Anterior cruciate ligament reconstruction: Single or double bundle?

SM Sedeek1*, AM Al Dawoudy2, MY Ibrahim3,

Abstract

Introduction
The anterior cruciate ligament consists of two bundles: a slightly larger anteromedial bundle and a postero-lateral bundle, both of which are crucial to knee stability. Anterior cruciate ligament reconstruction is one of the most common procedures performed by orthopaedic surgeons.

A single-bundle anterior cruciate ligament reconstruction has been the most commonly used operative treatment for anterior cruciate ligament injury. However, recent biomechanical studies have doubted the ability of this technique to restore normal knee kinematics. Therefore, the use of the double-bundle procedure has recently been recommended to restore the knee more efficiently.

This article presents an overview of the anatomic and biomechanical rationale for double-bundle anterior cruciate ligament reconstruction, in addition to the latest outcomes of single-bundle versus double-bundle anterior cruciate ligament reconstruction.

Conclusion
The choice of single-bundle technique or double-bundle technique should be based on individual measurements of the anterior cruciate ligament anterior cruciate ligament insertion site and femoral intercondylar notch size.

Introduction
The anterior cruciate ligament (ACL) consists of two bundles, the anteromedial (AM) and the posterolateral (PL) bundles. Each bundle functions at different angles of flexion and extension, but both work together to provide both anteroposterior and rotational stability of the knee. In addition to being the primary stabiliser of the knee, the ACL is also a neurosensory organ that contributes to proprioception.

ACL rupture and subsequent instability are a major injury among young athletes, and surgical management of ACL-deficient knee has been a topic of growing interest in the last few decades.

Single-bundle ACL reconstruction has been the most commonly used operative treatment for ACL injury. However, due to a better current understanding of the ACL anatomy, double-bundle ACL reconstruction techniques have recently been advocated, with the aim of reproducing the native form of the ACL and for better stability of the knee joint. The aim of this review was to discuss single- and double-bundle ACL reconstruction.

Anatomy of the ACL
The ACL has been recognised as a structure for a long time. However, it was only in 1975 that it was confirmed that the ACL consists of two separate and functionally distinctly anatomic bundles, by Girgis et al. In addition, anatomical studies on foetal specimens have supported the distinct double-bundle composition of the ACL during foetal development. Each bundle is named according to its insertion on the tibial footprint. On the tibial side, the AM bundle inserts anteromedially and the PL bundle inserts posterolaterally. On the femoral side, the AM bundle originates more superiorly and anteriorly on the lateral femoral condyle, while the PL bundle originates more inferiorly and posteriorly. The AM bundle tightens in flexion and relaxes in extension; conversely, the PL bundle tightens in extension.

The size and length of each bundle are unique. Studies have shown that the AM bundle is about 28–30 mm in length. However, the PL bundle has been less well studied. In a cadaveric study, Kummar and Yamamoto measured the PL bundle in 50 knees and found a mean length of 17.8 mm. The AM and PL bundles have similar diameters. In addition, a complex relation exists between both bundles throughout the normal range of motion. In extension, the two bundles are oriented in parallel to the sagittal plane; however, when the knee is flexed, the PL bundle becomes crossed with respect to the AM bundle.

Biomechanics
Anterior–posterior translation control
Initial biomechanical studies of the ACL focused on its function of resisting anterior translation. It has been shown that with the application of an anterior tibial load, the ACL shows high in situ forces between 0° and 90° flexion, occurring maximally at 15°. In situ forces are at their lowest point between 60° and 90°, with the minimum occurring at 90°.

Rotational stability
Traditionally, clinical evaluations of knee stability have focused on the anterior–posterior translation.

Licensee OA Publishing London 2013. Creative Commons Attribution License (CC-BY)

However, closer attention has recently been given to the rotational stabilising function of the ACL. Gabriel et al. studied a combined rotator load of 10 Nm valgus and 5 Nm internal tibial torques at 15° and 30° of flexion in 10 cadaveric knees. For the PL bundle, an in situ force of 21 N was recorded at 15° and 14 N at 30°. For the AM bundle, the in situ forces were 30 N and 35 N, respectively.

**Tensioning pattern**

Changes in the alignment of the AM and PL femoral insertion sites allow the ACL to twist around itself as it is passed across a complete range of motion. This crossing pattern, in addition to differences in the lengths of each bundle, has a crucial role in the tensioning pattern for the entire ligament.

**Biomechanics of single- versus double-bundle ACL reconstruction**

Many biomechanical cadaveric studies have demonstrated that anatomic double-bundle ACL reconstruction restores knee stability more closely to normal compared with conventional single-bundle ACL reconstruction.

