Restoration of the Joint Line Configuration Reproduces Native Mid-Flexion Biomechanics after Total Knee Arthroplasty: A Matched-Pair Cadaveric Study

In Jun Koh[1], Yong Deok Kim[2], Dai-Soon Kwak[1], Dohyung Lim[3], Sueen Sohn[4], Nicole Ejin Cho
[1]The Catholic University of Korea, [2]Eunpyeong St. Mary's Hospital, [3]Sejong University, [4]Inje University Sanggye Paik Hospital

INTRODUCTION:

Recent evidence supports that restoration of the pre-arthritic condition via total knee arthroplasty (TKA) is associated with improved post-TKA performance and patient satisfaction. Many daily activities, including walking and rising from a chair, are performed in the mid-flexion range; restoration of preoperative knee performance within that range is essential for TKA to be successful. It has been suggested that mid-flexion instability is inevitable after well-balanced MA TKA; joint line elevation after MA TKA was a risk factor for instability. Theoretically, KA TKA that restores both the joint line height and obliquity of the pre-arthritic knee should provide more natural mid-flexion kinematics and laxity than MA TKA. However, whether the restored pre-arthritic joint line simulates the native mid-flexion biomechanics remains unclear.

The objective of this matched-pair study was to determine whether the restored prearthritic joint line configuration after KA TKA provided femoral rollback closer to that of the native knee than the altered joint line perpendicular to the mechanical axis created after MA TKA, and whether KA TKA more effectively restored MCL strain in comparison to MA TKA.

METHODS:

Eight freshly frozen full-body specimens (human cadavers, 16 knees; five male pairs and three female pairs; mean age, 76 years; range: 58–86 years) were used. The two knees of each cadaver were randomly assigned to either the KA TKA or the MA TKA group. A senior surgeon performed all arthroplasties following a standard posterior-substituting (PS) prosthetic system. KA TKA was performed using the previously described calipered technique and MA TKA was performed with the conventional measured resection technique. Following preparation, each knee was affixed in its original axial position onto a customized knee-squatting simulator system; this induces continuous flexion–extension knee motion under physiological muscle loading and allows six degrees of freedom. (Fig1) A motion capture system combined with optical markers was used to measure knee kinematics. Five motion capture cameras were employed. Real-time variations in the mid-flexion MCL strain were examined with a noncontact video extensometer featuring a high-resolution digital camera and real-time image processing software.

RESULTS:

KA TKA restored the mid-flexion medial and lateral rollback and tibiofemoral axial rotation to levels closer to those of the native knee than MA TKA. The medial and lateral rollback of KA TKA and native knees was similar over the entire mid-flexion range. The medial and lateral rollback after MA TKA were significantly lower compared with native knees at both > 40 degrees and >20 degrees of flexion.

In addition, tibiofemoral axial rotation during flexion after KA TKA was similar to that of the native knee , while that of MA TKA differed from the native knee in the mid-flexion range. Remarkably, the femur moved forward during flexion after MA TKA over the entire mid-flexion range, except at 20 degees of flexion. (Fig 2-4)

KA TKA was better for restoring the MCL strain to that of the native knee over the entire mid-flexion range than MA TKA. The mean strain measurements following KA TKA and those of the native knee were alike over all ranges. The MCL strain after MA TKA was two-fold greater than that of the native knee at flexion angles > 20 degrees. (Fig5)

DISCUSSION AND CONCLUSION: We investigated whether restoration of the pre-arthritic joint line following TKA would affect post-TKA biomechanics. Restoration of the height and obliquity of the prearthritic joint line following KA TKA reproduces more natural rollback and MCL strain than alteration of the joint line following MA TKA over the entire mid-flexion range. Future studies focused on the development of both the motion analysis system that assesses the knee kinematics of patients in real clinical practice and the algorithm that recommends the optimal implant position restoring native knee kinematics are required.