IN-VIVO KINEMATICS OF THE ANTEROMEDIAL AND POSTEROLATERAL BUNDLES OF THE ANTERIOR CRUCIATE LIGAMENT DURING WEIGHT-BEARING FLEXION

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Introduction
Recent studies have suggested that ACL reconstruction does not prevent the long-term development of osteoarthritis1. As a result, there has been an interest in performing double-bundle ACL reconstruction in order to more closely restore the function of the bundles of the ACL. However, there is little data on the orientations of the functional bundles were measured as a function of flexion. Bundle length (L) was defined by the line connecting the tibial and femoral bundle attachments (Figure 1). Bundle length (L) was defined by the line connecting the tibial and femoral bundle attachments (Figure 1). The elevation angle of the bundles was minimal (<5°) at low flexion and increased significantly from 0° to 30°. No statistically significant differences in the deviation angle were observed. However, both bundles had similar deviation angles near full extension. (* p < 0.05)

Methods
MR images from seven healthy subjects were used to create 3D models of the knee. The attachments of the AM and PL bundles were outlined on each model. Next, the subjects performed a quasi-static lunge from full extension to 135° while being imaged using a dual orthogonal fluoroscopic system. The models and fluoroscopic images were used to reproduce the motion of the knee2. The length and orientation of the functional bundles were measured as a function of flexion. Bundle length (L) was defined by the line connecting the tibial and femoral bundle attachments (Figure 1). The elevation angle was defined as the angle between the bundle and the tibial plateau, projected onto the sagittal plane of the tibia (Figure 2). Deviation was the angle between the bundle and the mid-sagittal line, projected onto the tibial plateau (Figure 3). Twist was defined as rotation along the long axis of the ACL (Figure 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 AM and PL bundles were longest at low flexion angles (Figure 1). The elevation angle of the AM bundle decreased significantly from 0° to 120° of flexion, while the PM bundle elevation decreased significantly from 0° to 30°. No statistically significant differences in deviations were observed. However, the elevation and deviation angles of both bundles were similar at low flexion angles (<45°). The twist of the bundles was minimal (<5°) at low flexion and increased significantly with flexion between 60 and 120°.

Discussion
These data do not support the thought that the bundles of the ACL have a reciprocal function with flexion, as observed in early cadaver studies. Rather, both bundles had maximum elongation at low flexion angles. Therefore, both AM and PL grafts should be fixed at low flexion angles to prevent over-constraint. Furthermore, both bundles had similar deviation and elevation angles near full extension. As a result, two tibial tunnels might be needed to reproduce the parallel bundle orientation at low flexion angles. Anatomic reconstructions of the ACL should reproduce these bundle kinematics in order to restore the function of the intact ACL.

References

Figure 1. The length (L) of the AM and PL bundles were greatest near extension and shortened at high flexion. (* p < 0.05)

Figure 2. The elevation angle (α) of the AM bundle decreased significantly with flexion from 0° to 120°. The elevation angle of the PL bundle decreased significantly from 0° to 30°. Both bundles had similar elevation angles near extension. (* p < 0.05)

Figure 3. No statistically significant differences in the deviation angle (β) were observed. However, both bundles had similar deviation angles near extension. (* p < 0.05)

Figure 4. The twist of the bundles increased significantly between 60 and 120° of flexion. (* p < 0.05)