

IN VIVO DETERMINATION OF KNEE KINEMATICS DURING GAIT FOR
SUBJECTS
IMPLANTED WITH A UNICOMPARTMENTAL ARTHROPLASTY

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INTRODUCTION

Failure in the early years of knee arthroplasty was most commonly due to aseptic loosening, often associated with component malalignment, soft tissue imbalance, or use of constrained prosthesis. Isolated polyethylene wear failure in this era was uncommon. With improved instrumentation and soft-tissue balancing techniques, failure secondary to mechanical loosening has been minimal. More recently, failures secondary to catastrophic polyethylene wear have been observed, attributed to less conforming articular geometries, polyethylene sterilization methods, or disturbed knee kinematics. A better understanding of knee joint kinematics is important to explain the premature polyethylene wear failures observed, and serves as the purpose of this investigation.

To date, most experimental studies of knee kinematics have involved cadaveric, in vitro analyses, or have not tested the knee in a weight-bearing mode. Others have used exoskeletal linkages and skin markers that permit error due to undesired motions between markers and the underlying bone. More recently, fluoroscopy has been used to evaluate in vivo motions of total knee arthroplasty (TKA). Since interest in Unicompartamental Arthroplasty (UA) has increased significantly, we conducted a previous study to determine the in vivo motions of medial and lateral UA during a deep knee bend, as presented last year at the academy meeting. The objective of this present follow-up study was to determine the in vivo kinematics of subjects having UA during stance-phase of gait.

METHODS

In vivo kinematics were determined for 19 subjects who were implanted with a UA. Fifteen subjects were implanted with a medial UA and four subjects were implanted with a lateral UA. All UKAs were judged clinically successful (HSS scores > 90), with no ligamentous laxity or pain. The same surgeon performed all of the surgeries. Under fluoroscopic surveillance, each subject was asked to perform normal stance-phase of gait. The fluoroscopic images were stored on videotape for subsequent re-digitization using a frame grabber. The kinematics was analyzed at heel-strike, 33 and 66% of stance-phase and at toe-off.

The contact position between the medial condyle (medial UA) or the lateral condyle (lateral UA) and the tibia was determined using a 3D model fitting technique. The fluoroscopic images were captured onto a workstation computer. The three-dimensional (3D) computer aided design (CAD) solid models of the femoral and tibial components were overlaid onto the two-dimensional (2D) fluoroscopic perspective images. Once the 3D components were fit, the medial or lateral femorotibial contact positions were determined with respect to the midline of the tibia in the sagittal plane. A contact position anterior to the midline was denoted as positive and a position posterior was denoted as negative. The coronal view was used to assess for axial rotation. The angle between the longitudinal axis passing through the femoral component of the UA (posterior to anterior) was measured relative to a fixed axis through the tibial component.

RESULTS

ANTEROPosterior TRANSLATION

Although 8/15 subjects having a medial UA experienced posterior motion during stance-phase of gait, on average, these 15 subjects experienced an anterior slide of 0.8 mm from heel-strike to toe-off . At heel-strike, the average contact position for subjects having a medial UA was - 0.2 mm (6.1 to - 7.2) moving an average of 0.3 mm in the anterior direction to an average contact position of 0.3 mm (6.6 to - 7.2) at 33% of gait stance-phase. The subjects having a medial UA remained in a similar position at 66% of stance-phase with a contact position of 0.4 mm (7.7 to - 6.0). From 66% of stance-phase to toe-off these subjects experienced an average anterior motion, having a contact position of 0.6 mm (7.2 to - 8.0) at toe-off.

As stated earlier, 8/15 subjects (53%) experienced a posterior motion of their medial condyle from heel-strike to toe-off. Of the seven subjects that having an anterior motion of their medial UA 4/7 of these subjects experienced less than 3.0 mm of motion. The maximum anterior slide determined for these seven subjects was 7.7 mm. Of the eight subjects experiencing a posterior motion from heel-strike to toe-off, the maximum amount of motion was only - 2.3 mm. Eleven of the 15 subjects experienced less than 2.0 mm of medial UA motion (anterior or posterior), which is similar to the medial condyle for the normal knee during gait.

