INTRODUCTION
Constrained condylar knee (CCK) implants are widely used in revision total knee arthroplasty (TKA) and, in recent years, increasingly in primary TKA, especially in the presence of functional loss of the collateral ligaments or severe joint deformity. In 2007, of 3058 TKAs performed at Hospital for Special Surgery, 450 were CCK implants. Short- and medium-term results show low failure rates, but complications include increased polyethylene wear and aseptic loosening. Both these complications could be caused by the increased constraint provided between the large, rectangular tibial post and the intercondylar femoral box. Little is known, however, about the relative constraint provided by post-box contact, by collateral ligaments, and by contact between the bearing surfaces of the tibial and femoral components. Such information would provide objective measures from which to determine the need for a CCK implant, would establish the role of soft tissue balancing, and would suggest design improvements to minimize mechanical complications while maximizing constraint. Thus, we sought to determine how load is shared between post-box contact, the tibiofemoral bearing surfaces, and the surrounding soft tissues.

MATERIALS & METHODS
The load-displacement properties of eight cadaver knees pre- and post- CCK TKA (Zimmer Legacy, Warsaw, IN) were determined using a six degree of freedom (DOF) robot (Mitsubishi ZX165U) robot with 0.3 mm positional and 0.2° rotational accuracy) with a 6-DOF load cell mounted near the end of the robot arm (Fig. 1). Soft tissue balance was carefully performed during the surgery. Knees were loaded in their native intact state and after CCK-implantation from 0 Nm to a minimum of 10 Nm in varus and valgus (VV) at extension, 30°, and 90° of flexion with a 200N compressive load applied across the joint. The target loads and angles were based on clinical tests and loading data from the knee replacement literature for daily activities such as walking. The 10Nm was also a small enough load to protect the polyethylene tibial post from plastically deforming after contact with the femoral component. The motion for the knee specimens were calculated using a force feedback control algorithm, and the functional load across the joint measured by the load cell using custom software coded in Matlab.

Relative contributions of each stabilizing mechanism in the CCK were determined by repeating the previously recorded joint motion, while measuring the force and moment applied to the joint: with CCK intact, after removal of the tibial post and insert, and finally after reinserting the insert. Statistics were done using student t-test with p<0.05 for significance.

RESULTS
From the varus-valgus moment versus angular displacement curve, key parameters describing joint stability, such as range of motion (the angular displacement between the initial knee position and the varus-valgus angles corresponding to the applied moments) and joint stiffness (the local slope of the moment-angular displacement curve), were determined. Insertion of the CCK implant dramatically altered the load-angular deformation behavior of the knee; angular displacement decreased by the presence of the implant compared to the intact knee (Fig. 3). The angular displacements of the CCK TKA at all the flexion angles were significantly smaller than that of the native knee with 10 Nm applied varus-valgus moment (n=7, p<0.001). With the CCK, the bearing surfaces provided a considerable share of the resisting moment, primarily in the first half degree of varus-valgus motion before lift-off occurred on one plateau (as confirmed by the pressure sensor measurements). The tibial post provided additional constraint of ~30% of the total moment, but only after about a degree of angular displacement (Fig. 3). The percentile of load shared by tibial post increased as VV moment increased, and the load sharing on the bearing surface at 10 Nm target moment was significantly higher than that on the post (p<0.04). The ligaments provided little constraint within range of the 10Nm varus-valgus-moment (Fig. 4b).

DISCUSSION
As in the natural knee, the primary constraint in the coronal plane in a CCK knee arise from the shift in load between the contacting forces at the tibiofemoral bearing surfaces, though the amount of load sharing and the consequences on wear and fixation will depend on the particular design of the bearing surfaces. Contact between the femoral box and the tibial post adds some to the stability, especially when the constraint provided by the bearing surface had been saturated, a result both of the compliance of the polyethylene and the mechanical disadvantage of the central box-post geometry relative to the applied loads. The ligaments are a third mechanism, but add little to the stability in well balanced CCK TKA.

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