Appendix

Specimen Preparation

The tibia and the femur were sectioned mid-shaft and scraped clean of soft tissue to within 10 cm of the joint line. The bone ends were potted in cylindrical molds of polymethylmethacrylate acrylic cement for gripping in the test fixtures. The skin and all soft tissues surrounding the knee capsule were left intact to help prevent dehydration of ligamentous tissues. The 3 to 4-cm medial parapatellar arthrotomy incision (used for insertion of the drilling guide and visualization) was closed with sutures, and a wet towel soaked in saline solution was wrapped around the knee during testing.

After the tibia and femur were potted, the femur was clamped with its shaft parallel to the floor and the patella facing down. A weight was suspended from the tibia to produce a 2.5-N-m extension moment. The angle between the tibia and femur was defined as 0° of flexion (full extension).

A bone plug containing the tibial insertion of the anterior cruciate ligament was isolated with use of a tibial coring cutter. Prior to complete mechanical isolation of the bone cap containing the tibial insertion fibers of the anterior cruciate ligament, six miniature wood screws were fixed to its undersurface. The porous cancellous bone and protruding screw heads were incorporated into an acrylic cylinder containing a steel core. This core was connected by an attachment screw to the shaft of a custom-designed miniature load cell. The base of the load cell was attached by a hex-head bolt to a mounting plate, which in turn was incorporated into a large acrylic mass surrounding screws fixed into the tibial shaft. After final mechanical isolation of the bone cap, all ligament force passed through the load cell, which measured the three components of anterior cruciate ligament force as external loads were applied to the tibia. The tibial base of the ligament always remained in its precise anatomic location.

Constant Tibial Loading Tests

The potted femur (shown in Figure E-1) was attached to a fixture that allowed manual flexion and extension of the knee. Flexion angle was recorded by a rotary potentiometer mounted to the flexion-extension shaft. The distal end of the tibia was supported by a roller-bearing mounted to an extension shaft attached to the distal end of the tibial acrylic. This kept the tibia level as the femur was moved throughout a 120° range of motion (Fig. E-1). In this configuration, tibial rotation was unconstrained and free varus-valgus angulation of the tibia was allowed in the horizontal plane. Care was taken to mount the femur on the femoral fixture such that when the knee was moved through a range of motion, the tibia had minimal varus-valgus angulation and minimal tendency to "piston" in the proximal-distal direction.

For flexion tests with applied internal tibial torque, a weight was suspended from a long bar clamped in a horizontal position on the tibial extension shaft (Fig. E-1). Tibial rotation was recorded by the shaft of a rotary potentiometer connected to the end of the tibial extension shaft; the potentiometer housing was mounted on a roller assembly that followed any varus-valgus angulation of the tibia. Varus-valgus rotation was also recorded by a potentiometer connected to a four-bar linkage. For flexion tests with anterior tibial force, a loop of line was passed around the tibia near the joint line and a 100-N weight was suspended at this point, producing a constant anterior force to the tibia.

Each test began with the femur flexed to 120° (tibia level); a bar holding the femoral fixture was manually extended at approximately 20° per second until approximately 2° of knee hyperextension was obtained. Anterior cruciate ligament resultant force was plotted continuously versus knee flexion angle in real time on a video monitor as the knee was extended.

Graft Isometry Testing

Isometry testing with all single and double-bundle grafts was performed in the tibial loading apparatus. The tibial bone block of the graft was cemented into an acrylic cap replica attached to the end of the tibial load cell. A low-stretch synthetic line, whip-stitched into the free end of the graft, passed through a femoral split-clamp. The knee was extended to 0°, and a forceps clamp was attached to the cable at a fixed (reference) distance from the femoral split-clamp. The knee was then flexed to 90° at set increments. At each flexion angle, the distance between the forceps and the split-clamp was recorded with a dial caliper. During each measurement, the tibia was carefully placed at the midpoint of internal-external tibial rotation with tibiofemoral contact at both condyles. Changes in the distance between the forceps and split-clamp as the knee was flexed from 0° indicated relative length changes of the graft. Relative length measurements were recorded three times for each graft, and means were calculated at each flexion angle.

Anterior-Posterior Force Versus Displacement Test

For the anterior-posterior test, the knee was mounted in the fixture described above with one important change; the end of the tibial extension shaft passed through a spherical rod-end bearing, which acted as a pivot about which the proximal end of the tibia could angulate in the sagittal plane (Fig. E-2). The horizontal undercarriage bar attached to the large bearing housing held a roller-bearing, which contacted a vertical plate; this constrained anterior-posterior tibial motion to the vertical plane during the test. A spring-loaded plunger connected to the core of an LVDT (linear variable differential transformer) contacted a small plate mounted to the undercarriage bar at the knee joint line. Since the large tibial bearing was securely locked to the tibia during these tests, linear displacement of the undercarriage bar at this point was taken to represent motion of the tibia at the joint line. Anterior-posterior tibial force (to 100 N) was applied manually to the undercarriage bar by an instrumented force handle attached 3 in (7.6 cm) proximal to the joint line (Fig. E-2). The tibia was locked to a position of neutral rotation during anteroposterior displacement of the tibia; neutral rotation at each flexion angle tested was defined as midway between the tibial rotations produced by 5.0 N-m of internal and external tibial torque. After three preconditioning anteroposterior cycles (0 to 100 N), the fourth cycle was recorded.

