The Functional Flexion Axis of the Knee as a Basis for Femoral Component Positioning during TKA

William M. Mihalko1, Matthew J. Phillips2, David McQueen3, Joel Bach4, Michael Nogler5, Kenneth A. Krakow2
1Orthopaedic Surgery, University of Virginia, Charlottesville, VA; 2Orthopaedic Surgery, State University of New York at Buffalo, Kaleida Health, Buffalo, NY; 3Orthopaedic Surgery, University of Kansas, Kansas City, KS; 4Mechanical Engineering, University of Colorado, Colorado Springs, CO; 5Orthopaedic Surgery, University of Innsbruck, Innsbruck, Austria
wmnm4n@virginia.edu

Introduction: Computer navigation systems have now been utilized for over five years and reports are now verifying that these systems lead to decreased outliers of deformity and component positioning. Even though the computer assistance in the operating room seems to give less variance in alignment there are still questions concerning inter and intra observer variability since the digitization of bony landmarks during registration is all surgeon dependent. This study investigates the accuracy of the functional axis of the knee versus the registered epicondylar axis for femoral component rotation during TKA.

Materials and Methods: Twenty five knees from thirteen fresh whole cadaveric bodies performed at three institutions were utilized for the study. The lower extremity was draped in a similar manner that would be for surgical procedures to closely mimic the constraints to motion of the knee that occurs in during a primary total knee replacement. Reference base anchors using a 4.0 mm self locking cancellous screw was utilized to place tibial and femoral infrared emitters (Stryker Navigation, Kalamazoo, MI) within a medial parapatellar approach to each knee but were first placed percutaneously. Each knee had a passive and a distractive force applied to the knee throughout full extension to past 90 degrees. The ankle had a tether with a cord placed around it and a linear scale attached to apply a 25lb distractive force during flexion and extension of the knee. Testing groups for each knee consisted of the following: 1) Intact knee, 2) open parapatellar arthroscopy and anatomy survey performed, 3) ACL resection, 4) Tibial bone resection of 10mm, 5) femoral osteophyte removal, 6) femoral cuts made, 7) CR prosthesis placed (Triathlon, Stryker Orthopaedics, Mahwah, NJ), 8) PCL sacrifice, 9) PS Triathlon prosthetic placed. Each testing group then had the knee kinematics recorded for passive and distractive force applied for motion from full extension to 90 degrees of flexion and back for three trials by three different surgeons for analysis.

Prior to cadaveric testing each cadaveric body underwent fiducial marker placement of ten markers in the femur, tibia and ankle (Figure 1). Each cadaver underwent a CT scan of each leg separately with a 512x512 pixel image. A slice thickness of 1mm was obtained with no gantry tilt. The data was then utilized to digitize the fiducial markers and overlay the CT and imageless navigation data for analysis. The CT based transepicondylar axis was then calculated from the CT data and compared to the navigation determined average functional flexion axis of the knee.

Results: For the comparison of determined axes for femoral component rotation, the CT determined epicondylar axis, the digitized epicondylar axis, the digitized AP axis, and the axis determined by the average functional flexion axis of each knee were determined and averaged for comparison (Table 1). The results revealed that the means of each technique when compared to the CT determined EA (utilized as the ground truth) found that the functional flexion axis had the closest mean (0.89 degrees) axis. The robustness of each calculated axes can be viewed in figure 1. Here it is evident that the largest number of calculations for the functional flexion axis was found within the curve for the CT determined EA.

Comparison of FFA and intra-operative TEA versus TEA defined in CT

Discussion: The results of this study have shown that the functional flexion axis on average is as good a predictor for femoral component rotation than the epicondylar, or AP axes and compared well to the CT determined EA. Likewise the robustness of the method seems higher than the navigation digitized landmarks. One downfall is the fact that these specimens are mainly varus medial compartment osteoarthritic knees and it is unknown if the pathologic anatomy associated with a valgus knee will result in solutions that are equally robust. Selection of an axis for comparison is also difficult and can be a criticism of this study. Using a CT determined EA can be argued since it too is associated with variations in pixel size, human digitization and selection of anatomical landmarks. This study has determined that the functional flexion axis of the osteoarthritic varus knee from full extension to 90 degrees flexion may serve as a less variable landmark for femoral component rotation in TKA surgery. Further investigation is necessary for comparison of valgus knee effects as well as to determine if fail safe mechanisms must be put in place for the algorithm as well.