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Is the Load Carried from the ACL Mid-Substance Fibers During Anterior Tibial Translation Transmitted to the Posterior Fan-Like Extension Fibers on the Femoral Attachment?

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Summary:
This first study on biomechanics of the ACL attachment fibers demonstrated that in the wide ACL attachment, 66 to 84% of the resistance to tibial anterior drawer force arose from the fibers of the ACL which attached to the mid-substance area of the femoral attachment close to the roof of the intercondylar notch, and the fan-like extension fibers contributed very little.

Abstract:
INTRODUCTION
In “anatomic” single- and double-bundle ACL reconstruction procedures, there has been a controversy concerning the femoral tunnel positions. Namely, some surgeons have created femoral tunnels in the mid-substance (MS) fiber attachment, while others have created them in the attachment of the fan-like extension (FLE) fibers, which broadly spread out on the posterior condyle. The controversy is caused by deficit of our biomechanical knowledge on load transmission from the MS fibers to the femoral attachment. Recently, the authors reported that a deep fold is formed between the MS and FLE fibers in the femoral attachment, when the knee is flexed (KSSTA 2013). Therefore, there is a high possibility that the load carried from the MS fibers is not transmitted to the posterior FLE fibers on the femoral attachment. The purpose of this biomechanical study is to clarify how the load carried by the MS fibers during anterior tibial translation is distributed to the MS and FLE fiber attachments.

METHODS
A sequential cutting study was conducted using a robotic testing system with a 6-axis force/torque sensor. Eight fresh-frozen cadaveric knees were used. In each knee, the medial femoral condyle was separated using a reciprocating saw. Then, we drew 4 lines parallel to the long axis of the MS fiber attachment and 5 lines parallel to the Blumensaat’s line so that the whole femoral attachment of the ACL was divided into 12 partitions: 4 posterior (A-D), 4 central (E-H), and 4 anterior (I-L). Then, the separated femoral condyle was anatomically relocated and firmly secured. We applied 6-mm anterior translation of the tibia to the femur at 0, 30, 60, and 90 degrees of knee flexion. First, the intact knee was tested, and then the femoral attachment fibers were sequentially cut from the bone in the order from A to L. The data were analyzed by using the one-way ANOVA with the Tukey-Kramer post-hoc test. The significance level was set at $P<0.05$.

RESULTS
The posterior FLE attachment fibers carried only 11-15% of the load in anterior drawer at each angle of knee flexion, while the central MS fiber attachment carried 82-90% of the load. In these areas, 66-84% of the load was transmitted to the areas G and H, which corresponded to part of the anteromedial (AM) bundle, and 9-16% load to the areas E

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and F, which corresponded to part of the posterolateral (PL) bundle. The anterior fan-like extension area contributed only 2-3%.

DISCUSSION

This is the first study on biomechanics of the femoral attachment of the ACL fibers. This study demonstrated that most of the load carried from the MS fibers of the ACL, in which the load was distributed to the AM and PL bundles in different ratios as reported previously, was not transmitted to the FLE fiber attachment, but to the central MS fiber attachment. The aim of “anatomic” double- and single-bundle reconstructions is to reproduce the mechanical function of the native ACL. Therefore, in these procedures, we should not create femoral tunnels in the FLE fiber attachment, but in the MS fiber attachment.