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Respective In-Situ Length Change of Two Functional Anterior Cruciate Ligament Bundles Under Various Knee Loading States

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Summary:
The geometry of the human ACL was quantitatively investigated under various knee angle and in situ loading. Both the AM and PL bundles shortened with increasing of knee flexion angle in all loading conditions, and the lengths of both bundles were longer than the unloaded condition at all flexion angles under ATT loading. Neither the AM nor PL bundle showed isometric behavior during the tested rang

Abstract:
INTRODUCTION
Precise knowledge of the length change pattern of antero medial (AM) and postero lateral (PL) bundles of ACL is crucial to achieving anatomical ACL reconstruction because the knee bending angle at the time of graft fixation during surgery certainly influences the kinematics of the reconstructed knees.
Therefore, the purpose of this study was to investigate the geometry of the human ACL quantitatively under in situ loading.

METHODS
Eight fresh frozen human knees (57.5±8.0 years) were used in this study. Initially, a six degrees-of-freedom robotic arm was utilized to record the normal tibio-femoral kinematic paths for three loading conditions: unloaded, anterior tibial translation load (ATT) and simulated pivot shifting load (PS). Once the kinematic paths were defined, the knee was carefully dissected to preserve only the ACL and its attachments. The specimens were then remounted into the robot and moved through the previously recorded kinematic pathways. High-resolution 3D digitizing scanner was used to acquire the point data of ACL insertion site boundaries at each state.

The length of the ACL was analyzed as the end-to-end distance between the centroids of each insertion site boundary using 3D software. Statistical analysis was performed using two-factor ANOVA. Significance was set at $p<0.05$.

RESULTS
The AM bundle of ACL was longest at 0 degrees with ATT load (31.7± 2.6mm) and shortest at 90 degrees unloaded (27.1± 3.1mm). The PL bundle of ACL was longest at 0 degrees with PS load (28.1± 2.4mm) and shortest at 90 degrees unloaded (20.1± 2.8mm). Under ATT loading, length of both bundles was longer (ANOVA: $p<0.001$) than the unloaded condition at all flexion angles.

The most important finding is the lengths of the AM under ATT loading at all flexion angles were elongated to similar length. In the extension position, length increased significantly relative to the unloaded position for both ATT (4.6± 2.3%) and PS (2.9 ± 2.3%) loading conditions for AM bundle, and ATT (4.3± 4.0%) and PS (5.6 ± 5.3%) for PL bundle.

DISCUSSION

Both the AM and PL bundles shortened with increasing of knee flexion angle in all loading conditions, and the lengths of both bundles were longer than the unloaded condition at all flexion angles under ATT loading. Neither the AM nor PL bundle showed isometric behavior during the tested range of knee flexion angles. This study revealed that the length of AM under ATT loading at all flexion angles shows no statistical difference, and this fact may indicate that the AM bundle of the ACL works equally against ATT load at all tested angles of the knee.

SIGNIFICANCE

By performing measurements accounting for effects of both load and knee flexion angle, this study addresses previously neglected factors for evaluating the true in situ geometry of the ACL. It should be taken into account while surgical planning that the length elongates averaged 4.6% for AM bundle and 4.3% for PL bundle according to ATT loading compared to the length at 0 degree neutral load.