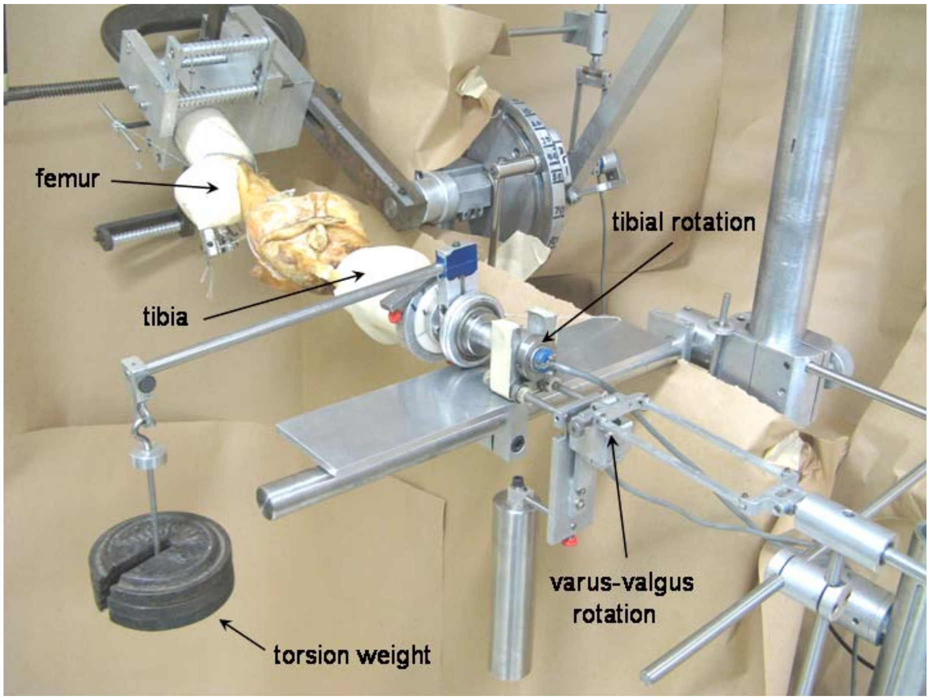

Fig. E-1
Testing apparatus for the constant tibial loading tests.

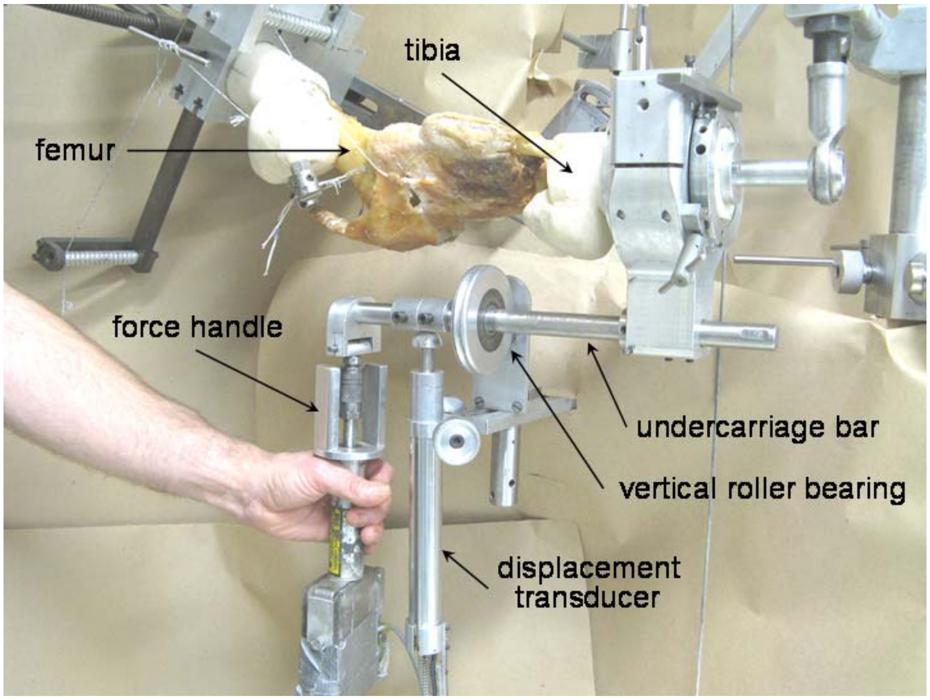

Fig. E-2
Testing apparatus for the anteroposterior force versus displacement test.