Contributions of the Posterolateral Bundle of the Anterior Cruciate Ligament to Anterior-Posterior Knee Laxity and Ligament Forces

Keith L. Markolf, Ph.D., Samuel Park, M.D., Steven R. Jackson, and David R. McAllister, M.D.

Purpose: The purpose of this study was to measure changes in anterior-posterior (AP) laxity and graft forces after cutting the posterolateral (PL) bundle of the anterior cruciate ligament (ACL). **Methods:** Twelve fresh-frozen cadaveric knees underwent AP laxity testing at ± 100 N of applied tibial force. Resultant forces in the ACL were recorded during passive extension from 120° to 0° with no tibial force, 100 N of anterior tibial force, 100 N of quadriceps force, and 5 Nm of internal tibial torque. The femoral origin of the PL bundle was identified, the ligament fibers were dissected from bone, and tests were repeated. **Results:** Cutting the PL bundle significantly increased mean laxity by +1.3 mm (at 0°), +1.1 mm (at 10°), and +0.5 mm (at 30°). For the passive knee extension tests, cutting the PL bundle significantly decreased mean ACL force at 0° for all loading modes; the mean decreases were 31 N (with no tibial force), 50 N (with 100 N of anterior force), 33 N (with 100 N of quadriceps force), and 40 N (with 5 Nm of internal torque). **Conclusions:** The decreases in ACL force at 0° from cutting the PL bundle are consistent with the commonly accepted view that the PL bundle tightens with knee extension. Cutting the taut PL bundle did significantly increase AP laxity between 0° and 30°, but the increases were relatively small. Therefore we conclude that the PL bundle plays a relatively minor role in controlling anterior tibial translation. **Clinical Relevance:** In view of our findings, the need to reconstruct the PL bundle for better restoration of a normal AP laxity profile is questioned. **Key Words:** Anterior cruciate ligament—Knee biomechanics—Posterolateral bundle—Double-bundle anterior cruciate ligament.

It is generally accepted that there are 2 functioning bundles of the anterior cruciate ligament (ACL). The anteromedial (AM) bundle tightens with knee flexion, and the posterolateral (PL) bundle becomes tight as the knee is extended.[1,2] Recently, some surgeons have advocated a double-bundle ACL reconstruction in an attempt to better replicate native ligament anatomy and restore intact knee stability.[3-11] However, the contributions of the native PL bundle to AP laxity and to forces developed in the native ACL have received limited study.[12,13] Knowledge of forces in the PL bundle of the ACL and its influence on AP laxity is necessary to understand the biomechanical requirements for a PL graft substitute and to provide guidance on possible tensioning protocols for the PL graft of a double-bundle reconstruction. The purpose of this study was to measure changes in anterior-posterior (AP) laxity and graft forces after cutting of the PL bundle of the ACL.

METHODS

Twelve fresh-frozen cadaveric knee specimens were used. The mean age was 36.6 years (SD, 9.6

From the Biomechanics Research Section, Department of Orthopaedic Surgery, David Geffen School of Medicine at UCLA, Los Angeles, California, U.S.A.

Supported a grant from NFL Charities. Graft tissues used in this study were provided by the Musculoskeletal Transplant Foundation. The authors report no conflict of interest.

Received November 29, 2007; accepted February 17, 2008.

Address correspondence and reprint requests to Keith L. Markolf, Ph.D., UCLA Department of Orthopaedic Surgery, Biomechanics Research Section, Room 21-67 UCLA Rehabilitation Center, 1000 Veteran Ave, Box 951759, Los Angeles, CA 90095-1759, U.S.A. E-mail: kmarkolf@mednet.ucla.edu

0749-8063/08/2407-7600$34.00/0

doi:10.1016/j.arthro.2008.02.012

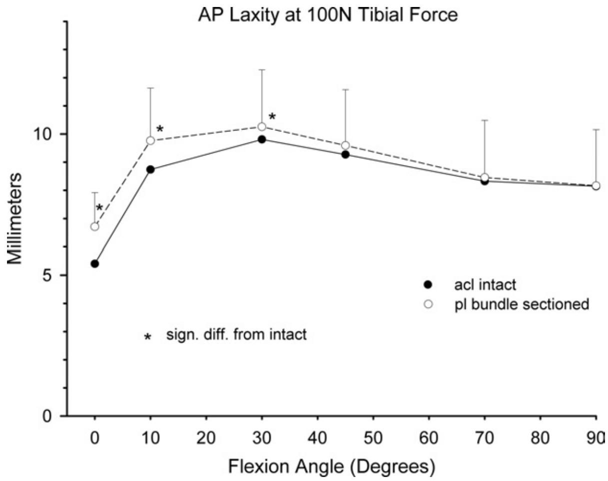

FIGURE 1. AP laxity at ± 100 N of tibial force before and after cutting of PL bundle of ACL. Mean values are shown (with 1-SD error bars). Mean values that are significantly different (sign diff) ($P < .05$) from the intact condition are indicated by asterisks.

