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Basic Science

Are We Subluxating Knees in Total Knee Arthroplasty? A Cadaveric Investigation

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ABSTRACT

Background: In comparison to coronal, sagittal, and rotational alignment, translational alignment parameters have been widely neglected in total knee arthroplasty (TKA) so far. As there is a certain variable range of possible component placement in mediolateral, ventrodorsal, and proximodistal direction, we hypothesized that relative positions between the femoral and tibial bones are changed after TKA, resulting in a subluxation of knees.

Methods: In 10 knees of Thiel-embalmed whole body cadavers, the relative position between the femur and the tibia during passive flexion was measured before and after TKA by means of a navigational device.

Results: After TKA, in extension, femoral bones in average shifted 5.3 mm (standard deviation [SD] = 4.0, $P = .002$) laterally and 2.4 mm (SD = 3.1, $P = .038$) proximally in extension which, however, decreased throughout flexion. Furthermore, the ventrodorsal femoral position was altered, resulting in a slight relative dorsal shift (2.6 mm, SD = 4.5, $P = .099$) in extension, which continuously changed into a ventral shift (2.6 mm, SD = 4.3, $P = .087$) during flexion.

Conclusion: The present investigation reveals changed translational parameters between the tibia and the femur after TKA. The resulting subluxation of the knee may be responsible for changed kinematic patterns. These changes in tibofemoral position should be considered in future biomechanical studies. Main reasons for this effect might be a noncentral placement of tibial and femoral implants in relation to the proximal tibial and distal femoral anatomy, obscured intraoperative articular geometry, symmetric implants, and operative techniques. Smaller steps between different component sizes, asymmetric tibial implant design, or individual (anatomic) implants could help to minimize subluxation in TKA.

Total knee arthroplasty (TKA) is one of the most successful orthopedic procedures in orthopedic surgery. Implant survival after 10 years is reported up to 95% for several implants [1]. In contrast, up to ~30% of the patients are dissatisfied with the outcome after TKA or have pain [2-4]. Patient-related factors such as female sex, higher body mass index (BMI), previous knee surgery, depression, and diabetes mellitus are associated with reduced functional outcome [5]. Implant malalignment is linked to decreased implant survival and inferior patients' satisfaction [6,7].

In general, a neutral alignment of the hip-knee-ankle angle is recommended, placing the femoral component 2°-8° valgus to the anatomic femoral axis and the tibial component perpendicular to the tibial mechanical axis [6,8,9]. Furthermore, a femoral component flexion between 0° and 3° and a tibial slope between 0° and 7° are suggested [8-10]. Regarding component rotation, slight femoral component external rotation of 2°-5° in relation to the surgical transepicondylar axis and tibial component rotation in accordance to the tibial tubercle axis (TTA) is proposed [8,9,11,12].

All these suggested values concern rotational parameters in relation to the coronal, sagittal, and transversal axis. With regards to component placement, translational parameters such as mediolateral, ventrodorsal, and proximodistal shifts can be actively influenced by the surgeon as well. Concerning proximodistal

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component alignment, also regarded as joint line, the reconstruction of the original height is usually desired [13,14]. Only few studies deal with the issue of mediolateral and ventrodorsal component placement, recommending a maximum coverage of the bone with a mediolateral overhang <3 mm [15,16].

Hence, femoral components may be placed within a certain mediolateral range. This is dependent on the implant fitting which is highly related to the ratio between the antero-posterior (AP) and mediolateral femoral diameter. As tibial components need to be externally rotated, especially in symmetric components, surgeons have to compromise on mediolateral and ventrodorsal shift to prevent implant overhang and gain maximum bone coverage.

Positioning of either the femoral or tibial components is therefore usually performed variably regardless of the exact natural articulating points between the femur and the tibia and the articulating points of the implant (Figs. 1-3).

Thus, we hypothesized that due to variable mediolateral, ventrodorsal, and proximodistal component placement of both tibial and femoral components without the knowledge of the original tibiofemoral articulating sites and implant specific changes of the articulating points, TKA might lead to (1) wrong mediolateral, (2) ventrodorsal, and (3) proximodistal tibiofemoral articulation causing subluxation of the knee.

