Introduction: Attaining proper prosthesis alignment during total knee replacement (TKR) is technically challenging, with rotational (axial) malalignment contributing to patellar maltracking, anterior pain, and wear. Mobile bearing TKR designs are advocated for their theoretical ability to self-align and accommodate small alignment errors, especially mismatch in axial alignment of the femoral and tibial components. However, the relationships between prosthesis axial alignment, polyethylene bearing motion and tibio-femoral kinematics are poorly understood. For many mobile bearing TKR, it is unknown whether axial rotation is accomplished through femoral component motion on the bearing articular surface or through motion of the bearing on the tibial baseplate.

This in-vivo study of subjects with mobile-bearing TKR assesses femoral and tibial component axial alignment and the magnitude of knee axial rotation that occurs during passive flexion. It was hypothesized that TKR with axial alignment within accepted surgical norms would present different kinematics and bearing motions compared to TKR with axial alignment outside surgical norms.

Methods: This prospective IRB approved study involved 67 patients (26 males, 41 females) with osteoarthritis undergoing TKR. Subject age and BMI averaged 67±9 (range, 47-84) years and 30.7±4.7 (range, 22-48), respectively. All patients were implanted with a cemented, unconstrained, cruciate-retaining TKR with a rotating platform polyethylene bearing (Scotia™ PCS, Stryker Orthopedics). Bearing motion was constrained to the transverse plane about a metal peg on the tibial baseplate. Three radiopaque markers embedded in each polyethylene bearing provided geometrically defined point clusters suitable for tracking bearing motion.

Three quantitative descriptors of transverse plane (axial) component alignment were measured (ID: PACS 3.6, Image Devices) from postoperative CT scans. Femoral component alignment relative to the transepicondylar axis and tibial component alignment relative to the medial third of the tibial tuberosity described axial alignment relative to anatomic landmarks. Angular divergence between the femoral and tibial components described combined relative axial mismatch. Based on these measurements, TKR were grouped according to defined tolerances for surgical axial alignment (±3° for femoral components, ±10° for tibial components). TKR within these limits were categorized as having “normal” axial alignment. TKR exceeding these limits were categorized as “outliers”.

Axial rotation during knee flexion was measured from fluoroscopic images (4±8 images/knee) acquired immediately after operative wound closure with the surgeon applying passive range of motion from full extension to approximately 120°. The three-dimensional positional and orientational data of the femoral and tibial bearing components was determined using surface models of the components projected onto the fluoroscopy images and previously published model-based shape matching techniques. Error due to image distortion and matching was 0.3° for rotations and 1.0 mm for translations in the image plane. Total axial rotation of the knee was defined as relative motion between the femoral component and metal tibial baseplate. Axial rotation of the femoral component on the polyethylene bearing (motion at the articular surface) and axial rotation of the bearing on the tibial baseplate (mobile bearing motion) were also distinguished.

Results: The range of external rotation during knee flexion was 4° to 6° for TKR in all groups (Table 1). However, approximately one-third of the TKR had axial alignment outside of defined tolerances for surgical axial alignment. Different trends in knee axial rotation were noted, depending on the axial alignment relative to anatomic landmarks and the combined axial mismatch of the femoral and tibial components.

Among TKR with normal axial alignment, external rotation steadily increased with knee flexion, with axial rotation motion distinguishable in two phases (Figs. 1-2). External rotation from 0° to approximately 80° occurred primarily due to axial rotation of the polyethylene bearing on the tibial baseplate. Beyond 80°, there was combined bearing motion and external rotation of the femoral component on the polyethylene articular surface, with the latter dominating the motion pattern.

This in-vivo study of subjects with mobile-bearing TKR assesses femoral and tibial component axial alignment and the magnitude of knee axial rotation that occurs during passive flexion. It was hypothesized that TKR with axial alignment within accepted surgical norms would present different kinematics and bearing motions compared to TKR with axial alignment outside surgical norms.

Three quantitative descriptors of transverse plane (axial) component alignment were measured (ID: PACS 3.6, Image Devices) from postoperative CT scans. Femoral component alignment relative to the transepicondylar axis and tibial component alignment relative to the medial third of the tibial tuberosity described axial alignment relative to anatomic landmarks. Angular divergence between the femoral and tibial components described combined relative axial mismatch. Based on these measurements, TKR were grouped according to defined tolerances for surgical axial alignment (±3° for femoral components, ±10° for tibial components). TKR within these limits were categorized as having “normal” axial alignment. TKR exceeding these limits were categorized as “outliers”.

Axial rotation during knee flexion was measured from fluoroscopic images (4±8 images/knee) acquired immediately after operative wound closure with the surgeon applying passive range of motion from full extension to approximately 120°. The three-dimensional positional and orientational data of the femoral and tibial bearing components was determined using surface models of the components projected onto the fluoroscopy images and previously published model-based shape matching techniques. Error due to image distortion and matching was 0.3° for rotations and 1.0 mm for translations in the image plane. Total axial rotation of the knee was defined as relative motion between the femoral component and metal tibial baseplate. Axial rotation of the femoral component on the polyethylene bearing (motion at the articular surface) and axial rotation of the bearing on the tibial baseplate (mobile bearing motion) were also distinguished.

