Review article:
Anatomic double bundle anterior cruciate ligament reconstruction

W Shen, S Jordan, F Fu
Department of Orthopaedic Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania, USA

ABSTRACT
The anterior cruciate ligament (ACL) consists of 2 bundles: a slightly larger anteromedial bundle and a posterolateral bundle, named according to their relative tibial insertion sites. Both bundles are crucial to knee stability. Although it is more technically demanding, a double bundle ACL reconstruction restores the knee biomechanics better and provides more rotational stability than a single bundle ACL reconstruction. Intermediate and long-term clinical investigation including the measurement of rotational laxity and the evaluation of osteoarthritic change is needed to confirm biomechanical and short-term clinical outcomes.

Key words: anterior cruciate ligament; biomechanics; reconstructive surgical procedures

ANATOMY
The anterior cruciate ligament (ACL) consists of dense connective tissue enveloped in a synovial membrane, which places the ligament in an intra-articular but extra-synovial position.1,2 It attaches proximally on the posterior aspect of the lateral femoral condyle, and runs in an oblique course distally through the intercondylar notch to insert between the medial and lateral tibial spines. The ACL consists of 2 bundles: a slightly larger anteromedial (AM) bundle and a posterolateral (PL) bundle, named according to their relative tibial insertion sites.3 The 2 bundle anatomy has been verified in a foetal study4 (Fig. 1) and cadaveric and arthroscopic studies.3

We have studied the bony topography of the femoral attachment of the ACL using foetal specimens, cadavers, and in vivo arthroscopic observation, and have identified 2 osseous ridges that define the origins of the AM and PL bundles. The lateral intercondylar ridge runs proximal to distal through the entire ACL femoral attachment. With the knee in extension, no fibres of the ACL are attached anterior to this ridge. The lateral bifurcate ridge divides the femoral attachments of the AM and PL bundles. When the knee is in full extension (anatomic position), the femoral origin of the AM bundle is located at the posterior and proximal portion of the
lateral intercondylar wall, while the origin of the PL bundle is located slightly distally, and the 2 bundles are parallel. As the knee flexes to 90°, the typical position during ACL reconstruction, the origins of the 2 bundles change to a horizontal alignment, and the bundles cross (Fig. 2). Similarly, when the knee is in 90° of flexion, the lateral intercondylar ridge delineates the superior border of the ACL femoral attachment, whereas the lateral bifurcate ridge runs from superior to inferior and separates the femoral AM and PL attachments (Fig. 3).

BIOMECHANICS

The 2 bundles are not isometric throughout the knee range of movement. The AM bundle maintains a constant tension throughout the range of movement, with some increase when the knee is in flexion reaching a maximum at 60°. The tension of the PL bundle is more variable: it tighten in knee extension and slackens in knee flexion past 30°. Thus, the AM and PL bundles have varying contributions to knee stability at different flexion angles. The AM bundle limits anterior-posterior translation throughout the knee range of movement, while the PL bundle limits anterior tibial translation and knee rotation.

Both bundles are crucial to knee stability. Double bundle ACL reconstruction better restores knee biomechanics than single bundle ACL reconstruction. The addition of the PL bundle produces in situ forces within each bundle that closely match the in situ forces found in a native ACL ligament. An in vivo
kinematics assessment done after ACL reconstruction using high-speed stereoradiography showed that single bundle ACL reconstruction sufficiently restored the anteroposterior tibial stability, but not rotational stability. Isolated transection of the AM bundle significantly increased anterior tibial translation at 60° and 90° of knee flexion, while isolated transection of the PL bundle significantly increased anterior tibial translation at 30° of knee flexion. In addition, PL bundle transection led to significantly increased rotation in response to a combined rotatory load at 0° and 30° when compared with the intact knee and AM bundle deficient knees. Thus, single bundle (AM bundle) reconstruction cannot restore native knee stability, particularly rotatory stability.

SURGICAL TECHNIQUE

Our surgical approach to anatomic double bundle ACL reconstruction utilises 3 portals including anterolateral, anteromedial, and accessory medial portals (Fig. 4). The accessory medial portal can be used as a working portal, with the arthroscope placed in the anteromedial portal to improve visualisation of the lateral femoral notch. Following diagnostic arthroscopy and investigation of the rupture pattern of the AM and PL bundles, the femoral and tibial remnants of the AM and PL bundles are removed and the native insertion sites of each bundle are marked, using a thermal device (Fig. 5).

The PL femoral tunnel is drilled first, using the accessory medial portal. The pin is placed at the previously marked PL native insertion site and the knee flexed to approximately 110°. If the native insertion sites are difficult to locate, as in chronic cases, PL placement can be located 5 to 7 mm posterior to and 3 mm superior to the border of the anterior articular cartilage, with the knee held in 110° of flexion. The PL tunnel is drilled with a 6 or 7 mm diameter acorn reamer, depending on the condyle size, to a depth of 25 to 30 mm. The far cortex is breached with a 4.5-mm EndoButton drill (Smith & Nephew, Andover [MA], US) and the depth gauge is used to measure the distance to the far cortex. The depth of reaming needed to allow the EndoButton to flip is calculated and the tunnel reamed by hand to that depth with a 7-mm reamer.

