable landmark that may achieve optimal tibial baseplate alignment in the transverse plane and agreed with a standard landmark of the medial third of the tibia tubercle in more than 80% of the trials performed. Further studies to validate this technique are warranted.

REFERENCES


