Kinematic differences before and after total knee arthroplasty

AKBARI SHANDIZ M, SAEVARSSON SK, YOO S, ANGLIN C

Biomedical Engineering, McCaig Institute for Bone and Joint Health, University of Calgary, Calgary, Canada

canglin@ucalgary.ca

Introduction: Two major goals of total knee arthroplasty (TKA) are to treat severe osteoarthritic pain and to restore knee function; this includes regaining normal kinematics. Around 18% of patients are not satisfied with the outcome of their surgery [1]. Many factors can affect knee kinematics following TKA, including implant design, component position and soft tissue tensions. The knee may be intentionally changed during the surgery to correct malaligned legs, misshapen arthritic knees and improper kinematics and to ensure good stability and range of motion, resulting in a different shape of the implanted knee compared to the original natural knee. Unintentional changes may occur due to standardized component sizing or non-patient-specific placement. A better understanding of these issues could aid computer-assisted surgery systems and improve patient outcomes and satisfaction.

The impact of TKA on knee kinematics has not been previously reported, to our knowledge, for all 12 degrees of freedom (DOF) of the knee. The purpose of the present study was to compare the 6 DOF patellofemoral (PF) and 6 DOF tibiofemoral (TF) pre-TKA kinematics in one group to the post-TKA kinematics in another group. Post-TKA measurements of the pre-TKA group are in progress, which will allow a direct comparison between the shape and kinematics of the same individuals before surgery and one year after surgery.

Materials and Methods: We imaged and analyzed the knees of 9 pre-TKA subjects compared to 15 post-TKA subjects, using a unique radiographic protocol developed by our group that allows both PF and TF 6-DOF kinematics to be studied under weightbearing throughout the range of motion [2]. The method can detect differences within 2 mm for translation and 2° for rotation. All post-TKA subjects had NexGen Legacy Posterior Stabilized (LPS) gender-specific, high-flexion components (Zimmer, Warsaw, IN).

The overall procedure consisted of four main steps, as follows: (1) Two sequential radiographic images were acquired at 8 knee flexion angles: 0°, 15°, 30°, 45°, 60°, 75°, 90° and max flexion (Fig. 1), with the subject in a weightbearing position, ‘just about’ to step up onto different step heights. One image was taken with the X-ray source directly horizontal (sagittal) and the other image with the source 10° below horizontal; it took less than 5 seconds to move between the two orientations. Static kinematics with this protocol were shown to be comparable to dynamic kinematics during a step up in all but one DOF for one subject (out of 12 DOF for ten subjects) [3]. (2) Two-dimensional (2D) images were calibrated with the use of a calibration frame around the subject’s knee (Fig. 1) and custom software. (3) Computed tomography (CT) imaging of the knee was used to create a three-dimensional (3D) model of the knee bones and implant [4]. Coordinate systems were assigned to the models using features on each prosthesis component and assigned to the bones using anatomic landmarks. CT images were segmented automatically using statistical shape models developed at the Zuse Institute Berlin, to generate femoral, tibial and patellar bone models. (4) The 3D bone and implant models were matched to the 2D calibrated images to determine the 6 DOF PF and TF kinematics throughout the range of motion, using JointTrack open-source software (sourceforge.net/projects/jointtrack/) (Fig. 1).

Statistical comparisons were made between the two groups using an ANOVA for each degree of freedom; if significant, unpaired Student’s t-tests were performed to examine differences at each flexion angle, with p<0.05 considered significant.
**Results:** There were clear, statistically significant differences between pre-TKA and post-TKA kinematics (Fig. 1). For the TF joint, the tibia was more posterior and inferior (max 20 mm and 15 mm, respectively) post-TKA compared to the pre-TKA group (p<0.001), and had neutral alignment post-TKA compared to varus alignment (max 9°) in the pre-TKA group (p<0.001). For the PF joint, the patella was shifted more posteriorly and medially and tilted more medially post-TKA compared to the pre-TKA group (p<0.001). There were no significant differences in PF superior/inferior translation and flexion/extension (p>0.5).

**Discussion:** Significant differences in kinematics were seen between patients with and without a TKA. These differences are due to a combination of surgical, implant and patient factors. Both groups show differences from normal kinematics. The question remains: could a different implant shape or different component positioning create more normal kinematics, resulting in a better clinical outcome? Comparing the shape and kinematics of the same individuals before and after TKA will allow us to make a direct evaluation of the effect of TKA on each individual for all 12 DOF. This has not been available previously. It will also allow us to compare the 12 DOF kinematics for two different implant designs, and evaluate inter-relationships between shape and kinematics. The data from this study can be used to improve implant design, implant selection and component positioning. The resulting patient-specific planning can be incorporated into computer-assisted surgery systems to reduce pain and restore more normal kinematics.
References