Next, the AM and PL tibial tunnels are created. A 4-cm skin incision is made over the anteromedial surface of the tibia at the level of the tibial tubercle. A direct ACUFEX drill guide (Smith & Nephew, Andover [MA], US) set at 45° is used for both the AM and PL tunnels. The tip of the drill guide is placed on the previously marked PL tibial footprint. The tibial PL bundle footprint is located adjacent to the posterior root of the lateral meniscus, and posterolateral to the AM bundle of the ACL. On the tibial cortex, the PL tibial drill starts just anterior to the superficial medial collateral ligament fibres, whereas the AM tibial drill is placed midway between the PL starting point and the anterior tibial tuberosity. 3.2-mm guide wires are passed into the base of the PL and AM tibial footprints (Fig. 6), which are then overdrilled, using a cannulated reamer.

---

Figure 5 The insertion sites of anteromedial and posterolateral bundles are identified by careful dissection, and are marked by a thermal device on the (a) tibial and (b) femoral sides.
Finally, a dilator is used to widen the tunnels to specific diameters; usually 8 mm for the AM tunnel, 7 mm for the PL tunnel. Following tibial tunnel drilling, the AM femoral tunnel is created, approximately 5 to 6 mm posterior to the posterior margin of the PL tunnel. Anatomic placement of the femoral AM tunnel can be achieved using 3 approaches: the trans-tibial AM tunnel approach, the trans-tibial PL tunnel approach, and the medial portal approach (Fig. 7). Trans-tibial approaches are usually attempted first in order to achieve longer, divergent femoral tunnels. The medial portal approach is used whenever the trans-tibial approach positions the tunnel in an unacceptably high, non-anatomic location. The AM tunnel is created in a similar fashion to the femoral PL tunnel, with a typical diameter of 8 mm.

The PL bundle graft is passed, followed by the AM bundle (Fig. 8). On the femoral side, an EndoButton CL (Smith & Nephew, Andover [MA], US) is used to secure each bundle, and on the tibial side bio-absorbable screws are used. The AM bundle is tensioned at 60° of flexion and the PL bundle at 0° of flexion.

OUTCOMES

Assessments of clinical outcomes following double bundle ACL reconstruction were first reported in...
Figure 8  Passed anteromedial (AM) and posterolateral (PL) grafts show a crossing pattern when in flexion. The PL bundle is mostly covered by the AM bundle.

1987, with excellent results in 12 of 14 patients. In 2004, the outcomes for 108 patients (55 single bundle, 53 double bundle) with a mean follow-up period of 32 (range, 24–36) months showed no statistically significant differences between the groups in knee joint stability (KT-2000) or proprioception; International Knee Documentation Committee (IKDC) scores and rotatory stability levels were not reported.

In 2006, 72 patients were randomised to one of 3 treatment groups: anatomic double bundle ACL reconstruction, non-anatomic double bundle ACL reconstruction, or single bundle ACL reconstruction. At the 2-year follow-up, those patients who received anatomic and non-anatomic double bundle ACL reconstructions had significantly better results than those managed with a single bundle ACL reconstruction in the pivot shift examination (p=0.025) and KT-2000 (p=0.002); there were no significant differences in knee movement, muscle torque, or IKDC evaluation.

In 2007, 60 prospectively randomised patients (20 double bundle ACL reconstructions, 20 AM bundle reconstructions, 20 PL bundle reconstructions) were examined under anaesthesia one year after surgery for knee stability using a KT-1000 arthrometer and pivot shift test. A customised 3-dimensional electromagnetic device was used to record the kinematics and velocity between the femur and tibia during the pivot shift test. No statistically significant differences in the side-to-side KT measurements or IKDC functional results were shown. Nevertheless, anatomical double bundle ACL reconstruction provided better control of rotatory torque than single AM or PL bundle reconstructions (p<0.05).

In a prospective, randomised clinical study dividing 65 patients into either double bundle (n=35) or single bundle (n=30) ACL reconstruction groups after a mean follow-up period of 14 (range, 12–20) months, the rotational stability was significantly better in the double bundle group, although there was no significant difference in anterior stability of the knee between the groups. There were 4 graft failures in the single bundle group, but none in the double bundle group.

From November 2003 to May 2007, we performed 431 anatomical double bundle ACL reconstructions (347 primary and 84 revision cases). Clinical measurements included the Lachman and pivot shift tests, KT-2000, range of movement, and overall IKDC rating. Short-term results demonstrated a better range of movement at postoperative one, 4, and 12 weeks in those with primary ACL double bundle reconstructions than in those with primary single bundle ACL reconstructions. At the 2-year follow-up of our first 100 patients to undergo primary double bundle ACL reconstructions, the side-to-side difference in range of movement was 2°±3° for extension, and 2°±5° for flexion. 70% of patients had a normal Lachman test and 28% were nearly normal. 94% of patients had normal pivot shift tests and 6% were nearly normal. The mean side-to-side difference in the KT-2000 test was 1.0±2.3 mm. Patient-oriented outcome scores yielded excellent results. 54% of patients described their current activity level as normal and 33% as nearly normal. 72% of patients participate in strenuous or very strenuous sports activities.

CONCLUSION

Anatomic double bundle ACL reconstruction is technically demanding, but provides better restoration of normal knee anatomy and kinematics than does single bundle ACL reconstruction. Intermediate and long-term clinical investigation, including the measurement of rotational laxity and the evaluation of osteoarthritic change, is needed to confirm biomechanical and short-term clinical outcomes.
REFERENCES