INTRODUCTION
Extramedullary alignment guides are commonly used for the tibia during total knee arthroplasty (TKA). One disadvantage is that this is easily affected by the condition of the ankle joint. The tibia has the anatomical feature that rotational mismatch between its proximal and distal ends can occur. We hypothesized that this rotational mismatch might cause incorrect positioning of the extramedullary alignment guide and evaluated this rotational mismatch on the predicted postoperative coronal alignment of the tibia.

MATERIALS AND METHODS

**Patient**
Fifty-three osteoarthritic knees with varus deformity in 51 patients (11 men and 40 women) who were evaluated using computerized tomography (CT) scan between 1999 and 2000. This study was approved by the Institutional Review Board. Patients were informed of the risk of the surgery deformities were 10 degrees or less to avoid measurement errors due to anatomical feature that rotational mismatch between its proximal and distal end. We selected a slice level of the proximal tibia 8 mm distal from the patellar tendon, and axis 2 connected the posterior notch and the medial border of the patellar tendon, and axis 5 connected the midpoint of the P-CEA and the medial 1/3 of the patellar tendon (Fig. 4).

**CT scan**
The scanning direction was set to be perpendicular to the fixed tibia shaft axis. Computerized tomography (CT) scans were taken with the knee and the ankle with 2 mm thickness. We analyzed the CT scan data by reconstructing three-dimensional bone models using computer software (Real INTAGE Ver.2.0, KGT, Inc. Tokyo).

**Definition of the AP axis of the ankle joint**
The anteroposterior (AP) axis of the ankle joint was defined as the line perpendicular to the anterior cortex of the tibia that approximates the straight line (Fig. 1).

**Definition of the AP axis of the proximal tibia**
We selected a slice level of the proximal tibia 8 mm distal from the lateral tibial plateau. Five different AP axes of the proximal tibia were evaluated.

<table>
<thead>
<tr>
<th>Axis</th>
<th>Simple Axis</th>
<th>Angle (Degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Medial</td>
<td>16.5 ± 7.4</td>
</tr>
<tr>
<td>2</td>
<td>Lateral</td>
<td>3.6 ± 6.8</td>
</tr>
<tr>
<td>3</td>
<td>Medial</td>
<td>19.7 ± 6.4</td>
</tr>
<tr>
<td>4</td>
<td>Lateral</td>
<td>5.9 ± 6.6</td>
</tr>
</tbody>
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**Measurement I: twisting angle**
For the five axes of the proximal tibia, we measured the difference in the rotational angle (the twisting angle) between the AP axis of the ankle joint and the AP axis of the proximal tibia (+: a positive value of the angle means an external rotation of the AP axis of the distal tibia).

**Measurement II: presumed postoperative tibial alignment**
We established spatial coordinates (X: anterior-posterior, Y: medial-lateral, Z: proximal-distal) to evaluate the effect of the angle on the predicted postoperative coronal alignment of the tibia. The distal end of the extramedullary guide was placed in front of the center of the ankle joint (on the line of the extended AP axis of the ankle joint), and the proximal end was placed on the line of the extended AP axis of the proximal tibia, while the guide was parallel to the tibial mechanical axis on the sagittal plane. The origin of coordinates (0,0,0) was defined as the midpoint of the AP axis of the proximal tibia. The distance D was defined as the distance between the origin of the coordinates and the proximal end of the extramedullary guide. The distance H was defined as the distance between the proximal tibia and the ankle joint (Fig. 5).

In this situation, the axis of gyration between the proximal end of the extramedullary guide and the center of the ankle joint is (D, 0, H). By rotating the angle θ around the unit vector U, the normal vector of the plane with posterior slope γ (-sin γ, 0, cos γ) was converted to be

\[
\begin{align*}
A &= \begin{bmatrix}
-\sin \gamma (\cos \omega + a) & -\sin \gamma (\cos \omega + b) & \cos \gamma (1 - \cos \omega) \\
-\sin \gamma (\sin \omega + a) & -\sin \gamma (\sin \omega + b) & \cos \gamma (1 - \cos \omega) \\
0 & 0 & 1
\end{bmatrix}
\end{align*}
\]

**RESULTS**
The twisting angle was positive in all axes, indicating that the ankle joint was externally rotated compared to the proximal tibia (Fig. 6). The average of the predicted tibial coronal alignment was a varus alignment for all of the AP axes of the proximal tibia. The twisting angle and the predicted tibial coronal alignment (Y-Z plane, θ; varus means plus) were calculated with and without 7 degrees of posterior tibial slope.

\[
\begin{align*}
\theta &= \text{Arc tan} \left( -\frac{-\sin \gamma (\cos \omega + a) + \cos \gamma (1 - \cos \omega)}{\cos \gamma (1 - \cos \omega) + \sin \gamma (\sin \omega + b) + \cos \gamma (1 - \cos \omega)} \right)
\end{align*}
\]

**DISCUSSION**
The results of this study suggest that varus alignment may occur due to the rotational mismatch between the proximal tibia and the ankle joint. When external torsion is applied to the tibia, the distal end of the extramedullary guide can shift laterally if the distal end of the extramedullary guide is placed in front of the center of the ankle joint. This would cause cutting the proximal tibia in varus and in more varus with posterior tibial slope.

To avoid cutting the proximal tibia with a varus alignment, the center of the proximal tibia and the center of the ankle joint should be determined in the same direction. First, the proximal end of the guide should be adjusted to the center of the proximal tibia and the cutting direction should be adjusted to the AP axis of the proximal tibia. Next, the distal end of the guide should be adjusted to the center of the ankle joint, but the rotational alignment of the guide should be kept identical to that of the proximal AP axis.