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Effects of lower limb rotation on the measurement accuracy of coronal alignment in long-leg radiographs after total knee arthroplasty

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Restoring proper lower limb alignment on the coronal plane after total knee arthroplasty (TKA) can decrease stress in the bone cement–implant interface, polyethylene wear, and implant loosening. Weight-bearing long-leg radiographs (LLRs) are used to assess the mechanical axis in the coronal plane, identify anatomic variations in the femur and tibia, and plan the degree of bone resection preoperatively. However, rotation or flexion of the lower limb may affect the accuracy of the measurement of alignment parameters from LLRs. Furthermore, known rotation-dependent linear changes can be used to relate the degree of lower limb rotation to the alignment parameters of the femur and tibia and the hip–knee–ankle (HKA) angle.[1]

Here, we aimed to analyze the types and range of rotational errors encountered while obtaining LLRs and recalculate the alignment of the lower limb and components to determine whether rotational errors could have an impact on our previous judgments on femoral and tibial component positions and lower limb alignment.[2]

We prospectively investigated a cohort of patients with grade three or four end-stage osteoarthritis (the classification described by Kellgren and Lawrence) who underwent unilateral TKA in Department of Orthopedics, First Affiliated Hospital of Xinjiang Medical University from December 2018 to January 2020. Patients with large bony defects, subluxation of the patella, severe osteophytosis, and previous surgeries, including high tibial or distal femoral osteotomies, that prevent complete knee extension, severe valgus, or varus deformity of both limbs were excluded. The hospital's Research and Ethics Committee approved the study protocol. We explained the procedure and its detailed implications to the patients and obtained written consent.

All included patients underwent the same surgical technique for TKA. The distal femoral osteotomy line was performed perpendicular to the femoral mechanical axis, which was measured from preoperative LLRs; the preoperative planning pursued a neutral mechanical axis. The gap balancing method was applied to the osteotomy procedure to achieve balance in the flexion and extension gaps of the femoral–tibial component.

Each patient received cemented posterior-stabilized total knee prosthesis implants (ATTUNE Rotation Plate [RP], DePuy Synthes, Warsaw, IN, USA), standardized and multimodal anti-pain therapy, prophylaxis of thromboembolism, and physiotherapy.

All patients underwent LLR with the same imaging equipment (General Electric, Boston, MA, USA) and by the same radiologist before surgery and 3 months postoperatively. During the imaging process, patients were allowed to stand at a distance of 180 cm from the radiography tube. The radiographic beam was centered on the knee joint. Patients were required to stand with their feet shoulder-width apart, and the patella was positioned straight forward at maximum knee extension.

The two orthopedic surgeons involved in this study were trained in measuring the implant alignment and rotation of the lower limb of patients after TKA using a digital software program (ImageJ2x, JAVA, National Institutes of Health, Rockville Pike, Bethesda, Maryland).

Coronal alignment (HKA) is the angle formed between the tibial and femoral mechanical axes. The alignment of the

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femoral component is the angle between the mechanical axis of the femur (axis between the femoral head and the center of the distal femur) and a tangent on the most distal points of the medial and lateral prosthetic condyles. Tibial component alignment is the angle between the mechanical axis of the tibia (axis between the center of the talus and the midpoint of the tibial plateau) and a line across the base of the tibial plate. Mal-alignment (outlier), also known as an outlier, was defined as a deviation in the alignment of the femur or tibia by >2° from 90° or >3° from a neutral HKA angle (0°).[3]

The degree of lower limb rotation was calculated using ImageJ2x software (JAVA, National Institutes of Health, Bethesda, MD, USA) from LLRs using the proposed formula:[3] = −14.20 −(0.17 × visible part of the fibula [%] + 0.35 × overlapped part of the fibular tip [%] + 0.31 × distance between the fibular tip and the lateral fibular cortex [%]). In the above research, multiple regression analysis showed a strong correlation between the measured fibular parameters and knee rotation (overlaps of the fibula, fibular tip, and distance from the fibular tip to the lateral cortex were determined for every rotational position). The relative distance (%) was calculated as the measured distance divided by the fibular width [Figure 1; Supplementary Table 1, http://links.lww.com/CM9/A931].