On average, subjects having a lateral UA experienced - 0.4 mm of posterior motion from heel-strike to toe-off . At heel-strike, the average contact position for subjects having a lateral UA was - 5.7 mm (-3.9 to - 83.9), at 33% of stance-phase the average was - 6.4 mm (-5.7 to -7.6), at 66% of stance-phase the average was - 7.3 mm (-2.4 to -9.9), and at toe-off the average contact position was - 6.1 mm (-4.3 to -8.0). On average, the greatest amount of posterior motion occurred from heel-strike to 66% of stance-phase (-1.6 mm), while an anterior slide of 1.2 mm occurred from 66% of stance-phase to toe-off.

Two of the four subjects having a lateral UA experienced a posterior motion from heel-strike to toe-off, while the other two subjects experienced less than 1.0 mm of anterior motion. Overall, all four subjects experienced less than 2.1 mm of motion, whether the motion occurred in the anterior or posterior direction .

AXIAL TIBIOFEMORAL ROTATION

On average, subjects having a medial UA experienced 0.94° of normal axial rotation from heel-strike to toe-off . Contrary to the medial UA, subjects having a lateral UA, on average, experienced -6.0° of opposite axial rotation from heel-strike to toe-off . Eight of fifteen (53.3%) subjects having a medial UA experienced normal axial rotation from heel-strike to toe-off. Two subjects experienced greater than 10° of normal axial rotation . One subject having a medial UA experienced minimal ($<1.0^{\circ}$) axial rotation and 6/15 experienced a significant amount of opposite axial rotation ($>3.0^{\circ}$). Two of four subjects having a lateral UA experienced greater

than 10° of opposite axial rotation . Only 1/4 subject's having a lateral UA experienced a normal axial rotation from heel-strike to toe-off.

DISCUSSION

In vivo fluoroscopic studies of the normal knee, during stance-phase of gait, have demonstrated minimal motion (1.0 to 2.0 mm) of the medial condyle and approximately 4.0 mm of posterior motion occurring with the lateral condyle, leading to normal axial rotation of the femur relative to the tibia. During gait, non-implanted subjects having an anterior cruciate ligament (ACL) deficient knee experienced significantly more motion of their medial and lateral condyles, often occurring in the opposite direction of the normal knee motion. The present study has determined that kinematic patterns (anteroposterior translation) for subjects having a medial UA are more similar to the normal knee than the lateral UA subjects during stance-phase of gait. On average, subjects having a medial UA experienced only 0.8 mm of average motion during stance-phase of gait and 11/15 subjects experienced either 2.0 mm or less motion, similar to the range for the normal knee. Four of the fifteen subjects having a medial UA experienced greater than 3.0 mm of anterior motion, which may be due to dysfunction of their ACL. Subjects having a medial UA also experienced more normal axial rotation patterns than subjects having a lateral UA. On average, the normal knee experiences approximately 4.0° of normal axial rotation from heel-strike to toe-off. On average, subjects having a medial UA experienced 0.9° of normal axial rotation, while subjects having a lateral UA experienced -6.0° of opposite axial rotation.

Similar to the previous study, certain subjects may have experienced ACL laxity over time that lead to their UA functioning more similar to an ACL deficient knee than a normal knee. In this study the mean time between implantation and fluoroscopic evaluation was six years, and progressive laxity of the ACL may have occurred over time. Overall, the subjects having a medial UA experienced kinematic patterns more similar to the normal knee during stance-phase of gait, which may be due to better ACL function than subjects having a lateral UA.

In conclusion this study showed that, on average, subjects implanted with a unicompartmental knee arthroplasty experienced similar kinematic patterns compared to the normal knee, and there was variability in the data. The high variability in the kinematic data for the subjects experiencing an anterior slide and opposite axial rotation may suggest that the ACL was unable to provide over time an anterior constraint force with the necessary magnitude to thrust the femur in the anterior direction at full extension. This might at least in part explain premature polyethylene wear occasionally seen in UKA. Therefore, our results support the findings of other studies that the ACL plays a significant role in maintaining satisfactory knee kinematics, which also may, in part, contribute to UKA longevity.

References furnished upon request.