Condylar Motion Patterns During Passive Knee Flexion Are Not Only A Result Of Osteoarthrosis

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INTRODUCTION: Although total knee arthroplasty (TKA) has improved considerably and became one of the most reliable joint replacement procedures, numerous studies indicate that approximately 20 % of patients are dissatisfied with the results of their TKA [1]. It has been hypothesized that restoration of the native knee kinematics may improve patient satisfaction following TKA [2]. However, it is not clear whether all native knees show the same kinematic behavior and, therefore, would be suitable for the same type of TKA design. In addition, it is currently unknown whether specific kinematic patterns are the result of a particular level of osteoarthrosis. For this reason, the aim of this study was to characterize the condylar motion of native knees and to investigate whether the kinematic behavior is related to the osteoarthrosis level.

METHODS: Within the scope of this in vitro study, thirteen fresh-frozen human cadaveric knees [3] were tested on a six degrees of freedom joint motion simulator (AMTI VIVO). To record the neutral path of motion of each knee, the knees were continuously flexed and extended from 0° to 90° with a compressive force of 50 N, while all other forces/moments were maintained at 0 N/Nm. Before testing, the femur and tibia of each specimen underwent a complex 3D fitting process (ARAMIS 12M, Carl Zeiss GOM Metrology GmbH) using segmented CT scans containing landmark-based femoral and tibial coordinate systems. Tracking the relative positions of the femoral and tibial coordinate systems and their corresponding bone geometries during testing allowed the projection of the flexion axis and the medial and lateral flexion facet centres (MFC and LFC) onto the tibial plane at different flexion angles. The resulting condylar motion is characterized by the anterior-posterior (AP) translation of the MFC and the rotation of the projected flexion axis when flexing the knee from 0° to 90°. After testing, the knee capsule was opened using a medial parapatellar approach and the osteoarthrosis level was determined by an experienced knee surgeon. To better visualize cartilage distributions and defects on the femoral condyles, 3D scans of each femur were acquired and matched to the segmented CT scans.

RESULTS: The condylar motion which is described by the AP translation of the MFC and the rotation of the projected flexion axis varied between the specimens (Fig. 1). However, two main kinematic pattern groups could be identified. In group 1, the posterior translation of the MFC was associated with a small rotational movement (< 5°), resulting in a symmetrical femoral rollback (Fig. 2a). In contrast, group 2 showed a posterior translation of the MFC combined with a higher rotation (> 5°, Fig. 2b). This pattern can be described as medial pivoting. In two specimens, the medial pivot was more prominent than in the main group (P10 and P12). Furthermore, four different osteoarthrosis levels of the femoral condyles were determined based on the experienced knee surgeon's assessment and evaluation of the 3D scans: 1. Slight degeneration medial and lateral (Fig. 3), 2. Moderate degeneration medial and lateral, 3. More medial than lateral degeneration, 4. More lateral than medial degeneration. Neither group of kinematic patterns is associated with a specific osteoarthrosis level.

DISCUSSION: It has been shown that the condylar motion of native knees can be divided into two main groups, with no kinematic pattern associated with a specific level of osteoarthrosis. This suggests that different kinematic patterns are not only a result of osteoarthrosis. Consequently, each knee has unique implant design and alignment requirements to mimic native knee kinematics. However, severe progredient osteoarthrosis was not investigated in this study. Therefore, no conclusions can be drawn about the kinematic behavior in this condition. A further study will investigate which implant designs best replicate the specimens' individual native knee kinematics.

SIGNIFICANCE: This study illustrates the different kinematic behavior of native knees, which is not only a result of the osteoarthrosis level, and thus reveals general aspects that need be considered in TKA to improve patient satisfaction.

REFERENCES: 1. Bourne et al. 2010, 2. Angerame et al. 2019, 3. Ethical approval by the Ludwig Maximilian University of Munich (No. 20-0856)

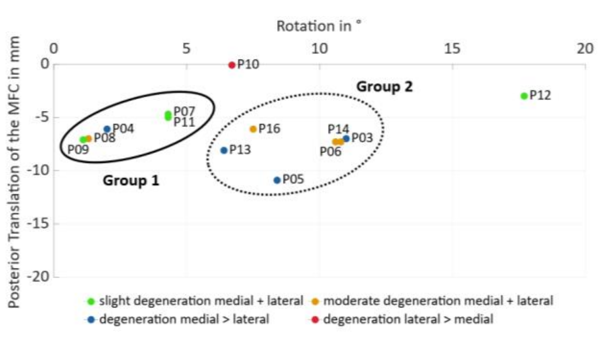

Fig. 1: Posterior translation of the MFC vs. rotation of the projected flexion axis of different specimens during passive knee flexion from 0° to 90° based on level of osteoarthrosis and kinematic pattern group. Group 1 shows a symmetrical femoral rollback, whereas group 2 displays a medial pivot.

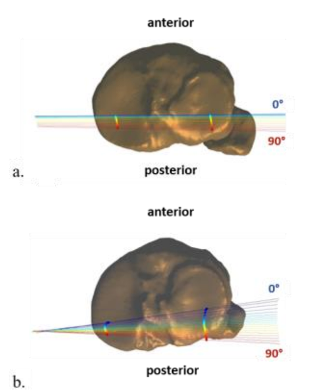

Fig. 2: Projection of the flexion axis and flexion facet centers onto the tibial plane at different flexion angles resulting in a symmetrical femoral rollback (a) and a medial pivot (b).

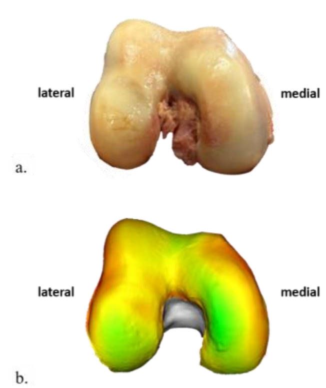

Fig. 3: Femoral condyles (a) and matched 3D scan of femoral condyles (b) of specimen P11 showing slight degeneration medial and lateral with cartilage swelling on the medial distal condyle. The thickness of the cartilage layer decreases from green to red.