A gold standard for the correct rotation of the tibial component has not been established in total knee arthroplasty (TKA). The target parameter of correct rotation is the facilitation of femorotibial rotation over the entire range of motion with no implant overhang. Although the origin of the lateral collateral ligament is a recognized landmark for determining the rotation of the femoral component (epicondylar axis), the attachment of the lateral collateral ligament has not been taken into consideration for adjusting tibial rotation until now. The objective of the current investigation was to examine whether the position of the fibular head, as the attachment of the lateral collateral ligament, influences femorotibial rotation. Seventy patients who underwent TKA were enrolled in this retrospective study. Computed tomography (CT) of the operated knee was performed 6 months postoperatively in all cases and the position of the lateral facet of the fibular head and the tibial tuberosity, and the geometric center of the tibia and the femoral epicondyles were determined. The angle between the lateral facet of the fibular head, the geometric center of the tibia, and the tibial tuberosity was 45.7°±6.9°. The angle between the surgical epicondylar axis and the line from tibial tuberosity to tibial center was 69°±6.3°. This close correlation (R=.73; P<.001) shows that the position of the fibular head determines femorotibial rotation. The fibular head may become a helpful landmark for establishing the rotation of the tibial component; it could be useful in interpretation of postoperative CT scans in knees suspected of tibial malrotation.
The position of the fibular head determines femorotibial rotation and may be a helpful new landmark for establishing the rotation of the tibial component. The correct rotation of the tibial and femoral components is critical for the functional outcome after a total knee arthroplasty (TKA). Malpositioning leads to pathological joint kinematics with pain, restricted movement, and instability. Various anatomical and functional methods have been established for the correct adjustment of implant rotation.

Besides the gap technique, the vast majority of methods use measured resection techniques using anatomical landmarks (eg, posterior condyles, Whiteside line, and epicondyles) to adjust the rotation of the femoral component. The position of the different adjustment lines in relation to each other is well known.

For the tibial component, no rational basis for deciding which adjustment option to choose at present exists. In the available surgical techniques, different anatomical landmarks (eg, medial third of the tibial tuberosity, anterior edge of the tibia, symmetry of the tibia plateau, best coverage, ankle joint, and metatarsal II) are given equal rank beside the functional approach of running-in of the trial plateau (particularly in revision arthroplasty).

The aim of all methods is the greatest possible coronal conformity of the femoral and tibial implants. However, the inter- and intraobserver variability of the different anatomical landmarks is considerable, even in cadaver specimens, with standard deviations of up to 28°. Besides the inaccuracy of intraoperative determination of the anatomical landmarks, there is also an anatomical variability between the tibial landmarks for determining rotation.

In computed tomographic (CT) investigations, a deviation of the axis through the medial third of the tibial tuberosity and the tibial stem center to the epicondylar axis of >5° was shown in 50% of cases, and >10° in 12% of cases. The alignment of the tibial implant according to the ankle joint or metatarsal II is already problematic as a result of the variable torsion of the tibia of up to 41°.

The functional alignment of the tibial implant through intraoperative running-in of the trial component is susceptible to errors as a result of the possible bone or soft tissue impingement, ligament laxity, and the intraoperatively reduced muscle tone. A principal disadvantage is the fact that the tibial trial positioning is biased by errors in determination of the femoral component rotation.

The significant variance between anatomically and functionally determined tibial rotation of up to 25° remains a source of concern until it is unclear what technique should be used in the individual case. Ikeuchi et al observed a range of 15°, and therefore warn against functional alignment of the tibial component alone.

Alignment according to the epicondyles is best for the femur kinematically, but is difficult to identify intraoperatively. The distal insertion of the lateral collateral ligament (LCL), (ie, in particular the fibular head), has been ignored for joint kinematics and the adjustment of tibial rotation until now. The inclusion of the fibular head as the distal insertion point of the LCL for determining tibial rotation would therefore appear to be logical and possibly explain the observed differences between the anatomical and functional tibial rotation landmarks.

This study postulated that the position of the lateral facet of the fibular head relative to the anatomical tibial axis through the tiberosity and tibia center determines femorotibial rotation and may represent a new landmark for adjusting tibial component rotation.

**Materials and Methods**

**Patients and Surgery**

Seventy patients who were partially investigated prospectively as part of another study were enrolled in this prospective study. All received a TKA with a rotating platform (Solution, Smith & Nephew, Marl, Germany) due to primary gonarthritis and underwent CT follow-up. The femoral implant was placed parallel to the intraoperatively registered surgical epicondylar axis, and the tibial implant was placed parallel to the axis through the medial third of the tibial tuberosity and the center of the tibial head.