Material and Methods

Surgical Procedure

Ten knees of Thiel-embalmed whole cadavers without any history of operations on the lower extremities, degenerative osteoarthritis of the hips or knees, or fractures were investigated for the present study. For both TKA implantation (all cuts) and assessing knee kinematics, a commercial computed tomography-free navigation device was used (Brainlab Knee 2.6, Brainlab, Feldkirchen, Germany). A median skin incision was performed, and the capsule was marked by a waterproof pen. By means of a parapatellar medial arthrotomy, the joint was opened without harming any ligaments, menisci, or other intracapsular structures. For the tibia, bicortical Schanz screws were attached 5 cm below the joint line; for the femur, bicortical Schanz screws were attached outside the capsule with an additional incision of 1 cm to avoid soft tissue problems. Subsequently, the passive optical reference arrays were fixed. The femoral head center was identified by circumduction. By means of a pointer, the required landmarks were digitized (femoral: distal femoral knee center, medial and lateral epicondyle, Whiteside line, articulating surface of the medial and lateral condyle; tibial: tibial plateau magnitude, medial and lateral malleolus, Akagi line [17] as tibial AP axis and the articulating surface of the medial and lateral tibial plateau). After anatomic closure of the capsule according to the markings, relative positions of the femoral and tibial bones between 0° and

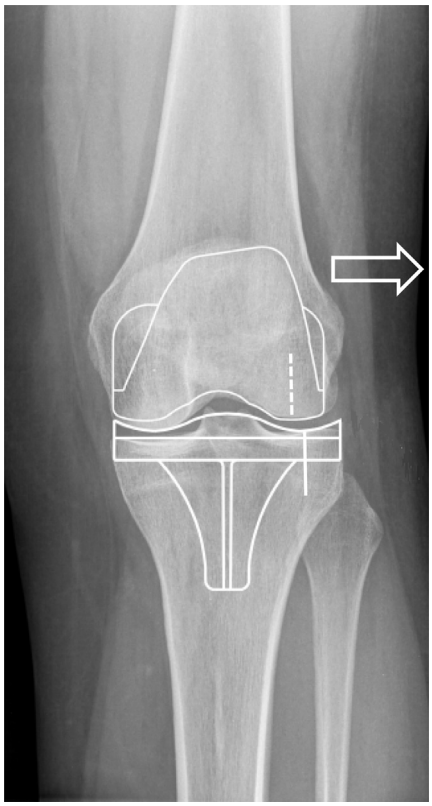

Fig. 1. Mediolateral component alignment. Especially if component sizes do not optimally fit, there is a certain range the implants can be mediolaterally aligned. Due to implant based articulating points, which are determined by the distance from the lateral borders, the femur might shift laterally in the present case.

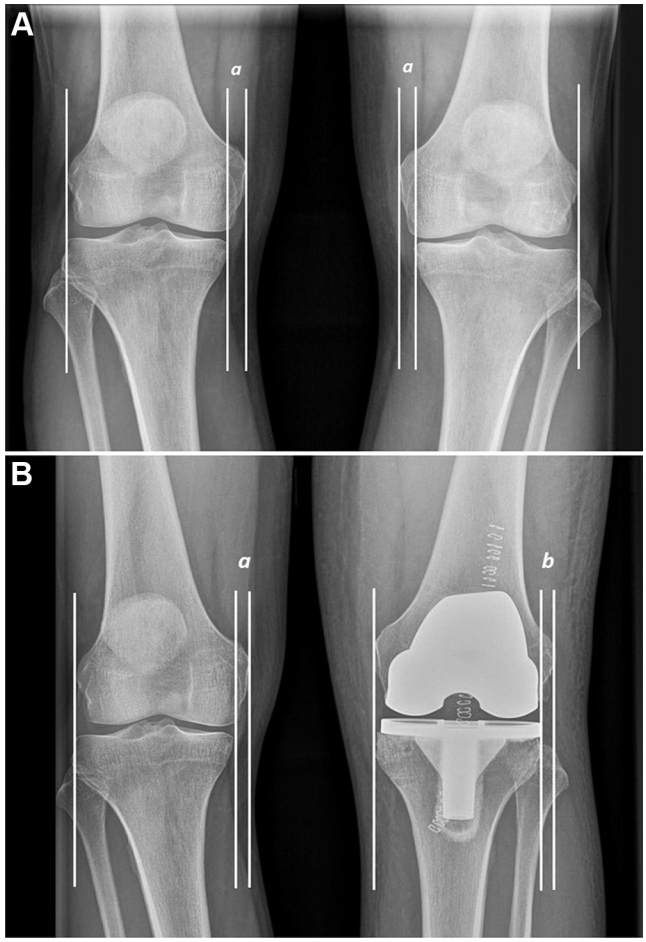

Fig. 2. Mediolateral shift before and after total knee arthroplasty. Preoperatively (A), the distances between the medial epicondyles and the medial tibial plateaus (marked as “a”) and the lateral epicondyles and the lateral tibial plateaus between left and right knee are comparable. Postoperatively (B), the left knee shows the same distances between the epicondyles and the tibial plateau, while the femur of the operated knee shifts laterally showing the distance “b” between the lateral epicondyle and the lateral tibial plateau and the missing distance between the medial epicondyle and the medial tibial plateau.