Three-dimensional analyses of tibia vara with reference to a mid-sagittal plane in total knee arthroplasty

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Objective: Although proximal tibia vara is physiologically and pathologically observed, it is certainly difficult to measure the varus angle accurately and reproducibly, since the accuracy of the radiograph is occasionally compromised by rotational and/or torsional deformities associated with osteoarthritis. Tibial coronal alignment in TKA has been reported to give more influence on implant longevity than femoral alignment. Thus in a case with severe tibia vara, intra- or extra-medurally cutting guide should be set carefully to obtain optimal coronal alignment. However, it is somewhat concerned that the varus angle has been overestimated including the posterior tibial inclination. In this context, we measured the proximal tibial varus angle by introducing 3D-coordinate system as a uniform evaluation basis.

Materials and Methods: After the IRB approval, 3D-dimensional models of 32 tibiae were reconstructed from the preoperative CT data of the patients undergoing CT-based navigation assisted TKA by using Mimics (Materialise NV, Belgium). The data included 23 females and 9 males (71.2 ± 7.8 years old).

Mid-sagittal plane based 3D-algorithm for tibia as a uniform basis: Clinically relevant mid-sagittal plane is defined by 3 anatomical bony landmarks comprising an apex of the tibial plafond that the midpoint on the line connecting each midpoint of the medial and lateral border of the tibial plafond, a center of posterior cruciate ligament enthesis at the level of the lateral condyle surface, and a proximal medial edge point of the tibial tuberocity. The origin of the coordinate was a projected midpoint of the medial/lateral eminences on this 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, which was contained within the sagittal plane (Fig).

Definition of a metaphyseal and a diaphyseal anatomical axis: The 3D-models of the tibia were aligned to the coordinate system that was described above. Then the cross-sectional contours of the tibial canal (cancellous/cortical border) were extracted along the Z (vertical) axis for the proximal diaphyseal axis and along the anterior tibial crest borderline for the metaphyseal anatomical axis. The ranges of the cross-sectional slicing for the proximal diaphyseal axis and the metaphyseal axes were between the midpoint of the diaphysis and the tuberosity, and between the tuberosity and the tibial joint surface. For each extracted cross-sectional contour, a least-square fitted ellipse was calculated. Then, least-square lines were fitted to define the proximal diaphyseal anatomical axis and the metaphyseal axis based on the centers of the allotted cross-sectional ellipses respectively (Fig).

Analyses of the proximal tibia vara: The proximal tibia vara was investigated in terms of distribution of proximal anatomical axis exits at the level of the joint surface, and of the defined angles as described below. TVA1 and TVA2 were defined to be a project angle on the coronal plane (xy-plane) between the metaphyseal tibial anatomical axis and the proximal diaphyseal anatomical axis, and that between the metaphyseal tibial anatomical axis and the tibial functional axis (z-axis), respectively. The correlations of each angle with age and femoro-tibial angle (FTA) in the whole lower extremity X-ray while standing were also examined.
Statistical analyses: Data for the location of the axis exit and the measured angles were presented as mean ± standard deviation, with the range in parentheses, and all statistical analyses were performed using SPSS 18.8 software (IBM, Armonk, NY). The correlations between MTVA and FTA were analyzed with Spearman’s correlation coefficients.

Results: The proximal anatomical axis exits distributed 4.3 ± 1.7 mm medially and 17.1 ± 3.4 mm anteriorly. TVA1 and TVA2 were 12.5 ± 4.5°(4.4〜23.0°) and 11.8 ± 4.4° (4.4〜22.0°), respectively. The correlations of FTA with TVA1 (r=0.374, p<0.05) and TVA2 (r=0.439, p<0.05) were statistically significant.

Discussion: As far as we know, this is the first study that analyzes tibia vara in the 3D-algorithym as a uniform evaluation basis and that investigates its correlations with FTA, which is a representative radiological parameter associated with varus deformity. In the coronal plane, proximal tibia was actually varus, and TVA varied substantially among patients and correlated with FTA. These data implicated that TVA was involved in the pathophysiology of osteoarthritic deformities, directly or indirectly. Also tibia vara should be considered while placing the instrument to cut proximal tibia to obtain optimal setting of the implant in total knee arthroplasty (TKA).