A novel and reproducible reference axis that indicates axial rotation of distal tibia

ENOMOTO H[1], NAKAMURA T[2], SHIMOSAWA H[1], WASEDA A[1], NIKI Y[1], TOYAMA Y[1], SUDA Y[1]

[1]*Department of Orthopaedic Surgery, Keio University, Tokyo, Japa*
[2]*Johnson and Johnson Japan, Tokyo, Japan*

hiro-eno@joy.ocn.ne.jp

Introduction: Appropriate implant alignment is essential for successful clinical outcome as well as implant longevity in total knee arthroplasty (TKA). Recently the malalignment of tibia rather than femur revealed to compromise the implant survivorship [1]. However, the anatomical landmarks of tibia for intra-operative reference are less distinct and not consistently identifiable compared to those of femur [2]. In addition, the definition of distal front of tibia is not consistent among surgeons. In the last CAOS meeting, we introduced our plafond axis as another reference axis that indicates axial rotation of distal tibia. Here we measured tibial torsion with reference to 2 proximal and 2 distal axis of tibia.

Materials & Methods: Three-dimensional models of 32 tibiae were reconstructed from the less-affected side of lower-limb pre-operative CT data for primary TKA by using Mimics (Materialise NV, Leuven, Belgium). The data included 23 females and 9 males with average age of 71.2 ± 7.8 years old.

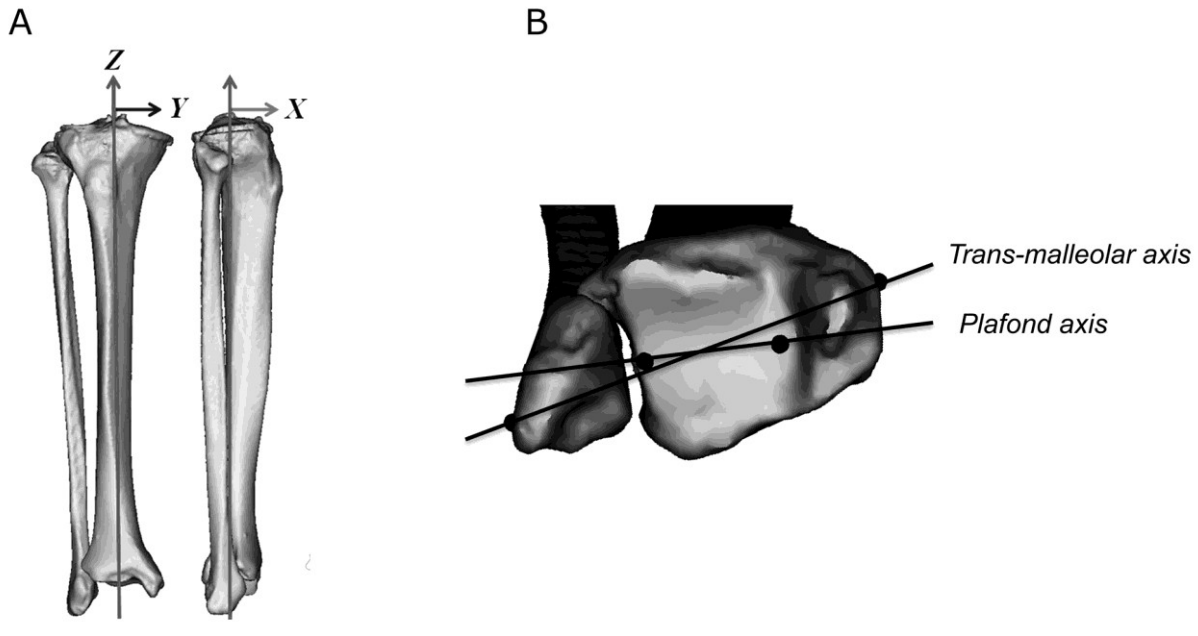
Definition of mid-sagittal plane

Clinically relevant mid-sagittal plane is defined by 3 anatomical bony landmarks described below, which are less affected even by arthritic deformities.

