Where Is The Appropriate Proximal Reference Point Of The Tibia In Total Knee Arthroplasty?

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Introduction: Two-reference points define the mechanical axis of the tibia. The proximal tibia could be determined as one reference point in 3D templating, however the mechanical axis of the tibia has been under discussion and is still very controversial, especially for patients suffering from knee osteoarthritis with varus and medial torsion deformities like many Japanese patients.

The aim of this study is to investigate where the proper reference point is regarding the mechanical axis. Three tibial axis were advocated for this study; the axis that passes through the bone center of diaphysis of the tibia (LBC: Line passing through the ankle center and the bone center), the axis that passes through the center of the intercondylar eminence (LCE: Line connected from the ankle center to the center of the intercondylar eminence), the axis that passes through the anteroposterior (AP) axis (LAP: Line passing through the ankle center and the middle point of AP axis). At that position, the ankle center was defined as a distal reference point. These axes have to pass through the center of the tibial tray because of the lower leg alignment.

Methods: This study involved 41 Japanese patients (34 Females and 7 Males) analysing 50 varus knees. The mean age at the time of surgery was 76.5±6.6yrs. The mean height was 151.6±7.0cm and the mean weight was 61.0±9.2kg.

In the radiographic assessment, the severity of OA according to the Kellgren-Lawrence classification was Grade 2 in 3 knees, Grade 3 in 8 knees and Grade 4 in the remaining 39 knees. The Hip - Knee - Ankle angle (HKA) measured from full-length, weight bearing AP radiographs was 192.5±8.9° of varus alignment.

We obtained multi-slice CT scans of the hip to ankle using 1mm slices. Patients were scanned in knee-extension with the patella facing upwards. The obtained DICOM data was imported into 3D preoperative TKA planning software. On the CT scan, the points, lines [axes], and angles were marked. The center of the talar joint surface or the center of the distal tibial joint surface were defined as the ankle center meaning of the distal reference point of the mechanical axis.

Authors drew three lines. The first line represented the bone center point (BC) defined in axial view 116.2±12.9mm distal from the proximal tibial articular surface. The line connecting the ankle center and BC was defined as a reference line named LBC. The second line indicated the AP axis of the proximal tibia. This was drawn as a line connecting the middle point of the PCL and the medial one third of the tibial tubercle. The middle point of AP axis is referred to as MAP. The line connecting the ankle center and MAP was defined as LAP. The third line marked the center of the intercondylar eminence set as PCE. Then LCE was drawn passing from PCE to the ankle center. The angle between LBC and LCE was defined as ACE. The angle between LBC and LAP was defined as AAP. The points that LBC and LAP penetrated the CT sliced plane (including PCE) were defined as PBC and PAP, respectively (Fig.1, 2).

The first method plans to cut perpendicular to LBC (method 1), the others are to cut perpendicular to LCE (method 2) and LAP (method 3).
The AP axis was defined as Y-axis and X-axis, perpendicular to the Y-axis on the CT sliced plane including PBC. PBC which exists on the intersection of the two axes. The angle between LBC and LCE, LAP was measured and the distances between the lines on the resected surface of proximal tibia were also measured.

**Results:** LCE exists most medially and LAP exists between the others in all patients. The mean ACE and AAP were 2.7±0.9° and 1.6±0.7°, respectively. The median ACE was 2.7° whereas AAP was 1.5°. DCEX (X component of DCE) was 14.6±5.3mm and DAPX (X component of DAP) was 3.2±2.3mm. The median DAPX was 3.0mm whereas DCEX was 14.8mm. DCEX positively correlated with HKA ($R^2 = 0.29375$, $p < 0.001$) and DAPX also correlated with HKA ($R^2 = 0.28053$, $p < 0.001$), and furthermore, the range of PAP is more concentrated than PCE.

These results show that PCE always existed more medially than PAP in each case. ‘DAPX is 3.2±2.3mm’ which means PAP still remains on the medial side of PBC however very close to it.

**Discussion:** The techniques used in the TKA procedure were developed through the collection of Caucasian normal knee data. It has been reported that almost all Japanese patients with osteoarthritis of the knee have varus deformities of the tibia. It is therefore difficult to determine the landmark of the mechanical axis and to find an accurate point on the tibial articular surface during surgery. If the proximal point on the tibial shaft is set as the wrong point, alignment outliers will easily result. We looked at how big the misalignment is when the center of the eminence is set as a longitudinal axis for Japanese patients. When the outlier of the tibial cutting angle is defined as greater than 3 degrees, if PCE is taken as a proximal point on the tibial shaft, it is more likely that alignment outliers will result. DCEX is too far from the tibial shaft axis regardless of the HKA angles. In addition, the dispersion of DCEX is larger than DAPX.

When we use navigation systems or patient matched technology, the proximal bone of the tibia can be cut and components inserted correctly. If however, these are not used, a landmark on the tibial articular surface is necessary. How are we able to detect the center of the resected tibial surface then? AP axis will be the most proper landmark. To take PAP as the center of the resected tibial surface is guarantee the positional relationship of femur and tibia. Furthermore, LAP could be a postoperative mechanical axis. The distance from PBC to PAP directly correlates with HKA. Therefore, in order to decide an appropriate position of the tibial component, we must position the center of the tibial component in line with the proximal center point of the mechanical axis so that the tibial component is perpendicular to the longitudinal axis of tibia.

Authors explained the importance of patellar tendon for kinematics of the knee. Patellar tendon is one of the regulations of knee movement and PCL could not be ignored when it retained, so that PAP can be used as a reasonable proximal landmark. The authors described two important effects; first one is the relationship of the femoral and tibial condyles, the other is the direction of the load. When the proximal tibia is cut perpendicular to the tibia by method 1, the tibial component has to be set laterally of the resected tibial plateau so that the axis of the rotation may be significantly changed. This means a variation of the patellar tracking. When method 2 is selected, the proximal tibia will be cut varus. Furthermore, the appropriate mediolateral position and rotation of the tibial component could not be found during surgery when cut by method1 or 2. Method 3 therefore satisfies these two problems.

**Significance:** The center of the eminence should not be used for the alignment of the proximal tibia because the proximal tibia will be cut varus when the center of the eminence is defined as a proximal
reference point. It is more remarkable when the knee is more varus. The middle point of the anteroposterior axis is set as a proximal reference point of the tibia, it is satisfied the conditions for the postoperative mechanical axis and the relationship of the femur and tibia. This method may be a good answer for TKA if you retain the posterior cruciate ligament because the anteroposterior axis is defined by PCL and patella tendon. The middle point of the AP axis will be an answer for the proximal reference point of the tibia when the tibial tray is positioned appropriately. It can be a reference point before and during surgery.