Three-dimensional Lower Extremity Alignment In The Weight-bearing Standing Position In Osteoarthritis Subjects

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Introduction: The operation such as total knee arthroplasty (TKA), uncompartmental knee arthroplasty (UKA) and high tibial osteotomy (HTO) is performed in osteoarthritis (OA) patients in the knee. Knowledge of preoperative three-dimentional(3D) lower extremity alignment is important to perform. Improper rotation of the femoral and tibial components in TKA may lead to various patellofemoral complications such as subluxation, dislocation, and wear. Despite the current high success rate of TKA, patellofemoral complications remain the most common cause of revision surgeries. Rotational deformity is important because of the rotational mismatch of the femoral and tibial components in TKA. Knowledge of the rotational deformity also is useful to understand the aggravating mechanism of varus OA of the knee. Although an internal torsion of femur and an external torsion of tibia were reported in knees with OA, the results obtained on the rotational deformity in the femorotibial joint are controversial.

In the result of 3D knee kinematics analysis of our group, the UKA group was internal rotation by the full extension position as compared with the healthy group. Our hypothesis was that knees with OA were internal rotation of the tibia to the femur. The purpose of this study was to examine the alignment of rotational deformity knees with OA. The anatomical extension-flexion angle and the adduction-abduction angle which can be evaluated simultaneously with rotational deformity were investigated, and each correlation were also investigated.

Methods: We assessed 106 limbs of OA knee subjects who are going to be performed TKA or UKA in our hospital and Niigata University. There are 86 women and 20 men. There are 72 knees of preoperative TKA and 34 knees of preoperative UKA. The average age of the subjects was 74.8 years (range 47-86 years). All cases were OA grade III or IV according to the Kellgren-Lawrence scale. Exclusion criteria patients with previous knee surgery such as a HTO or osteosynthesis, knees with a valgus deformity. A weight-bearing, 3D, lower extremity alignment assessment system (KneeCAS, LEXI, Inc., Tokyo, Japan) was used for the quantitative measurement of knee alignment. This system consisted of a 2D-3D image matching technique using biplanar computed radiography (CR) and 3D bone models of the full-length lower extremity reconstructed from CT data. The 3D functional axes of the femur (3DFA-f) was defined as a line connecting the center of the femoral head and the midpoint of the spheres that represent the medial and lateral posterior femoral condyles. The 3D functional axes of the tibia (3DFA-t) was defined as a line connecting the midpoint of the eminences of the medial and lateral tibial spines and the center of the ankle joint. The adduction-abduction angle was defined as the angle between 3DFA-f and 3DFA-t projected onto the femoral coronal plane. The extension-flexion angle was defined as the angle between 3DFA-f and 3DFA-t projected onto the femoral sagittal plane.
Additional axes were defined to assess rotational alignment. For the femur, the clinical transepicondylar axis (CEA) was defined as a line connecting the prominences of the medial and lateral epicondyles. For the tibia, the anteroposterior axis of the tibia (APA-t) was defined as a line connecting the anterior-most point of the tibial insertion of the posterior cruciate ligament and the medial edge of the tibial tubercle projected onto the axial plane of the tibial coordinate system. The relative rotational angle between the femur and tibia at the knee joint was defined as the angle between CEA and APA-t projected onto the axial plane of the femoral coordinate system.

**Results:** The mean adduction-abduction angle was 8.0°(S.D. 7.9°), the mean extension-flexion angle was 190.4°(S.D. 5.0°), the mean rotational angle was 96.3°(S.D 7.5°). This result showed flexion, adduction and internal rotation in OA knees.

There was no significant correlation between the extension-flexion angle and the adduction-abduction angle, and between the extension-flexion angle and the rotational angle. There was significant correlation between the adduction-abduction angle and the rotational angle. This result showed that internal rotation increased with the progression of varus deformity.

**Discussion:** Ariumi et al. previously investigated 3D lower extremity alignment in healthy elderly subjects, using the same method and parameters. The study reported that the mean adduction-abduction angle was -3.6°(S.D. 5.9°), the mean extension-flexion angle was 181.8°(S.D. 2.4°), the mean rotational angle was 85.7°(S.D 5.1°). The results of our study showed flexion, adduction and internal rotation in OA knees as compared with normal knees.

Flexion and varus deformity in OA knee have been reported by some authors. Our study investigated in the weight-bearing standing position in 3D was also the same result.

The results obtained on the rotational deformity in the femorotibial joint are controversial. Eckhoff et al. and Matsui et al. reported that increased external rotation of the tibia in OA knee. Yagi et al. and Moussa et al. reported no difference between OA and normal knees. Nagao et al. reported that in supine position no significant difference in knees with OA, but in weight bearing position increased internal rotation. In our study, the femoral epicondyles and the tibial tuberosity were chosen as reference because they showed little change even in presence of advanced OA, and rotational deformity were investigated in the weight-bearing standing position in 3D. This result showed that OA knee is about 10 degrees internal rotation as compared with normal knee, and internal rotation increased with the progression of varus deformity.

The important clinical implication is that the tibia tended to locate in internally rotated position in the knees with severe varus deformity. Therefore, surgeons performing TKA, UKA and HTO should be aware of these considerations and check for rotational mismatch.

The results of this study also provide useful information to help elucidate the pathogenesis of OA of the knee. The pathomechanism of underlying rotational deformity has not been elucidated. It has been hypothesized that cartilage degeneration starts anteromedially and progresses posteromedially. The tendency for the tibia to rotate internally has, at least partly, substantiated the hypothesis.

**Significance:** Our study showed the relationship between varus deformity and rotational deformity in knees with OA.

This finding is important and may be used to determine appropriate rotational alignment in TKA, UKA and HTO.

The study also provides additional insight into the pathogenesis of varus OA of the knee.
previous study (healthy elderly knee) | this study (OA knee)
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age | 65.1 (60-77) | 74.8 (47-86)
adduction-abduction angle | -3.6±5.9° | 8.0±7.9°
extension-flexion angle | 181.8±2.4° | 190.4±5.0°
rotational angle | 85.7±5.1° | 96.3±7.5°