THE IN-VIVO FUNCTION OF THE POSTERIOR CRUCIATE LIGAMENT BUNDLES DURING WEIGHT-BEARING FLEXION

Papanagari, R; DeFrate, L E; Nha, K W; Moses, J M; Moussa, M; Gill, T J; Li, G
+Bioengineering Laboratory, Massachusetts General Hospital and Harvard Medical School, Boston, MA
gill1@partners.org

INTRODUCTION
Double-bundle reconstruction of a ruptured posterior cruciate ligament (PCL) has increasingly attracted attention in sports medicine. However, the in-vivo biomechanics of the two functional bundles of the PCL are still not well understood. A thorough understanding of these functional bundles during in-vivo weightbearing knee flexion is critical to optimizing surgical treatments of PCL rupture. The objective of this study was to investigate the in-vivo function of the PCL bundles during weightbearing flexion of the knee using a combined dual-orthogonal fluoroscopy and magnetic resonance (MR) imaging technique.

METHODS
Seven knees from normal, healthy subjects were MR scanned. The MR images were used to create 3D models of the femur, tibia and PCL attachment sites (Fig 1). The lines connecting the centroids of the corresponding bundle attachment sites on the femur and tibia represented the anterolateral (AL) and posteromedial (PM) bundles of the PCL. Each knee was imaged using a dual-orthogonal fluoroscopic system while the subject performed a single leg lunge from 0° to 135° of flexion. The length and orientation of the functional bundles were measured as a function of flexion. The length of the PCL bundle was defined as the length of the line connecting the centroids of the tibial and femoral bundle attachment sites (Fig 1). The elevation was defined as the angle between the projection of the bundle on the sagittal plane and the AP axis of the tibia (Fig 2), and the deviation was defined as the angle between the projection of the bundle on the tibial plateau and the AP axis of the tibia (Fig 3). The relative rotation of the femoral and tibial attachment sites with respect to the long axis of the PCL was defined as the twist angle (Fig 4). A repeated measures ANOVA and the Student-Newman-Keuls post-hoc test were used to detect statistically significant differences in length and orientation as a function of flexion. Differences were considered statistically significant where p < 0.05.

RESULTS
The lengths of the AL and PM bundles increased with flexion from full extension to 120° of flexion (34.7±7.5 mm and 27.1±9.9 mm, respectively), and decreased beyond 120° of flexion (Fig 1). At full extension, the PM bundle had a higher elevation angle than the AL bundle (62.7±4.8° versus 53.8±5.1°) (Fig 2). However, the AL bundle had a higher elevation angle than the PM bundle beyond 30° of flexion and was almost perpendicular to the tibial plateau (85.6±4°) at maximal flexion. At full extension, the PM bundle had a larger deviation angle compared to that of the AL bundle (41.2±5.5°) (Fig 3). However, the AL bundle had a larger deviation angle than the PM bundle beyond 75° of flexion and reached maximum of 72.4±12.3° at maximal flexion. At full extension, the tibial attachment of the PCL was externally twisted by -21.6±11.2° relative to femoral attachment (Fig 4). The PCL twisted internally with increasing flexion and reached a maximum of 86.4±14.7° at 135° of flexion (p<0.05).

DISCUSSION
Both PCL bundles elongated maximally between 90 and 120° of flexion. These data suggest that there is no reciprocal function of the bundles with flexion, which is contrary to previous findings using cadaveric specimens. The elongation, elevation, deviation and twist patterns observed for AL and PM bundles suggest that at high flexion, the AL bundle might play an important role in constraining the mediolateral translation, while the PM bundle might play an important role in constraining the anteroposterior translation of the tibia. These data provide a better understanding of the biomechanical function of the PCL bundles and might help to improve the design of the two bundle reconstruction techniques of the ruptured PCL.

REFERENCES