The Impact of Anteromedial and Posterolateral Bundle Graft Fixation Angles in Double-Bundle Anterior Cruciate Ligament Reconstructions

INTRODUCTION
Despite the recent popularity of double-bundle anterior cruciate ligament (ACL) reconstructions, the impact of knee flexion angles used for fixation of the anteromedial (AM) and posterolateral (PL) bundle grafts on knee kinematics has not been conclusively evaluated. Furthermore, no consensus exists for an optimal set of AM and PL graft fixation angles [1]. Our purpose for this study was to biomechanically test the effects of varying knee flexion angles during fixation of the AM and PL grafts on the kinematics of the knee. Our hypothesis was that graft fixation angles which resemble the peak tensions of the native AM and PL bundles of the ACL would produce kinematic results most similar to the intact knee, while graft fixation angles outside this range would over- or under-constraining the knee.

METHODS
Twelve non-paired, fresh-frozen human cadaveric knees with no evidence of prior injury or disease with a mean age of 50.9 years (range, 29-66) were used for this study. For preparation of each specimen, adequate amounts of soft tissues were removed, a threaded fiberglass rod was secured in the intermedullary canal of the tibia for the application of test forces, and the femur was potted in polymethylmethacrylate to allow secure fixation of the specimen in a previously described custom testing apparatus [2]. The knees were tested in the intact state, in the sectioned state, and in the reconstructed state at a randomized order of seven predetermined graft fixation angle combinations of (AM graft fixation angle/PL graft fixation angle) 0°/0°, 60°/0°, 45°/15°, 75°/15°, 30°/30°, 60°/60°, and 90°/90°. For each testing state, six-degree-of-freedom positional data were collected for 88 N anterior tibial loads, 10 Nm valgus torques, 5 Nm internal rotation torques, and two separate simulated pivot-shifts consisting of a 5 Nm internal rotation torque combined with either a 10 Nm valgus torque or an 88 N anterior tibial load at 0°, 20°, 30°, 60°, and 90° of knee flexion.

All double-bundle ACL reconstructions were performed by the same board-certified orthopaedic surgeon. Seven-millimeter tunnels were reamed at the anatomic footprints of each bundle immediately following resection. The distal end of each graft was whip-stitched to a custom fabricated metal fixation tab, allowing multiple fixations without causing damage to the grafts. For each fixation angle combination, the PL graft was fixed before the AM graft for consistency. Each graft was tensioned to 20 N, a posterior tibial force was applied, and a 3.5 mm cortical screw was used to secure the tab and graft to the tibia.

Two-way analysis of variance was performed to compare each of the graft fixation states to the intact and sectioned states following a square root transform for data distribution normalization. Tukey’s honest significant difference test was used for post hoc comparisons. A difference was determined to be statistically significant for P < 0.05.

RESULTS
In response to the 88 N anterior tibial loads, all graft fixation states reproduced normal anterior tibial translation (ATT).

In response to the 10 Nm valgus torques, the 60°/60° fixation state caused significant reductions in valgus angulation compared to the intact state at 60° (P < 0.05) and 90° (P < 0.05) of knee flexion.

In response to the 5 Nm internal rotational torques, significant reductions in internal tibial rotation (ITR) compared to the intact state were found at 0° of knee flexion from the 30°/30° (P < 0.05), 60°/60° (P < 0.0005), and 90°/90° (P < 0.0001) fixation states, at 20° of knee flexion from the 60°/60° (P < 0.05) and 90°/90° (P < 0.005) fixation states, and at 30° of knee flexion from the 60°/60° (P < 0.05), and 90°/90° (P < 0.005) fixation states, and at 30° of knee flexion from the 60°/60° (P < 0.05), and 90°/90° (P < 0.005) states (Figure 2).

DISCUSSION
In this study, the kinematic impacts of seven different combinations of graft fixation angles in double-bundle ACL reconstructions were evaluated biomechanically. The results demonstrated that under various loading conditions, the AM and PL graft fixation angle combinations of 30°/30°, 60°/60°, and 90°/90° over-constrained the knee while the 0°/0°, 60°/60°, 45°/15°, and 75°/15° fixation angle combinations restored normal knee laxity without constraining the knee. These results indicate that as long as the PL graft is fixed in the range of 0° to 15°, the AM graft can be fixed up to 75° without restricting normal knee laxity. However, fixation of the PL graft at 30° of knee flexion and above over-constrains the knee and may predispose the graft to failure.

REFERENCES

ACKNOWLEDGEMENTS
Funding provided by Health South-East (Norway) Grant #2009064

Figure 1. Internal tibial rotation during 5 Nm internal rotation torque. Significant differences noted with an * (P < 0.05)

Figure 2. Anterior tibial translation during 5 Nm internal rotation and 10 Nm valgus pivot shift. Significant differences noted with an * (P < 0.05)