Woo et al. found that conventional single-bundle ACL reconstructions are relatively successful in limiting anterior tibial translation under anterior tibial loads. However, in response to a combined rotational load, reconstruction was not as effective in reducing anterior tibial translation. The authors concluded that conventional single-bundle techniques place the graft too close to the central axis of the knee, which restricts the ability of the graft to resist rotational loads.

Yagi et al., in an in vitro study, demonstrated that with the application of 134 N, anterior tibial translation in anatomic double-bundle reconstruction was significantly closer to that of the intact knee than was the single-bundle reconstruction. In addition, with a combined rotational load of 10 Nm valgus torque and 5 Nm internal tibial torque at 30° of knee flexion, the normalised in situ force achieved with the single-bundle and double-bundle reconstructions was 66% and 91%, respectively.

Similarly, Mae et al. demonstrated that double-bundle ACL reconstruction using hamstring tendon grafts and two femoral tunnels provides greater anterior stability compared to single-bundle techniques.

Yamamoto et al. compared knee kinematics after anatomic double-bundle ACL reconstruction with single-bundle ACL reconstruction of the PL bundle alone. They found that there were no significant differences in response to combined rotator loads between the groups. Nonetheless, the single-bundle ACL reconstructed group showed increased anterior tibial translation on application of anterior loads at higher knee flexion angles.

Last, Tashman et al. studied a three-dimensional in vivo kinematics of the knee joint after single-bundle ACL reconstruction using high-speed stereoradiography. They found that while single-bundle ACL reconstruction sufficiently restored the anteroposterior tibial translation, there was an increased internal tibial rotation.

**Clinical outcomes**

Data on the clinical long-term functional outcome after anatomic double-bundle ACL reconstruction are limited. Zaricznyj published the first clinical results for double-bundle ACL reconstruction in 1987. The ACL was reconstructed in 14 patients using a doubled semitendinosus tendon graft. One femoral tunnel and two separate tibial tunnels were made. Utilising a standard rating system, 12 patients were rated excellent or good after surgery, and two were rated fair.

In 1999, Muneta and associates published the results of 2 years of follow-up of 54 patients who underwent double-bundle reconstruction. They suggested that the double-bundle procedure showed better anterior stability compared with patients undergoing a single-bundle procedure. However, no formal statistical analysis was provided.

Yagi and associates reported on 60 consecutive patients who were randomly assigned to one of three groups: single-bundle AM, single-bundle PL and double-bundle (AM, PL) reconstruction. All of the patients were examined 1 year after surgery. Anteroposterior laxity was measured by KT-1000 and a pivot shift test. A customised three-dimensional electromagnetic device was used to record kinematics and velocity between the femur and tibia during the pivot shift test. Clinical examination and KT-1000 results were equal between the groups; however, the electromagnetic sensor demonstrated better control of complex and rotational stability in the double-bundle group.

Asagumo et al. retrospectively reviewed 123 consecutive patients, 71 of whom underwent double-bundle reconstruction and 52 of whom underwent single-bundle reconstruction. The same postoperative rehabilitation protocol was used for all patients, and the patients were followed-up for a mean of 33 months. The authors evaluated manual knee laxity, anterior knee laxity as measured with a KT1000 arthrometer, range of knee motion, isokinetic peak torque of knee extension, flexion strength adjusted for body weight as determined by Cybex testing and Lysholm score. The only significant difference between the two groups was in the range of knee motion. Therefore, the findings of this study did not support the routine adoption of double-bundle reconstruction.

Hamada et al. followed 160 consecutive patients with unilateral chronic ACL insufficiency who underwent endoscopic single- or bi-socket ACL reconstruction alternately using a multiple-stranded medial hamstring tendon and EndoButton.
femoral fixation. All patients underwent the same postoperative rehabilitation protocol, and 106 were available for a two-year follow-up. The results showed that both surgical techniques provided satisfactory anterior stability. In addition, there were no statistically significant differences in subjective results or measured restored stability between the two groups.

In a different prospective approach, Ishibashi and colleagues29 used a navigation system to record the intraoperative rotational stability of the knee at various stages of double-bundle reconstruction. The study included 32 patients after reconstruction of the AM, PL or both bundles. There was a significant improvement in both anterior and rotational stability when both bundles were reconstructed compared to one-bundle reconstruction.

