Relationship of the Fibular Head and Proximal Tibia in X-ray Views, Focusing on Posterior Edges in Lateral Views as Alignment Indicators

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INTRODUCTION:
It is well-established that rotational alignment directly impacts treatment outcomes in Total Knee Arthroplasty (TKA), and that it also holds significance in High Tibial Osteotomy (HTO). Despite several studies on accurate frontal view estimation and prediction of lower limb rotation, there are no references to help determine the axis perpendicular to the tibial anteroposterior (AP) axis from an accurate lateral view. Our study delves into the relationship between the fibular head and the proximal end of the tibia in X-ray images, especially in lateral views. We hypothesize that the posterior edges of the tibial condyle and the fibular head, as seen in a lateral view, can be key landmarks for this purpose. This study aims to determine whether the distance between these posterior edges can be a landmark for determining the axis perpendicular to the tibial AP axis, enabling surgeons to accurately position the plate during HTO.

METHODS:
In this cross-sectional study, we included 70 lower limbs of 35 Japanese subjects who underwent primary total hip arthroplasty (THA) at our hospital between 2018 and 2020. We chose THA patients for our study because knees in such patients generally exhibit fewer degenerative alterations compared to those receiving TKA. Computed tomography scans, taken as part of the standard preoperative process, provided data. Exclusion criteria included rheumatoid arthritis, previous lower limb surgery (except contralateral THA), and knee osteoarthritis (OA) with a Kellgren-Lawrence grade of 2 or higher. Patients with severe limb length discrepancies were not included. Our study received approval from the Institutional Review Board of Nihon University School of Medicine (approval number: RK-200714-8). All procedures conformed to the 1964 Helsinki declaration. All patients gave written consent.
A 3D preoperative planning support software system was used to create the tibial bone model based on the tibial AP axis. The axis was defined as the line connecting the midpoint of the posterior cruciate ligament and the medial edge of the patellar tendon attachment. The overlap percentage (overlap%) on a frontal view was calculated using the bone model, and was defined as the mediolateral distance of the overlapping area between the fibular head and the proximal tibia, divided by the maximum mediolateral width of the fibular head (Fig. 1). We also measured the anteroposterior distances between the posterior edges of the medial/lateral tibial condyle and the fibular head (MF/LF) (Fig. 2). When the posterior edge of the proximal tibial condyle was anterior to that of the fibular head, the distance was considered positive. Conversely, when posterior, it was considered negative. Differences in these measurements and gender-based variations were calculated. In addition, MF and LF measurements were taken with an external rotation of 10° and an internal rotation of 10° from the original tibial bone model to derive a regression formula for predicting rotational alignment.
Data analysis utilized IBM SPSS software, version 28. Intra-rater and inter-rater reliability were determined using intraclass correlation coefficients. Differences between measurements and gender differences were evaluated using paired and Student's t-tests, respectively. The required sample size was calculated as 34 for both tests. Linear regression analysis helped predict tibial rotation. External rotation was represented as a positive value and internal rotation as a negative value. Statistical significance was set at $P<0.05$.

RESULTS SECTION:
The sample size for our study was 70 lower limbs. The mean overlap% was 55.7% (SD 8.5) as a whole, 53.4% (SD 8.4) for females and 58.1% (SD 8.0) for males, with a significant difference ($P<0.05$). The mean MF was 0.9 mm (SD 2.5) and the mean LF was 4.7 mm (SD 2.2), with a significant difference ($P<0.001$), but no significant gender-based differences were detected. Our measurements demonstrated strong intra-rater and inter-rater reliability for the distance between the posterior edge of the proximal tibial condyle and the fibular head, with coefficients of 0.993/0.995 (MF) and 0.965/0.989 (LF). With increasing tibial rotation, both MF and LF increased. Regression analyses yielded the following formulas for tibial rotation: $-1.05+1.04\times MF$ ($R^2 = 0.87$, $P<0.001$) and $-8.75+1.85\times LF$ ($R^2 = 0.50$, $P<0.001$). Higher correlation was seen in the MF formula.

DISCUSSION:
The central finding of our study indicated that the posterior edge of the medial tibial condyle was positioned a mere 0.9 mm anterior to the posterior edge of the fibular head based on the tibial AP axis model. We developed linear regression formulas to predict tibial rotation from MF and LF, offering new insights into determining the axis perpendicular to the tibial AP axis using lateral radiographs. Our observations align with prior research. Specifically, Insall et al. demonstrated that when the tibial plate was positioned correctly in TKA, it exhibited a posterolateral overhang. Similarly, Graw et al. reported that the posterior condylar line of the tibia was internally rotated between 5 to 10° relative to the femoral trans epicondylar axis, which is the perpendicular line of the tibial AP axis. Such findings, consistent with our study, underscore the significance of the differential positioning of the medial and lateral tibial condyles. In our research, the mean value for MF was 0.9 mm, suggesting that when the posterior edges of the medial tibial condyle and the fibular head align, they provide an approximation of the perpendicular view to the tibial AP axis. The derived regression formulas allow for predicting tibial rotation, but accurate measurements of MF and LF are crucial. For instance, when MF is 0 mm, an estimated internal rotation of 1.0° occurs, and with LF at 0 mm, the rotation stands at 8.8°. From a clinical perspective, our results regarding overlap%, MF and LF values can enhance HTO alignment accuracy on frontal and lateral views. This has implications for the tibial posterior slope and the stability of the osteotomy site.
However, there are limitations. Our study predominantly focused on patients without significant knee OA and those with intact anterior cruciate ligaments (ACLs). Thus, the applicability of our results to patients with ACL insufficiencies could be limited. Additionally, lower limb rotational abnormalities exist in some THA cases. Given the narrow focus on the proximal tibia in this study, the influence of such abnormalities is likely minimal.

SIGNIFICANCE:
This study provides critical insights into using overlap% and especially MF value for ascertaining accurate rotational alignment in surgical procedures such as HTO. These findings have the potential to enhance surgical accuracy, impacting both the tibial posterior slope and the stability of the osteotomy site, thus influencing patient outcomes postoperatively.

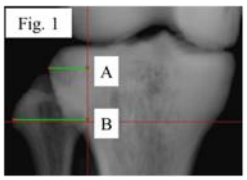

Figure 1. The overlap percentage (overlap%) is defined as the mediolateral distance of the overlapping area between the fibular head and the proximal tibia (A), divided by the maximum mediolateral width of the fibular head (B).

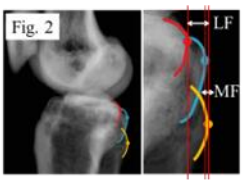

Figure 2. The anteroposterior distance between the posterior edge of the medial/lateral tibial condyle and the posterior edge of the fibular head (MF/LF).