KNEE FLEXION ANGLES AND TOTAL KNEE ARTHROPLASTY: CAVEAT EMPTOR

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Introduction
Total knee arthroplasties (TKA) are designed to accommodate ranges of knee flexion/extension encountered in activities of daily living, typically -15° to >120°. However, TKA’s are generally NOT placed in line with the sagittal mechanical axis of the leg (hip center – knee center – ankle center) due to the anterior bow of the femur and posterior tibial slope (Figure 1). This introduces a potentially significant extension offset of the arthroplasty components, which may have implications for arthroplasty function (e.g. impingement in extension), design, and testing. This study compared external (hip-knee-ankle) and internal (TKA component) measures of knee flexion during gait and kneeling to determine the magnitude of this difference.

Methods
Ten subjects with well aligned, clinically excellent knee arthroplasties were observed using simultaneous reflective marker based motion capture and fluoroscopy during treadmill gait. Knee flexion angles were determined from the reflective markers using standard methods, including positioning the markers in measured locations relative to the joint centers, and commercially available software (Orthotrak, Motion Analysis Corp., Santa Rosa, CA). Flexion angles of the implant components were determined from the fluoroscope images using CAD model based shape matching techniques, with reported accuracy of approximately ±1°. In a separate study, eleven subjects with clinically excellent, well aligned arthroplasties of a different design were characterized using fluoroscopy and manual goniometry during kneeling. An experienced physical therapist determined the knee flexion angle using a goniometer immediately before the fluoroscopic image was acquired. Implant component flexion was determined from the images as previously explained. All subjects gave informed consent for their participation, and the protocol was approved by both institutions’ ethics committee.

Results
The gait comparison revealed the external measure of knee flexion was an average of 9.8 degrees greater than the TKA component flexion (p<0.001, two factor repeated measures ANOVA). For the kneeling activity, the external goniometer measurement indicated 9.3 degrees greater flexion than the TKA component flexion angle (p=0.0015, paired t-test).

Discussion
Knee arthroplasty components are implanted with an average of 9 degrees (or more) hyperextension relative to the anatomical flexion/extension axis. This finding forces us to reevaluate some of the long-held assumptions about the range of flexion angles a knee arthroplasty needs to accommodate, as well as many of the component test protocols. For example, a TKA design that accommodates 15 degrees of hyperextension prior to impingement may be very close to this limit during every heel-strike and toe-off in gait. Consistent with this observation, several laboratories have recently reported evidence of anterior post/notch impingement in a majority of retrieved posterior cruciate substituting TKA components [1,2]. At the other extreme, TKA design efforts to accommodate full anatomical flexion (~140°) may really only need to optimize implant mechanics to 130° of flexion.

Many centers are performing knee wear studies using multi-axis wear testing systems and a standardized set of waveforms based on gait analysis data. For these waveforms, knee flexion during stance phase is typically between 0° and 20°. Should it be between -10° and +10° to more accurately reflect the surgical positioning of TKA components?

This simple observation, that TKA components are not positioned directly in-line with the long axis of the bones, might be useful to consider in future TKA design efforts, in interpreting wear on retrieved TKA components, and in designing wear test scenarios for more accurate prediction of in vivo TKA function.

Figure 1. Lines connecting the joint centers define the flexion/extension axes of the lower extremity, and markers for gait analysis are typically placed to identify these axes. The femoral component of a total knee arthroplasty is generally placed parallel to the distal femur, which is relatively flexed in the sagittal plane due to anterior bow of the femur. The tibial component of a total knee arthroplasty is generally placed with 3 to 5 (or more) degrees of posterior tibial slope. The net result of this implant alignment is that the arthroplasty components experience flexion angles that can be substantially different from those measured by connecting the joint centers.

References

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