Surgical technique of anatomic anterior cruciate double-bundle reconstruction

We used the same surgical approach of Zelle and Fu4 to establish anatomic double-bundle ACL reconstruction. Three portals are utilised, including anterolateral, anteromedial and accessory medial portals. First, the torn ACL is carefully dissected and the anatomic footprints of the PL and AM bundles are marked. The PL femoral tunnel is drilled first, using the accessory medial portal. This portal is established with an 18-gauge spinal needle inserted medially and distally to the standard anteromedial portal, just above the meniscus. The arthroscope can then be switched to the standard anteromedial portal for better visualisation of the lateral wall of the intercondylar notch. A 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 5–7 mm posterior to and 3 mm superior to the border of the anterior articular cartilage, with the knee held at 110° of flexion.

The PL tunnel is drilled to a depth of 25–30 mm. The far cortex is breached with a 4.5-mm EndoButton drill, and a 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 is reamed by hand to that depth with a 7-mm reamer.

For the PL tibial tunnel, the elbow ACL tibial drill guide is set at 45°. On the tibial cortex, the drill is placed just anterior to the superficial medial collateral ligament fibres. The tip of the drill guide is placed intra-articularly on the tibial footprint of the PL bundle. The PL tibial insertion is located anterior and medial to the posterior root of the lateral meniscus. The insertion is lateral and anterior to the posterior cruciate ligament and PL to the AM bundle insertion site. Thus, the PL tibial insertion site is located within the triangle formed by the AM bundle, the posterior cruciate ligament and the posterior root of the lateral meniscus. To drill the AM tibial tunnel, the elbow ACL tibial drill guide is set at 45°, and the tip of the drill guide is placed on the tibial footprint of the AM bundle.

On the tibial cortex, the drill is placed medial and proximal to the PL wire; there should be an osseous bridge of at least 1 cm between the two tunnel entry points. The tip of the drill guide is placed on the tibial footprint of the AM bundle. The AM insertion site is located slightly anterior to the AM tibial tunnel location used in the conventional single-bundle technique.

The femoral AM tunnel is the last tunnel to be drilled. A transtibial technique is used, similar to that used to drill a femoral tunnel for ACL single-bundle reconstruction. The PL bundle graft is inserted first via a Beath pin with a loaded looped suture, and the EndoButton is flipped in the standard fashion to establish the femoral graft fixation. Next, the AM bundle graft is passed and the EndoButton is flipped in the standard fashion to establish the femoral AM bundle graft fixation. The PL bundle graft is fixed at 0°–10° of flexion, and the AM bundle graft is fixed at approximately 60° of flexion.

Discussion

Generally, the major goal of surgical ACL reconstruction is the restoration of normal knee stability and normal knee kinematics.22,29,32 Recently, long-term outcome studies of single-bundle ACL reconstruction have shown that the incidence of degenerative osteoarthritis of the knee after ACL injury did not decline.22,29 Furthermore, the suboptimal outcomes of traditional transtibial single-bundle reconstruction have been the motivation for exploring the possibilities of double-bundle reconstruction. Double-bundle ACL reconstruction has several advantages. First, a double-bundle ACL has wider contact areas between and graft and bone compared with a single-bundle ACL. Second, anatomic reconstruction with the double-bundle technique leads to the two bundles functioning independently at different degrees of knee flexion.

However, the double-bundle technique has some drawbacks. As all grafts need time to heal, a double-bundle graft may be weaker in the early phase after surgery, until the bundles heal together and facilitate their synergistic effect. In addition, the double-bundle procedure is technically demanding, and therefore, the clinical failure rate could be higher with inexperienced surgeons.

To date, assessment of the clinical outcomes of double-bundle ACL reconstruction has focused on the ability of the procedure to restore normal anteroposterior and rotational laxity of the knee. However, in the future, authors need to consider the effects of double-bundle reconstruction on the standard fashion to establish the femoral graft fixation.
the sense of instability and the ability to participate in strenuous sport activities.31.

Regarding the ideal procedure for ACL reconstruction, each patient should be individualised based on both anatomical and graft considerations. In other words, the ‘one-size fits all’ philosophy does not exist nowadays. For instance, there are some conditions in which a patient might not be a proper candidate for double-bundle reconstruction, such as those with narrow notch width or shallow notch heights.30.

Nonetheless, the double-bundle concept should be used when approaching all primary ACL reconstruction. This concept demonstrates awareness that the native ACL consists of two bundles; thus, when reconstructing the ACL, whether using either a single- or double-bundle technique, it is crucial to keep in mind the locations and functions of both bundles.30.

Conclusion
Anatomic double-bundle ACL reconstruction is technically demanding; however it provides better restoration of normal knee anatomy and kinematics compared with single-bundle ACL reconstruction. The choice of single-bundle technique or double-bundle technique should be based on individual measurements of the ACL insertion site and femoral intercondylar notch size.

Abbreviations list
ACL, anterior cruciate ligament; AM, anteromedial; PL, posterolateral.

References