Results: The range of external rotation during knee flexion was 4° to 6° for TKR in all groups (Table 1). However, approximately one-third of the TKR had axial alignment outside of defined tolerances for surgical axial alignment. Different trends in knee axial rotation were noted, depending on the axial alignment relative to anatomic landmarks and the combined axial mismatch of the femoral and tibial components.

Among TKR with normal axial alignment, external rotation steadily increased with knee flexion, with axial rotation motion distinguishable in two phases (Figs. 1-2). External rotation from 0° to approximately 80° occurred primarily due to axial rotation of the polyethylene bearing on the tibial baseplate. Beyond 80°, there was combined bearing motion and external rotation of the femoral component on the polyethylene articular surface, with the latter dominating the motion pattern.

This in-vivo study of subjects with mobile-bearing TKR assesses femoral and tibial component axial alignment and the magnitude of knee axial rotation that occurs during passive flexion. It was hypothesized that TKR with axial alignment within accepted surgical norms would present different kinematics and bearing motions compared to TKR with axial alignment outside surgical norms.

Three quantitative descriptors of transverse plane (axial) component alignment were measured (ID: PACS 3.6, Image Devices) from postoperative CT scans. Femoral component alignment relative to the transepicondylar axis and tibial component alignment relative to the medial third of the tibial tuberosity described axial alignment relative to anatomic landmarks. Angular divergence between the femoral and tibial components described combined relative axial mismatch. Based on these measurements, TKR were grouped according to defined tolerances for surgical axial alignment (±3° for femoral components, ±10° for tibial components). TKR within these limits were categorized as having “normal” axial alignment. TKR exceeding these limits were categorized as “outliers”.

Axial rotation during knee flexion was measured from fluoroscopic images (4±8 images/knee) acquired immediately after operative wound closure with the surgeon applying passive range of motion from full extension to approximately 120°. The three-dimensional positional and orientational data of the femoral and tibial bearing components was determined using surface models of the components projected onto the fluoroscopy images and previously published model-based shape matching techniques. Error due to image distortion and matching was 0.3° for rotations and 1.0 mm for translations in the image plane. Total axial rotation of the knee was defined as relative motion between the femoral component and metal tibial baseplate. Axial rotation of the femoral component on the polyethylene bearing (motion at the articular surface) and axial rotation of the bearing on the tibial baseplate (mobile bearing motion) were also distinguished.

Results: The range of external rotation during knee flexion was 4° to 6° for TKR in all groups (Table 1). However, approximately one-third of the TKR had axial alignment outside of defined tolerances for surgical axial alignment. Different trends in knee axial rotation were noted, depending on the axial alignment relative to anatomic landmarks and the combined axial mismatch of the femoral and tibial components.

Among TKR with normal axial alignment, external rotation steadily increased with knee flexion, with axial rotation motion distinguishable in two phases (Figs. 1-2). External rotation from 0° to approximately 80° occurred primarily due to axial rotation of the polyethylene bearing on the tibial baseplate. Beyond 80°, there was combined bearing motion and external rotation of the femoral component on the polyethylene articular surface, with the latter dominating the motion pattern.

This in-vivo study of subjects with mobile-bearing TKR assesses femoral and tibial component axial alignment and the magnitude of knee axial rotation that occurs during passive flexion. It was hypothesized that TKR with axial alignment within accepted surgical norms would present different kinematics and bearing motions compared to TKR with axial alignment outside surgical norms.

Three quantitative descriptors of transverse plane (axial) component alignment were measured (ID: PACS 3.6, Image Devices) from postoperative CT scans. Femoral component alignment relative to the transepicondylar axis and tibial component alignment relative to the medial third of the tibial tuberosity described axial alignment relative to anatomic landmarks. Angular divergence between the femoral and tibial components described combined relative axial mismatch. Based on these measurements, TKR were grouped according to defined tolerances for surgical axial alignment (±3° for femoral components, ±10° for tibial components). TKR within these limits were categorized as having “normal” axial alignment. TKR exceeding these limits were categorized as “outliers”.

Axial rotation during knee flexion was measured from fluoroscopic images (4±8 images/knee) acquired immediately after operative wound closure with the surgeon applying passive range of motion from full extension to approximately 120°. The three-dimensional positional and orientational data of the femoral and tibial bearing components was determined using surface models of the components projected onto the fluoroscopy images and previously published model-based shape matching techniques. Error due to image distortion and matching was 0.3° for rotations and 1.0 mm for translations in the image plane. Total axial rotation of the knee was defined as relative motion between the femoral component and metal tibial baseplate. Axial rotation of the femoral component on the polyethylene bearing (motion at the articular surface) and axial rotation of the bearing on the tibial baseplate (mobile bearing motion) were also distinguished.

Results: The range of external rotation during knee flexion was 4° to 6° for TKR in all groups (Table 1). However, approximately one-third of the TKR had axial alignment outside of defined tolerances for surgical axial alignment. Different trends in knee axial rotation were noted, depending on the axial alignment relative to anatomic landmarks and the combined axial mismatch of the femoral and tibial components.

Among TKR with normal axial alignment, external rotation steadily increased with knee flexion, with axial rotation motion distinguishable in two phases (Figs. 1-2). External rotation from 0° to approximately 80° occurred primarily due to axial rotation of the polyethylene bearing on the tibial baseplate. Beyond 80°, there was combined bearing motion and external rotation of the femoral component on the polyethylene articular surface, with the latter dominating the motion pattern.