1. Apex of the tibial plafond: This replicates center of the foot joint. It was defined as the midpoint on the line connecting each midpoint of the medial and lateral border of the tibial plafond. These lateral/medial midpoints of plafond margins also defined our plafond axis, which was used as one of reference lines at distal tibia.

2. Center of posterior cruciate ligament enthesis: Marked on the intercondylar facet at the same horizontal level of the lateral condyle surface.

3. Proximal medial edge of the tibial tubercle.



Construction of the tibial coordinate

The origin of the tibial coordinate was projected midpoint of the medial/lateral eminences onto the sagittal plane. Then the Z (vertical) axis was defined as the line between the origin and the apex of the tibial plafond. The normal vector of the sagittal plane was assigned as medial-lateral axis (Y axis). The anterior-posterior axis (X axis) was finally determined as a cross product of the Z axis and the Y axis, contained within the sagittal plane. (Fig. A)

Proximal and distal reference lines to measure the angles of tibial torsion

One of proximal reference axis is ML line that corresponds to the y-axis, and the other proximal is the posterior condylar axis (PCL) that is adjacent to joint level but not involved in osteophyte. As for the distal reference, the plafond axis (PLA) that connects each midpoint of medial and lateral border of talocrural facet, and the trans-malleolar axis (TMA) line that connects tips of medial and lateral malleolus (Fig. B). The angles of tibial torsion were defined to be projected angles onto the xy-plane between each of the proximal lines and each of the distal lines.

Statistical analyses

The intra- and inter-observer reliabilities were examined by measuring intraclass correlation coefficients (ICC) (1, 1) and ICC (2, 1) respectively. All observer-dependent steps to designate the bony landmarks to establish the tibial coordinate, the plafond axis, and trans-malleolar axis were repeated. For the intra- and inter-observer reliability, ICC > 0.7 was considered to be almost perfect reproducibility [3].

Results: In terms of ICC, the intra- and inter-observer reliabilities were all more than 0.95. Likewise, while designating apexes of medial and lateral malleolus to define TMA and midpoints of medial and lateral margin of talocrural facet to define PLA, those were also above 0.95. When the proximal ML axis was applied, the angles of the tibial torsion with reference to PLA and TMA were 12.0 ± 8.4 degrees (-6.0 ~ 26.2 degrees), and 23.3 ± 8.6 degrees (4.2 ~ 40.1 degrees) respectively. Meanwhile, when PCA was applied as the proximal reference axis, those were 18.7 ± 9.5 degrees (-5.9 ~ 34.8 degrees), and 30.1 ± 9.8 degrees (4.3 ~ 48.0 degrees) respectively. The correlations of torsional angles with reference to PLA and TMA were statistically significant when compared with the proximal ML axis ($r = 0.81$, $p < 0.01$) and PCA ($r = 0.86$, $p < 0.01$) as well.

Discussion: As far as we know, this is the first study to measure the torsional angle of tibia with reference to PLA as another reference axis implicated in the axial rotation of distal tibia, which is not extraarticular but intraarticular reference axis that associates with talocrural joint as well. For the torsional angle to be measured precisely, a reproducible coordinate system is essential. Our coordinate system is based upon 3 bony landmarks to define the mid-sagittal plane that contains the clinically relevant anterior-posterior axis (Akagi's line) in TKA [4]. The intra- and interobserver reliabilities to designate the landmarks to define the coordinate system and the reference axis were confirmed, since ICC were all > 0.95. In addition, PLA is as clinically valuable as TMA considering the significant correlations of torsional angles based upon those 2 axes. We expect PLA to be a novel reference axis, which is applicable in the simulation prior to TKA and in analyzing anatomical variations of talocrural facet.

References

[1] Magnussen, RA, et al (2011) Clin Orthop Relat Res 469: 3443-50
[2] Graw,BP, et al (2010) Clin Orthop Relat Res 468: 2734-8
[3] Landis,JR, et al (1977) Biometrics 33: 159-74
[4] Akagi, M, et al (2004) Clin Orthop Relat Res 420: 213-9