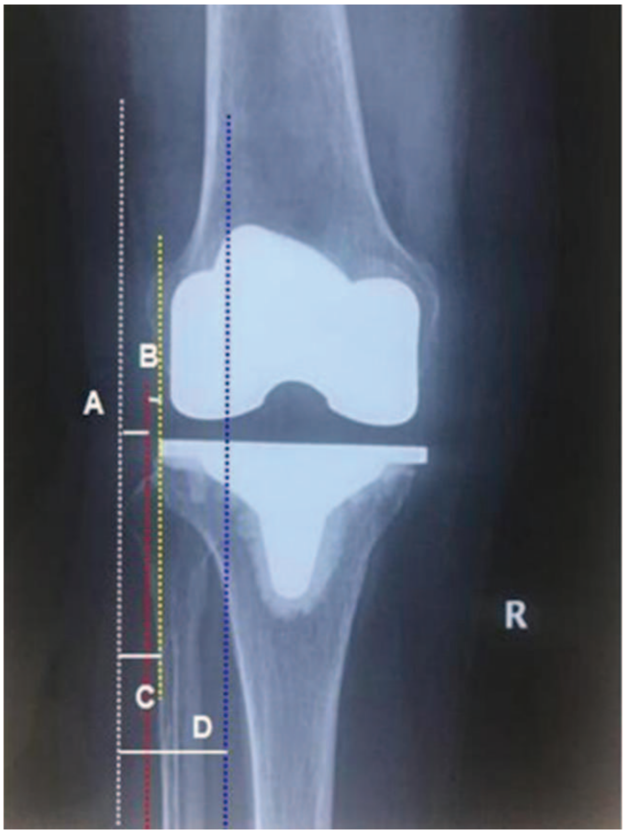

Figure 1: The relative distance (%) was calculated as the measured distance divided by the fibular width. (A) The distance between the lateral fibular cortex and the lateral tibial cortex (visible part of the fibular); (B) the distance between the tip of the fibula and the lateral tibial cortex (overlapped part of the fibular tip); (C) the distance between the lateral fibular cortex and the fibular tip; (D) the distance between the lateral fibular cortex and the medial fibular cortex (the proximal fibular width).

Lower limb rotation had a highly significant effect on the anatomic alignment and mechanical angles measured from LLRs and the linear regression as follows:

The measured femoral component alignment changes by 0.08 per limb rotation angle. The measured tibial component alignment changes by 0.05 per limb rotation angle.[2] The measured HKA angle changes by a factor of 0.0697 for each degree of rotation in fully extended knees.[3] The minus sign (−) represents valgus alignment or internal rotation; the positive sign (+) represents varus alignment or external rotation.

The mean values of the measurements performed by both raters were calculated for all analyses. The reliability of the measurements was assessed by determining the intra-rater and inter-rater reliabilities using the intraclass correlation coefficient (ICC [3,1], consistency). Statistical significance was set at $P < 0.05$. All statistical analyses were performed using SPSS software (version 22.0; IBM, Chicago, IL, USA).

In total, 63 patients were included. Seven patients with extra joint deformity (with a history of fracture or other lower limb operation) and four patients who could not completely extend their knees 3 months after surgery were excluded. Another two patients were excluded because the observers could not agree on the patients' rotation degrees, as they did not recognize the tibio-fibular joint. In summation, a total of 50 patients were analyzed. The mean HKA angle of the patients was 4.07° ± 8.70°, ranging between varus 15° and valgus 13.5°, preoperatively. Twenty-two patients were diagnosed with grade three osteoarthritis, whereas 28 were diagnosed with grade four osteoarthritis. The ICCs for the measurement of the basic characteristics of patients, mechanical axes, and other related parameters were excellent. The baseline characteristics of the 50 patients are shown in Supplementary Table 2, http://links.lww.com/CM9/A931. The design of the study is shown in Supplementary Figure 1, http://links.lww.com/CM9/A931.

Using the formula mentioned in the study by Radtke *et al*,[4] the mean degree of rotation of the operated limb at 3 months after surgery was 9.30° ± 8.37° (range, 26.70° [internal] to 6.18° [external]) [Supplementary Table 1, http://links.lww.com/CM9/A931]. The true values of the alignment angles were calculated by correcting the measurements after excluding the rotational error using regression analysis.[4] The HKA angle before the correction was 1.79°± 3.47° and that after the correction was 1.14° ± 3.53°. There were 30 and 24 outliers before and after the correction, respectively. After the correction of rotational errors in the HKA angle, 14 patients changed from outliers to inliers, whereas eight patients changed *vice versa*.