**CT Measurements**

One year postoperatively, CT was performed on the operated knee joints (10 cm below and above the joint plane with 1-mm slices). The tip of the tibial tuberosity, the lateral facet of the fibular head, the center of the tibia at the level of the joint plane (inlay surface), the lateral epicondyle, and the sulcus between the superficial and deep attachment of the medial collateral ligament were determined as spatial coordinates in the CT (Figure 1). The points were projected mathematically to the joint plane, and the following angles were calculated:

- $\alpha =$ surgical epicondylar axis vs tibial tuberosity to tibial center
- $\beta =$ fibular head tip to tibial tuberosity vs tibial tuberosity to tibial center

Angle $\alpha$ represents the resulting femorotibial implant rotation when the femur is implanted parallel to the surgical epicondylar axis and the tibial tuberosity is used as an anatomical landmark for determining tibial rotation. The standard deviation and range of the $\alpha$ angles reflect the spread in determination of the correct tibial rotation using the tuberosity as the sole landmark.

Angle $\beta$ is a measure of the position of the lateral facet of the fibular head in relation to the tibial axis through the tibial tuberosity and tibial center.

**Statistics**

Statistical analyses were performed with XLStat (Addinsoft). The Pearson correlation between angles $\alpha$ and $\beta$ was tested on a level of $P < .05$. 
Results

The tibial components were positioned with a mean deviation of 7°±5° in relation to Akagi et al’s line (range, 27° internal rotation to 15° external rotation). Angle α was, on average, 69°±8.3° (range, 46.6°-89.3°) (Figure 2). The 21° deviation from the expected orthogonality between anatomical tibial rotation axis and surgical epicondylar axis results from the use of the tip of the tuberosity instead of the medial third of the tibial tuberosity and from the final rotation of the tibia in full extension of the knee joint.

On average, angle β, as a representative of the position of the lateral facet of the fibular head, was 45.7°±6.9° (range, 30.4°-65.2°) (Figure 3). A close linear correlation was found between α and β, according to α=87.9°-6°β (R=.73; P<.001) (Figure 4).

DISCUSSION

Malrotations of the tibial component have been more forgiving as errors in the adjustment of rotation of the femoral component until now. When using a congruent rotating platform, as in the investigated patient population, it is generally held but not documented in the literature that the inlay rotation may compensate rotational errors in relation to the tibial plateau. Tolerance is limited by inlay impingement against bone or soft tissues, as well as by the kinematic changes with an increasingly greater posterior slope. Kinematically, femorotibial malrotation in a flat-on-flat design leads to increased wear, and with increasingly higher conformity of the implant, to a significant disturbance of the course of femorotibial and patellofemoral movement. Precise positioning of the tibia is necessary. For the femur, it is known that the surgical epicondylar axis, as the connection of the attachments of the lateral ligaments, is the best kinematic approximation to correct femoral rotation, whereas the LCL insertions have been neglected for the lower limb to date.

This study shows that the position of the fibular head determines femorotibial rotation. Even perfect orientation of the tibial component according to the tibial tuberosity and the tibial center does not lead to a reproducible femorotibial rotation in extension. The missing link between the anatomical landmark according to Akagi et al. and the functional method of running-in of the trial plateau that explains the significant variability between these landmarks, seems to be the fibular head. Only by additionally taking its position into account is it possible to predict femorotibial rotation in extension from bone landmarks. This reflects the fact that femorotibial rotation is guided, among other things, by the LCL where it attaches to the lateral facet of the fibular head.

By integrating the demonstrated connection between fibular head position and femorotibial rotation into a navigation system, an additional parameter for intraoperative determination of tibial component rotation should be established. In clinical practice, the center of the tibial tuberosity and the lateral facet of the fibular head would be additionally palpated during navigated implantation procedure through the skin. In connection with the center of the tibia, which is determined by the navigation system anyway, the system could calculate the probable ro-
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The rotational position of the epicondylar axis on the tibial plateau based on the shown formulae with an acceptable tolerance before cutting the tibia. This approach corresponds with a virtual running-in of the tibial plateau based on landmarks independent from the femur and before any preparation (eg, tibia first technique). However, because this proposed method of using the fibular head for determination of the tibial rotation was not applied in a prospective study, the real value of this method to reduce the wide range of tibial component rotation is not clear. Although a correlation exists between fibular head and tibial rotation based on computed tomography that may be a helpful new landmark, further prospective studies using this method are required to determine its practical use in navigated total knee arthroplasty.

Another clinical application may be the postoperative evaluation of the tibial component rotation in clinically suspicious cases with CT based on the formulae. This may result in different findings in comparison to the established techniques (eg, Akagi et al’s line), especially in knees with variations of the fibular head position against the tibial head.

REFERENCES

Feature Article


