Functional alignment in total knee arthroplasty restores in vivo cruciate ligament forces and knee kinematics more effectively than mechanical alignment.

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INTRODUCTION: In bicruciate-retaining total knee arthroplasty (BCR-TKA), whether cruciate ligament forces in various coronally aligned knees differ from those in normal knees remains unknown. The purpose of this study was to compare the in vivo cruciate ligament force and kinematics in knees after mechanical alignment (MA) TKA or functional alignment (FA) TKA to those in normal knees during high-flexion activity.

METHODS: Twenty normal knees, 19 knees with MA TKA, and 18 knees with FA TKA were fluoroscopically examined while performing a squatting activity. The analysis determined that a minimum of twelve knees was required to achieve an alpha level of 0.05, a power of 0.8, and an effect size of 0.4. In MA TKA, the coronal bone resections of the distal femur and proximal tibia were set to be perpendicular to the mechanical axis. In FA TKA, the distal femoral cut was made to reproduce pre-arthritic condyle thickness. Varus–valgus stress was applied to evaluate the medial and lateral joint laxity under navigation, and the amount of proximal tibial cut was decided based on the joint laxity. A two-dimensional/three-dimensional registration technique was employed to measure tibiofemoral kinematics (axial rotational angle, varus–valgus angle, anteroposterior translation (APT) of the surgical epicondylar axis (SEA) and low contact points (LCPs) of the femur relative to the tibia) (Fig. 1). The APT of LCPs was evaluated as the variation beyond 0° of flexion. Ligament strains and tensions in the anteromedial and posterolateral bundles of the ACL (aACL and pACL) and the anterolateral and posteromedial bundles of the posterior cruciate ligament (aPCL and pPCL) during knee flexion were analyzed. All volunteers and patients provided written informed consent to participate, and the study was approved by The University of Tokyo Institutional Ethics Review Board.

RESULTS SECTION: MA and FA TKA knees displayed more external femoral rotation than normal knees (MA TKA: At 0° and 10° of flexion, FA TKA: At 0° of flexion). Both TKA knees were less varus aligned than normal knees (MA TKA: Up to 70° of flexion, FA TKA: At 20° of flexion). In the medial side of SEA, MA TKA knees were more anteriorly located than normal knees at 0° of flexion. In the lateral side of SEA, both TKA knees were more posteriorly located than normal knees up to 10° of flexion. In medial LCPs, both TKA knees were more posteriorly located than normal knees (MA TKA: from 10° to 20° of flexion, FA TKA: 10° of flexion). Additionally, both knees were more anteriorly located than normal knees (MA TKA: beyond 70° of flexion, FA TKA: beyond 50° of flexion). In lateral LCPs, both TKA knees were more anteriorly located than normal knees (MA TKA: beyond 50° of flexion, FA TKA: beyond 30° of flexion) (Fig. 2). Both aACL and pACL tensions decreased with flexion. There were no significant differences between the TKA knees and normal knees. In contrast, aPCL and pPCL tensions increased with flexion. Beyond 80° of flexion, the aPCL tension of MA TKA knees was larger than that of normal knees. Beyond 90° of flexion, the pPCL tension of MA TKA knees was larger than that of normal knees (Fig. 3).

DISCUSSION: The key findings of this study indicate that PCL forces in MA TKA knees were significantly greater than those in normal knees. However, PCL forces in FA TKA knees did not significantly differ from those in normal knees. A previous study reported that BCR-TKA knees with a symmetrical articular surface, compared to the contralateral native knees, exhibited significant PCL overstretching during flexion. This suggested that adjustment of joint laxity in FA TKA reduced the PCL tightness. On the other hand, the ACL forces in BCR-TKA knees did not significantly differ from those in normal knees. An in vitro study reported that the ACL in situ force in the knees after BCR-TKA was higher than that in the intact knees during a passive path. A previous study reported that ACL force after BCR-TKA was significantly greater than that before the surgery. These findings suggested that in vivo ACL force during weight-bearing high-flexion activity was re-tensioned to get closer to normality by BCR-TKA.

Regarding the APT of the LCPs, the posterior translation of both medial and lateral LCPs was reduced from mid-flexion to high-flexion compared to normal knees. Generally, medial and lateral menisci are removed in TKA. Previous studies reported that menisci underwent large displacements and played larger roles in transmitting contact force in deep flexion; in other words, menisci are an important AP stabilizer. In addition, several studies demonstrated that preoperative OA knees had reduced posterior translation during knee flexion motion. These facts suggested that even though the cruciate ligaments are preserved, BCR-TKA did not completely recreate the APT on the articular surface. Only patients who could perform squatting activities were included in the current study; therefore, our findings may not be generalizable to those who cannot perform such activities. In conclusion, the cruciate ligament forces, especially the PCL force of the knees after MA TKA, were larger than those of the normal knees.

SIGNIFICANCE/CLINICAL RELEVANCE: FA TKA could obtain a more normal cruciate ligament balance.

IMAGES AND TABLES:

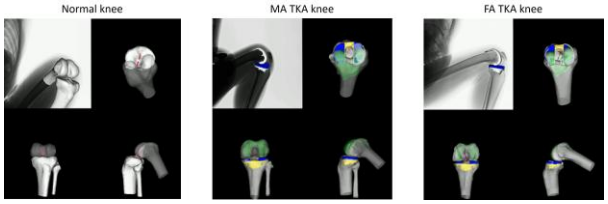

Fig. 1. 2D/3D registration and ligament force evaluation.

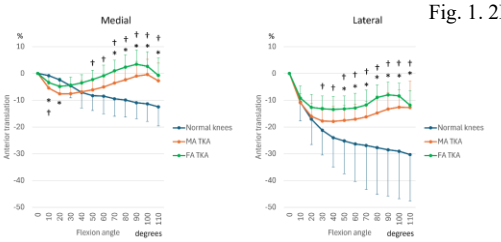

Fig. 2. APT of the LCPs during squatting. * p<0.05

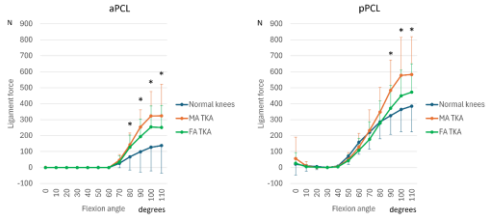

Fig. 3. PCL Force during squatting. * p<0.05