INTRODUCTION:
Achieving deep flexion after total knee arthroplasty (TKA) is an important goal for many patients all over the world. Previous in vivo fluoroscopic studies have revealed relationships between kinematics and clinical outcomes. For example, TKAs achieving greater posterior femoral translation exhibit greater knee flexion1 and it has been suggested that preservation of knee rotation is necessary to maximize flexion after TKA2.
Anterior cruciate ligament (ACL) deficiency diminishes knee stability and function and reduces patient satisfaction. ACL deficiency after TKA diminishes knee stability and function and causes femoral forward motion during knee flexion, which some call “paradoxical motion”, and is thought to be related to absence of the “feeling of a normal knee”. Bi-cruciate substituting TKA (BCS-TKA), which seeks to replicate some function of both anterior and posterior cruciate ligaments, incorporates both anterior and posterior post-cam mechanisms to reduce abnormal kinematics resulting from AP instability (Fig. 1). In addition, the BCS-TKA tibial articular geometry has a concave medial compartment and convex lateral compartment. These features are designed to guide backward motion with knee flexion in the lateral compartment with less backward motion in the medial compartment during flexion knee flexion.

The purpose of this study was to determine if the BCS-TKA design replicates the kinematics of the designers’ intent. Specifically, we wanted to determine if BCS-TKA restored anatomic posterior femoral translation and tibial internal rotation during weight-bearing knee flexion.

METHODS:
Twenty patients with twenty-five BCS-TKA (Journey™ BCS, Smith & Nephew, Memphis, TN) were available to participate and enrolled. This study was Institutional Review Board approved and all patients provided written informed consent to participate. All knees were diagnosed with osteoarthritis (OA) and all TKAs were performed by the same surgeon (WR) from September 2005 to July 2007. A mini mid-vastus surgical approach with posterior cruciate ligament (PCL) resection and patellar resurfacing were used in all cases. The average age of patients at surgery was 63 years old (range, 43-73). The study observations were performed 30±4 months after the operation.

Knee motions were recorded using video-fluoroscopy while subjects performed stair up and down, lunge activities. The lunge data were performed as previously reported to observe maximum knee flexion under partial or weight-bearing conditions4. The radiographs were digitized and analyzed using published techniques5. The three-dimensional position and orientation of the implant components were determined using model-based shape matching techniques, using nonlinear least-squares minimization to refine an initial manual solution. Three-dimensional angles between femoral and tibial components and anterior-posterior condylar locations at each posture were evaluated. The locations of medial and lateral condyles were estimated as the lowest point on each femoral condyle relative to the transverse plane of the metal tibial baseplate.

RESULTS:
All TKAs were well aligned and well functioning. Implant flexion angles during lunge were 128°±11° (range, 99°-143°). Twenty knees (80%) out of twenty-five achieved more than 120° flexion during weight-bearing activities.

During the stair up and down activity from 0° to 70° knee flexion, the tibia rotated from 2° to 10° internal rotation, with little additional rotation beyond 70° flexion (Fig. 2A). Tibial internal rotation averaged 10°±3° (range, 3° to 17°) during the maximally flexed lunge position. All TKAs exhibited tibial internal rotation during lunge. Tibial rotation did not increase significantly for flexion greater than 70°.

The medial condyle was located 4mm±3mm posterior to the tibial AP centerline with the knee extended, and moved posterior 1mm at 30° flexion. There was less than 1mm average medial condyle translation from 30° to 80° flexion, followed by an average of 1mm posterior translation from 80° to 100°. The lateral condyle was located an average of 8mm±4mm posterior to the tibial centerline with the knee extended, and moved a total of 4mm posterior in two phases from 0° to 10° and from 40° to 70° flexion (Fig. 2B). In maximal flexing activities, both medial and lateral condyles moved further posterior. The medial and the lateral condyles were located at 9mm±3mm and 19mm±4mm posterior to the tibial centerline during the kneeling activity.

The general pattern of tibiofemoral kinematics showed a medial pivot characteristic from 0° to 70° flexion and an almost symmetric posterior translation of the condyles from 70° to 128° flexion (Fig. 3).

DISCUSSION:
The BCS-TKA utilizes two femoral cams articulating on the anterior and posterior aspects of a tibial intercondylar post to substitute for the cruciate ligaments. The anterior post-cam articulation is designed to engage from extension to 20° flexion. The posterior post-cam mechanism is designed to engage in flexion beyond 60°, and has an asymmetric cam face that is designed to maintain an anterior directed force vector as the femur externally rotates with flexion. Catani et al. provided in vivo and computational observation showing the post-cam features were engaged over these flexion ranges6. In addition, the BCS-TKA incorporates asymmetric tibial and femoral components, with greater medial than lateral conformity, which are intended to promote a medial pivot kinematic pattern as observed in the healthy knee for deep knee bending activities. Our fluoroscopic knee kinematics data for these weight-bearing activities suggest the in vivo BCS-TKA function is generally consistent with the designers’ intent. These observations complement and generalize observations reported in previous studies.

REFERENCES: