Equal Kinematics Between Central Anatomic Single-Bundle and Double-Bundle Anterior Cruciate Ligament Reconstructions

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Purpose: The purpose of this study was to compare the kinematics of a central anatomic single-bundle anterior cruciate ligament (ACL) reconstruction with a double-bundle ACL reconstruction by use of hamstring grafts and anatomic tunnel placement. **Methods:** Anterior tibial translation and rotation were measured with a computer navigation system in 8 pairs of fresh-frozen cadaveric knees by use of a 133-N anterior force, an internal and external torque of 10 Nm, and an anterior force (133 N) combined with an internal rotation torque (10 Nm). Tests were performed at 30° and 60° of flexion with the ACL intact, the ACL transected, and after reconstruction of one side of a pair with either a single or a double-bundle construct. **Results:** At 30° of flexion, cutting the ACL increased anterior translation under an anterior force ($P < .0001$), an internal rotation torque ($P = .02$), and a combined anterior force plus internal rotation torque ($P = .01$). At 60° of flexion, transecting the ACL led to increased anterior translation only when an anterior force was used ($P < .0001$). Both single- and double-bundle reconstructions restored normal kinematics at 30° and 60° of knee flexion. **Conclusions:** Central anatomic single-bundle ACL reconstruction with tunnels centered within the tibial and femoral insertions and double-bundle ACL reconstruction can restore normal anterior translation to the knee under anterior and rotational loads applied at 30° and 60° of flexion. **Clinical Relevance:** The primary kinematic effect of an ACL injury is an increase in anterior tibial translation, but there is no significant change in maximum internal or external rotation. Single- and double-bundle ACL reconstructions are equally effective in restoring normal anterior translation to the knee under both anterior and rotational loads. **Key Words:** Anterior cruciate ligament—Biomechanical—Double bundle—Computer navigation—Cadaveric.

The native anterior cruciate ligament (ACL) is composed of 2 distinct bundles, the anteromedial (AM) bundle and the posterolateral (PL) bundle.[1] Endoscopic reconstructive surgery of the ACL concentrates on restoration of the AM bundle only while giving little regard to the PL bundle. Although this single-bundle technique has yielded good to excellent results in most cases, a failure rate of 11% to 30% has been reported, where patients have continued knee pain and instability regardless of the type of graft and fixation method.[2,3] Some authors hypothesize that reconstructing both the AM and PL bundles of the ACL (double-bundle reconstruction) can improve knee kinematics in comparison to the single-bundle tech-

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Supported by a grant from the New England Baptist Hospital Research Funding Award Program.
The authors report no conflict of interest.
Received June 13, 2008; accepted February 16, 2009.
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0749-8063/09/2505-8333$36.00/0
doi:10.1016/j.arthro.2009.02.013

nique.[4,5] Clinical outcomes between the 2 reconstruction methods have been controversial. Whereas some studies have shown better results with the double-bundle technique,[6,7] others have shown similar results.[8]

Some biomechanical models have shown that double-bundle ACL reconstructions restore normal anterior translation under anterior and rotational loads more effectively than single-bundle constructs.[9-11] Although these studies showed improved restoration of normal knee kinematics with a double-bundle technique, they used only 1 tibial tunnel for the double-bundle procedures, which is not the standard clinical practice. Moreover, these comparative studies used a single-bundle construct where the tibial tunnel was placed abnormally posterior on the tibia or in a position not well described or controlled. None of the comparative studies placed single-bundle constructs in the center of the anatomic ACL footprints.

The purpose of this study was to compare knee kinematics between a double-bundle reconstructive technique that used 2 femoral and 2 tibial tunnels and a central anatomic single-bundle construct where the tibial and femoral tunnels were well placed within their respective ACL footprints. Our hypothesis was that there would be no kinematic differences between the 2 reconstructive techniques.

METHODS

Specimen Preparation

Eight matched pairs of fresh-frozen cadaveric knees were thawed at room temperature for 24 hours. The knee specimens were from 4 women and 4 men, with a mean age (± standard deviation) of 68.8 ± 10.1 years (range, 51 to 83 years) and a mean weight of 66.0 ± 7.0 kg (range, 54.4 to 76.2 kg). The femur, tibia, and fibula were cut a minimum of 25 cm from the joint line. The gracilis and semitendinosus tendons were harvested from each knee and wrapped in saline solution–soaked gauze. The grafts were prepared for insertion by folding them in their midsection and placing whip-stitched sutures in each tendon end (No. 2 Ethibond; Ethicon, Somerville, NJ). Grafts were sized by passing them through sizing tubes. The knees were dissected free of soft tissues except for the capsule, collateral ligaments, cruciate ligaments, and extensor mechanism. All knees showed no evidence of previous injury, surgery, or significant arthritis by history and gross examination.

Testing System

An image-guided surgical navigation system (VectorVision; BrainLAB, Munich, Germany) was used to measure femoral and tibial motions. The system measured knee flexion, anterior-posterior translation, and internal-external rotation. It has a reported accuracy of 0.5 mm for translation measurements and 0.5° for rotational motions.[12]

Femoral and tibial reference arrays containing 3 infrared reflective spheres were attached to the femur and tibia, with two 3-mm-diameter threaded pins used for each array. Each array was placed approximately 15 mm from the joint line and away from the region used for the ACL reconstruction.

A fluoroscopic registration disk was attached to the image intensifier of a C-arm fluoroscope (Ziehm 7000; Ziehm, Riverside, CA) (Fig 1). This registration disk had infrared reflective markers around its perimeter and placed a grid of tungsten markers (approximately 75) on acquired fluoroscopic images. The camera arm of the navigation system was placed approximately 8 ft lateral to the C-arm and was directed to image the reflective markers on the knee and the reflective markers on the registration disk. Anterior-posterior and lateral fluoroscopic images of the knee were acquired to obtain true anatomic images of the knee. The second step of the registration process was to scroll a pointer with 3 infrared reflective markers over multiple points on the intercondylar notch, the tibial plateau, and the ACL insertion sites on both the femur and tibia. The navigation system thereby acquired coordinates for the anatomy relevant to the ACL.

The femur was clamped to an adjustable vertical strut of a knee laboratory workstation with clamps placed 15 to 25 cm proximal to the joint line (Fig 2). The vertical strut could be adjusted to change the knee flexion angle. A fluted rod was inserted into the distal 10 cm of the tibia and bonded in place with acrylic resin. The fluted rod extended through the ring of a traction bow, which was secured to the rim of the workstation. The ring secured the tibial shaft to prevent flexion and extension, but it did not constrain internal-external rotation of the tibia. Internal-external torques were applied to the tibia by the fluted rod.

Anterior tibial force was applied manually with a 40-lb spring gauge force applicator (Taylor Precision Instruments, Oak Brook, IL), which was attached with a large hook through the patellar tendon. A short vertical incision in the patellar tendon just distal to the patella provided a point of attachment for the hook. The anterior force of 133 N was applied manually in