INTRODUCTION

A total knee arthroplasty (TKA) that closely approximates the feel and function of a healthy un-operated knee is increasingly identified by both patients and clinicians as an objective of knee replacement surgery\(^1\). Although TKA surgery enjoys 90% of outcomes with good to excellent results, some patients have difficulty adjusting their gait to accommodate the new articulations inherent in contemporary implant designs. Paradoxical motions inclusive of anterior sliding and lateral pivot are examples of aberrant TKA kinematics.

The GMK-Sphere Total Knee is a contemporary design which has a conforming “ball-in-socket” medial femoral tibial articulation intended to confer anterior-posterior stability while the lateral femoral tibial articulation is sagittally unconstrained to allow the rollback observed in the natural human knee. These design features may reduce paradoxical motion and provide more natural kinematics.

This paper compares the motion of the GMK-Sphere TKA design with \textit{in vivo} kinematic data of the healthy, un-operated knee during a deep flexion activity by employing a computational kinematic model of the design which facilitates comparison.

COMPUTATIONAL KINEMATICS

KneeSIM software (LifeModeler, San Clemente, California) provides a dynamic, physics-based, musculoskeletal modeling environment of the left leg of a nominal sized, male, virtual patient (Figure 1).

GMK-Sphere component geometries were derived from the measured articular surfaces of implantable quality components employing a three dimensional laser scanner, rather than relying on idealized computer aided design (CAD) models. The benefit from this reverse-engineering procedure is a determination of actual component fit which directly relates to the accuracy of the manufacturing process.

Activities of daily living, such as deep knee bend, are propelled by flexor and extensor muscle groups and restrained by the capsular and ligamentous structures surrounding the knee. A generalized contact algorithm allows the TKA components to articulate in a natural manner during a full activity cycle. Animations of component motions and quantitative data plots are generated to characterize the resulting kinematics, allowing comparison to those of the healthy intact knee.
Reference markers called Flexion Facet Centers (FFCs) are determined for both the medial and lateral femoral condyles for ten male subjects in the in vivo kinematic study. The markers are located at the geometric center of each condyle (Figure 2). They help quantify the motion of the patient’s femur with respect to the tibia, showing the anterior-posterior motion for each condyle as flexion progresses during a stand to squat activity.

The computational kinematic model also uses FFC markers to quantify the progressive path of motion of the GMK-Sphere femoral component (Figure 3). An arbitrary ending flexion angle of 120 degrees was selected for the simulated stand to squat activity. The resulting synchronized animations of component motions and FFC data plots characterize the GMK-Sphere (Figure 4). The anterior-posterior translation of medial and lateral FFCs (dotted lines) are compared in the data plot with FFC motion reported in the in vivo kinematic study of weight bearing, healthy intact knees (solid lines).

![Figure 2 - Intact knee FFC reference point (reproduced with permission from Elsevier)](image1)

![Figure 3 - GMK-Sphere FFCs (blue is lateral FFC, red is medial FFC)](image2)

![Figure 4 - GMK-Sphere anterior-posterior translation of FFC markers (dotted lines) closely match intact healthy knee FFC anterior-posterior translation (solid lines)](image3)
DISCUSSION

In general, the GMK-Sphere kinematic pathway compares very favorably with *in vivo* kinematic data of the healthy, un-operated knee. The lateral FFC begins 2 millimeters anterior of the midline of the tibial insert at full extension and progresses in a manner similar to the intact healthy knee’s lateral FFC as flexion progresses. The medial FFC begins 5 millimeters posterior to the midline of the tibial insert, but closely follows the same trend as the intact medial FFC, remaining in the same position for most of the high flexion activity.

CONCLUSION

The medially stabilized design of the GMK-Sphere offers stability in the anterior-posterior direction while still offering a natural posterior translation of the lateral femoral condyle, both hallmarks of the healthy, un-operated knee during high flexion activities.

REFERENCES


