ISAKOS

International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine

10th Biennial ISAKOS Congress • June 7-11, 2015 • Lyon, France

Paper #94

In Situ Analysis of Anterior Cruciate Ligament Shape and Morphology

Eric Thorhauer, BS, USA
Yoshimasa Fujimaki, MD, JAPAN
Ruben O'Hara-Plotnik, BS, USA
Freddie H. Fu, MD, USA
Scott Tashman, PhD, USA

University of Pittsburgh
Pittsburgh, PA, USA

Summary:
This study objectively quantified ACL in situ shape and dimensions using non-contacting, automated methods in multiple physiological loading configurations. Cross-sections shapes were predominately elliptical and the idea of the ACL being a "ribbon" was rejected.

Abstract:

INTRODUCTION

The shape of the anterior cruciate ligament (ACL) is a debated topic, having been described as a series of bundles, a band, or a thin ribbon. Previous cadaveric studies have destructively assessed ACL morphology by excising the ligament after freezing it or embedding it in paraffin. Observing the ACL once removed from the joint or in non-physiologic positions simplifies measurements, but cannot mimic the natural behavior of the knee/ligament, especially in terms of shape and fiber orientation. Previous descriptions of ligament shape have been qualitative and highly subjective. The purpose of this study was to objectively quantify how ACL morphology and shape change as a function of applied load and flexion angle.

METHODS

Nine fresh-frozen human knee specimens (all male, 47-68 yrs.) with no signs of degeneration were carefully dissected using loupes without disrupting the ACL and its tibiofemoral attachments. Knees were mounted in a robotic simulator and placed in a physiological range of flexion angles with and without applied anterior load. At each position, high-resolution 3D laser scanning of the entire ACL was performed.

Custom software cut cross-sections from the ACL laser scan models, calculating ligament cross-sectional area (CSA), width and thickness, and aspect ratios (width/thickness). An automated, objective algorithm classified ACL cross sectional shapes as 1) Triangular, 2) Bean or C-shape, 3) Elliptical. Differences in morphological variables in response to flexion and load were assessed using a repeated-measures ANOVA model (knee position * ACL slice location), with a=0.05.

RESULTS

ACL cross-sectional area was minimum at 45-55% of the distance between insertions and increased towards both femoral and tibial insertions. The ACL width decreased and thickness increased from the femoral to tibial insertion. Anterior loading caused the ACL to become thinner and wider (p=0.01). ACL aspect ratio ranged between 1.4-2.8 and decreased closer to the tibial insertion site. Anterior load caused an average 0.31 increase in aspect ratio (p=0.04). Increasing flexion angle decreased the aspect ratio for the unloaded (p=0.038) and anterior load (p=0.04) conditions. The most common shape was elliptical, occurring in 48% of cross sections in the unloaded condition. ACL shape became more elliptical (increased to 67%) with applied anterior load. Bean/c-shapes occurred most often near the femoral insertion site (34% of unloaded and 26% of loaded ACL cross sections). Triangle shapes were detected in 18% of cross sections when unloaded and 7% under anterior load, and were concentrated near the tibial insertions.

Paper #94

DISCUSSION

These data support the description of the ACL as a “trumpet” shape. The increasing aspect ratio with extension and applied load fit with the model of the ligament being an uncompressible, viscoelastic material. The maximum aspect ratios observed were not large enough to support the idea that the ACL is a “ribbon”. The 1.5-2 times increase in CSA between the midsubstance (50% region) and insertion sites highlights the necessity of accounting for femoral notch size (rather than relying only on insertion site size) to choose graft diameter.