years; range, 17 to 46 years); all were male. The ACL's tibial insertion was mechanically isolated by use of a cylindrical coring cutter. The cap of bone containing the entire ligament footprint was incorporated into a cast cylindrical construct of polymethyl methacrylate acrylic, which contained a threaded metal core for attachment to a load cell that recorded resultant force in the ligament. When fixed to the tip of the load cell, the bone cap remained in its precise anatomic position.[14] Resultant force in the native ACL was recorded as the knee was passively extended from 120° to 0° flexion with (1) no tibial force, (2) 100 N of anterior tibial force, (3) 100 N of quadriceps force, and (4) 5 Nm of internal tibial torque. Internal-external tibial rotation and varus-valgus rotation were unconstrained during the passive knee extension tests.

AP laxity testing at ± 100 N of applied tibial force was performed with the intact ACL at 0°, 10°, 30°, 45°, 70°, and 90° of flexion. At each flexion angle, the tibia was locked at its midrange of internal-external tibial rotation during AP testing. This was done to simulate the straight clinical AP drawer test, where the tibia is firmly grasped to prevent tibial rotation during application of AP force. The specific details of our bone cap isolation technique, test apparatus, and testing protocols have been described in detail in previous publications.[14-17]

The knee was flexed to 90°, and an anterior force was applied manually to the tibia. Origins of the slackened PL fiber bundle on the lateral wall of the femoral notch were identified and cut at their femoral footprint attachment sites. Graft force measurements during passive knee extension and AP laxity measurements were then repeated. A 1-way repeated-measures analysis of variance was used to determine the statistical significance of mean laxity differences. A 2-way repeated-measures analysis of variance, with pairwise comparisons, was used to compare graft forces before and after cutting of the PL bundle. The level of significance for both analyses was $P < .05$.

RESULTS

Cutting the PL bundle produced small but statistically significant increases in laxity between 0° and 30° of flexion (Fig 1); mean laxity increases were 1.3 mm (0°), 1.1 mm (10°), and 0.5 mm (30°). There were no significant increases in mean laxity at 45°, 70°, and 90° (Fig 1).

During passive knee extension with no applied tibial force, cutting the PL bundle significantly decreased mean ACL force at flexion angles of less than 10° (Fig 2); the mean decrease at 0° was 31 N. With 100 N of anterior tibial force, cutting the PL bundle significantly decreased mean ACL force at flexion angles of less than 25°; the mean decrease at 0° was 50 N (Fig 2).

Cutting the PL bundle significantly decreased mean ACL force by 33 N at 0° with 100 N of quadriceps force (Fig 3).

With 5 Nm of internal tibial torque, cutting the PL bundle significantly decreased mean ACL force by 40

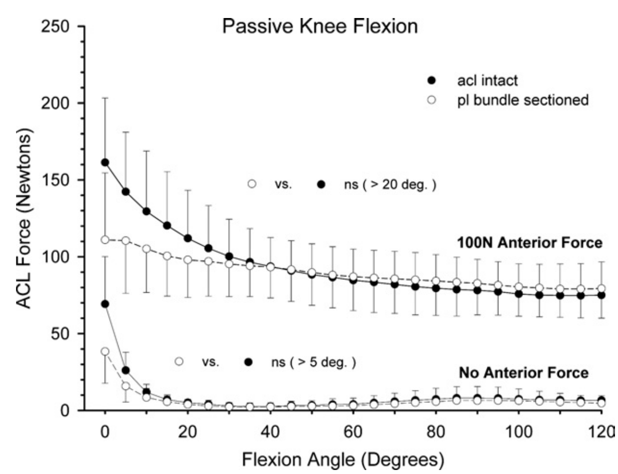

FIGURE 2. Mean curves of ACL force versus knee flexion angle for passive knee flexion with no applied tibial force and 100 N of anterior tibial force. Mean curves are shown for the intact knee and after cutting of the PL bundle of the ACL. All comparisons between graph symbols at a given flexion angle are significantly different ($P < .05$) unless otherwise indicated (not significant [ns]).