The femoral component alignment was found to be 89.96° ± 3.33° before correction and 90.73° ± 3.43° after correction, five measurements changed from outliers to inliers, and four measurements changed *vice versa*. For the tibial component alignment, five measurements changed from outliers to inliers and two measurements changed *vice versa*. In the measurement of all three parameters, the changes before and after the correction of rotational errors are shown in Supplementary Table 3, http://links.lww.com/CM9/A931.

The study results suggest that limb rotation has some effect on the correct measurement of radiographic alignment of component positions after TKA.

Although every patient was asked to stand in position with the patella facing forward while conducting the LLR, we found that lower limb rotation still existed from 26.7° (internal) to + 8.4° (external) in our processes. While performing radiography, requesting the patients to position their knee forward may cause internal lower limb rotation as the anatomical position of the patella is located slightly lateral and osteophytes around the patella may have affected the recognition of the true position of the patella. Considering that the actual mechanical alignment axis did not change significantly within 3 months after TKA,[5] we conducted standing LLRs after 3 months postoperatively, at which the patients were able to bear the physiological load and extend their knee completely. To eliminate the effects of knee flexion and varied surgical practices used by surgeons, certain parameters were considered: all patients in our study were selected to have the same prosthesis, were able to extend their knees completely, and the proximal tibial bone cut was fixed at the same 3°.

After taking the rotational degree, the lower limb alignments and component angles were recalculated after excluding the rotational errors according to the proposed formula. Of the 50 patients, 22 were wrongly divided into either mal-aligned or well-aligned. In terms of component alignment, nine femoral and seven tibial components (out of 50 patients) were wrongly divided into either mal-aligned or well-aligned.

Our measurements were comparable to those obtained in previous studies. In another study, 11% of patients were incorrectly assigned to mal-aligned or well-alignment, with valgus and varus errors of 3.5° and 1.6°, respectively.[3]

As all study participants could fully extend their knees, we did not consider the changes due to incomplete extension. These findings lead to the question of whether weight-bearing LLRs are accurate enough and should be scrutinized again before making the preoperative plan and evaluating the lower limb axes and component alignment postoperatively. Currently, a gold standard does not exist for the positioning of the lower limb while conducting LLRs.

The limitations in our study include a small sample size and that all radiographs were conducted in a single department. Second, the formula used to calculate the degree of rotation and its linear correlation with related angle changes were measured using the saw bone model. This calculation formula may not completely reflect the true alignment parameters; three-dimensional weight-bearing evaluation of implant malalignments should be involved in further research for more accurate results.

To conclude, the presence of internal or external rotations may influence the measurement accuracy of coronal component alignment during lower limb rotation. Surgeons should be aware of rotational errors and calculate and implement related correction values in clinical practice.

Conflicts of interest

None.

References

1. Innocenti B, Bellemans J, Catani F. Deviations from optimal alignment in TKA: is there a biomechanical difference between femoral or tibial component alignment? J Arthroplasty 2016;31:295–301. doi: 10.1016/j.arth.2015.07.038.
2. Hunt M, Fowler P, Birmingham T, Jenkyn T, Giffin J. Foot rotational effects on radiographic measures of lower limb alignment. Can J Surg 2006;49:401–406.
3. Maderbacher G, Baier C, Benditz A, Wagner F, Greimel F, Grifka J, *et al*. Presence of rotational errors in long leg radiographs after total knee arthroplasty and impact on measured lower limb and component alignment. Int Orthop 2017;41:1553–1560. doi: 10.1007/s00264-017-3408-3.
4. Radtke K, Becher C, Noll Y, Ostermeier S. Effect of limb rotation on radiographic alignment in total knee arthroplasties. Arch Orthop Trauma Surg 2010;130:451–457. doi: 10.1007/s00402-009-0999-1.
5. Zahn R, Fussi J, von Roth P, Perka C, Hommel H. Postoperative increased loading leads to an alteration in the radiological mechanical axis after total knee arthroplasty. J Arthroplasty 2016;31:1803–1807. doi: 10.1016/j.arth.2016.01.034.

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