INTRODUCTION: Total knee arthroplasty (TKA) designs typically are divided into two groups: those that retain the posterior cruciate ligament (PCL) are known as cruciate-retaining (CR), and those that sacrifice the PCL and provide a post-cam substitute are called PCL-substituting (PS). In CR designs, the PCL is responsible for maintaining the femur posterior on the tibia in flexion, providing joint stability and enhancing knee flexion. However, when a CR device is employed but the PCL is incompetent or lost postoperatively, there is the potential for instability and loss of weight-bearing range of motion. Ideally, a robust CR-TKA design should still provide similar clinical and functional outcomes despite significant variation in the quality of the retained PCL. CR implants that employ relatively concave tibial articular surfaces may provide stability comparable to PS designs, but their flexion performance is not well studied.

In this study, we sacrificed the PCL in half of patients who received a CR-TKA. The implant incorporated a deep concavity on the lateral tibial plateau to stabilize the knee in extension, effectively acting as an anterior cruciate ligament (ACL) substitute. The goal of this study was to determine differences in knee kinematics in ACL-substituting arthroplasty with or without the PCL. We hypothesized that knees without the PCL would exhibit less femoral posterior translation and less maximum knee flexion.

METHODS: We studied prospectively 24 osteoarthritic knees receiving an ACL-substituting arthroplasty. The study was IRB approved and all subjects provided informed consent. The PCL was preserved in 12 knees (PCL+) and sacrificed in 12 knees (PCL−). There were no significant differences in pre-operative age (PCL+: 76±6, PCL−: 76±7), sex (PCL+: M/F=3/9, PCL−: M/F=2/10), range of motion (PCL+: 115±17°, PCL−: 117±24°), femoral-tibial angle (PCL+: 187±6°, PCL−: 183±9°) or Knee Society Score (KSS) (PCL+: 75±22, PCL−: 71±25) between the two groups. All subjects were studied at least one year after surgery.

Flat-panel radiographic images were acquired during dynamic deep squats, and in three static knee poses: full extension standing, lunging and kneeling at maximum flexion. The three-dimensional position and orientation of the implant components were determined using model-based shape matching techniques. The results of this shape-matching process have standard errors of approximately 0.5° to 1.0° for rotations and 0.5 to 1.0 mm for translations in the sagittal plane.

Unpaired t-tests and chi-squared tests were used to compare pre-operative demographic data. Analysis of variance (ANOVA) with post hoc test (Tukey) was used for kinematic comparisons. Probability (p) values less than 0.05 were considered significant.

RESULTS: Clinical results, including KSS (PCL+: 162±24, PCL−: 156±20), showed no significant differences between the two groups. However, the clinical range of motion was significantly greater in the PCL+ group (PCL+: 105±11°, PCL−: 117±12°, p<0.05).

In the squatting activity, the maximum skeletal flexion angle averaged 106±10° for knees with PCL and 113±13° for knees without PCL (p<0.05). Maximum skeletal flexion during lunging also was not significantly different (PCL+: 107±10°, PCL−: 113±13°). During kneeling, PCL− knees showed significantly greater skeletal flexion (PCL+:110±10°, PCL−:122±11°, p<0.05).

During squatting, PCL− knees showed a more anterior medial condylar position, but the same lateral condylar position compared to PCL+ knees (Fig. 1a,b). Directly related to these condylar translations, PCL+ knees showed a bias towards greater femoral external rotation (Fig. 1c). The same trends were observed during the kneeling and lunging activities: PCL+ knees showed more anterior medial condylar positions, while the lateral condylar position was similar to the PCL+ knees, resulting in greater femoral external rotation (Table 1).

DISCUSSION: We examined the kinematics of 24 patients with ACL substituting arthroplasty with or without the PCL. Consistent with our hypothesis, knees retaining the PCL showed more posterior medial condylar positions. However, there was no difference in knee flexion during squatting and lunging activities. Contrary to our hypothesis, knees without the PCL obtained better similar to the PCL+ knees. A more anterior medial condyle position resulted in greater femoral external rotation in the PCL+ knees. This study includes only a small number of unselected knees, and further study may strengthen these initial findings.

The main role of the PCL is to keep the femur posterior in flexion, and previous studies have shown positive correlations between femoral posterior translation and greater knee flexion angle. Hence, we expected PCL-sacrificed knees to show less flexion. Instead, we found no difference for squatting and lunging activities, and the PCL+ knees showed greater flexion during kneeling. Future studies might examine the relationship between joint gaps and laxity in flexion as a possible mechanism to explain our findings.

The implant used in this study had a deep lateral concavity and a relatively more shallow medial concavity on the tibial articular surface. The deep lateral concavity stabilized the lateral condyle in extension, and provided posterior lateral translations that were the same regardless of PCL status. The medial surface did play a role in stabilizing translations in the PCL− knees, where the medial condyle was seen to translate farther anterior on the concave medial tibial surface. It would appear that CR designs with comparable features can provide sufficient stability to obtain good results with or without the PCL, and in our specific case, comparable results with sacrifice of the PCL.

SIGNIFICANCE: Our results show it is possible to provide adequate stability to the PCL− knee without the use of a post/cam substitute in a suitably designed CR-TKA. These observations may be useful for future development of enhanced surgical procedures and implant designs.