NORMAL KNEE KINEMATICS AFTER UNICONDYULAR KNEE REPLACEMENT

INTRODUCTION:
Increasing numbers of patients are presenting at a younger age for knee replacement with unicompartmental disease. These patients are often more athletic and expect better function than the typical patient with tricompartmental disease.

Knee kinematics have been extensively studied in normal knees, knees with ligament deficiencies, and joints that have undergone knee arthroplasty. Almost all studies have shown that total knee arthroplasty significantly changes the kinematic profile of the knee. This can be attributed to several factors including differences between the geometry of the normal knee articular surface and the replacement prostheses, loss of the anterior and/or posterior cruciate ligaments, and altered neuromuscular patterns due to preexisting pathologies.

Theoretically, unicompartmental knee replacement offers great potential in restoring knee kinematics. Since only one compartment is diseased, the overall geometry of the knee is better preserved. In addition, current indications for a unicompartmental replacement necessitate the presence of an intact anterior cruciate ligament. Therefore the ligamentous stability and soft tissue balance of the joint can be restored more closely to normal. A recent study has suggested that knee kinematics after replacement with the Oxford unicompartmental design may be similar to those of normal knees. A carefully controlled evaluation of knee kinematics after unicompartmental knee replacement is therefore warranted.

METHODS:
Kinematics of six fresh-frozen knees from human cadavers were measured in closed kinetic chain knee extension on a custom knee rig (based on the Oxford knee rig design). Electromagnetic sensors (SPACE FASTRAK, Polhemus) were fixed rigidly to the femoral and tibial shafts. An electric motor applied dynamic quadriceps tension (recorded through a load cell). The quadriceps tension generated a peak knee flexion moment of approximately 40 N-m comparable with that reported in vivo during stair climbing after total knee arthroplasty. Each knee was tested before implantation with intact capsule and ligaments. Then the knee was implanted with the Preservation unicompartmental design (Depuy Johnson & Johnson, Warsaw, IN) and kinematics measured again. This study had low tibiofemoral conformity, a cobalt-chrome alloy femoral component, and an all polyethylene onlay tibial component. The anterior cruciate ligament was resected and kinematics were measured a third time. The unicompartmental components were removed and kinematics recorded after implantation with a posterior cruciate retaining tricompartmental design (Sigma PFC, Depuy Johnson & Johnson).

Statistical Analysis: Repeated measures multifactorial analysis of variance (ANOVA) was used to test for differences in femoral rollback, tibiofemoral rotation, and quadriceps tension between the following conditions (normal, unicompartmental arthroplasty with intact ACL; unicompartmental arthroplasty with resected ACL; and tricompartmental arthroplasty) at 10° incremented flexion angles between 0° and 120°.

RESULTS:
In the normal knee, knee flexion was accompanied by femoral rollback and tibial internal rotation. This ranged between 12 to 20 mm of femoral rollback and between 15° to 30° of tibial rotation. Since there was a marked variation between knees, conditions within individual specimens were graphically represented rather than means across all specimens. Fairly similar patterns of rollback and rotation were seen in the unicompartmental condition with little variation from the natural knee. No significant changes in knee kinematics were noted after resecting the ACL. However, significant differences in tibial rotation were noted after total knee arthroplasty (Fig 1). Femoral rollback and quadriceps tension did not change significantly between conditions.

DISCUSSION:
In this study, a current generation fixed-bearing unicompartmental design with low conformity was tested. The low tibiofemoral conformity allows for the sliding and axial rotation that normally occurs at the knee. This hypothesis was substantiated in this study by the fact that knee kinematics were largely unchanged between normal and unicompartmental conditions. The kinematic data suggests that this may in part explain the preservation of normal kinematics after a low conformity unicompartmental replacement. Kinematic behavior tends to vary from knee to knee which makes in vivo clinical comparison difficult because of the wide variations between patients. The cadaver model allowed for control of variation between knees since the kinematics were measured for different conditions in the same knee and could be treated as repeated measures. In the same cadaver knee, the soft tissues, ligament tension, extensor mechanism alignment, and bone lengths were maintained, thus removing variations due to differences in these parameters. In addition, differences in neuromuscular activation patterns that may be seen in vivo were also reduced, since the knee rig generated a similar extension loading profile for each condition.

Indications for unicompartmental knee replacement include unicompartmental disease (either medial or lateral), no significant patellofemoral arthritis, and an intact functioning anterior cruciate ligament. However, these findings have been based on trial and error and in observational cohort studies. No systematic analysis of the effect of the presence or absence of the anterior cruciate ligament has been done. This cadaver study permitted a careful comparison of the importance of the anterior cruciate ligament in maintaining normal knee kinematics and quadriceps forces. Surprisingly, resecting the anterior cruciate ligament after unicompartmental replacement did not change knee kinematics. This suggests that under the conditions tested, the role of the anterior cruciate ligament in anteroposterior stability and axial rotation is not as important provided the surface geometry is restored.

On the other hand, femoral rollback was not significantly affected by any of the conditions tested. This can be explained by the fact that the posterior cruciate ligament was preserved in all conditions. Quadriceps forces also did not change among different conditions. This was consistent with the finding of relatively unchanged femoral rollback. Rollback has been shown to affect the extensor moment arm and the magnitude of quadriceps forces. It may be that rollback in arthritic knees could be more variable after total knee arthroplasty as suggested by in vivo kinematic data.

The unicompartmental design offers exciting potential to enhance function after total knee arthroplasty. Restoration of knee function to normal may benefit patient rehabilitation, extensor function, implant survival, and wear. Evidence also exists to support the premise that unicompartmental disease does not spread to the other compartments after replacement with a unicompartmental knee design. In view of the advances in design, instrumentation, and materials, the unicompartmental design is rapidly maturing into a unique therapeutic approach to restore function in younger, more active patients with localized knee disease.

Figure 1: Tibial axial rotation