Does the posterolateral bundle influence rotational movement more than the anteromedial bundle in anterior cruciate ligament reconstruction?

A CLINICAL STUDY

The biomechanical function of the anteromedial (AM) and posterolateral (PL) bundles of the anterior cruciate ligament (ACL) remains controversial. Some studies report that the AM bundle stabilises the knee joint in anteroposterior (AP) translation and rotational movement (both internal and external) to the same extent as the PL bundle. Others conclude that the PL bundle is more important than the AM in controlling rotational movement.

The objective of this randomised cohort study involving 60 patients (39 men and 21 women) with a mean age of 32.9 years (18 to 53) was to evaluate the function of the AM and the PL bundles of the ACL in both AP and rotational movements of the knee joint after single-bundle and double-bundle ACL reconstruction using a computer navigation system. In the double-bundle group the patients were also randomised to have the AM or the PL bundle tensioned first, with knee laxity measured after each stage of reconstruction. All patients had isolated complete ACL tears, and the presence of a meniscal injury was the only supplementary pathology permitted for inclusion in the trial. The KT-1000 arthrometer was used to apply a constant load to evaluate the AP translation and the rolimeter was used to apply a constant rotational force. For the single-bundle group deviation was measured before and after ACL reconstruction. In the double-bundle group deviation was measured for the ACL-deficient, AM- or PL-reconstructed first conditions and for the total reconstruction.

We found that the AM bundle in the double-bundle group controlled rotation as much as the single-bundle technique, and to a greater extent than the PL bundle in the double-bundle technique. The double-bundle technique increases AP translation and rotational stability in internal rotation more than the single-bundle technique.

Although the histological and anatomical features of the anterior cruciate ligament (ACL) are generally accepted, the biomechanical function of the anteromedial (AM) and posterolateral (PL) bundles remains incompletely understood.1-7 In some studies the AM bundle has been reported to stabilise anteroposterior (AP) translation and rotational movements of the knee to the same extent as the PL bundle.8,9 However, a difference in the stability of the knee joint after single- and double-bundle ACL reconstruction has been reported.10,11 Some authors conclude that the PL bundle is more important than the AM in controlling tibial rotation.12-14

The purpose of this study was to determine the influence of the individual ACL bundles on AP and rotational movement of the knee joint using a computer navigation system, following reconstruction of the ACL using the single- and double-bundle techniques. Our hypotheses were that the AM bundle is more important for rotational stability than the PL bundle; that the double-bundle technique stabilises rotational movement of the knee joint more than the single-bundle technique and that the double-bundle technique stabilises AP translation more than the single-bundle technique.

Patients and Methods
We studied 60 patients (60 knees; 26 right, 34 left) who underwent ACL reconstruction between March 2010 and May 2011. There were 39 men and 21 women with a mean age of 32.9 years (18 to 53). The interval between injury and treatment was within seven days in all cases, with the injury as a result either of sport or motor vehicle accident. All gave informed consent to being included in prospective research. A total of 20 patients had a
single-bundle reconstruction using hamstring tendons, 20 had a double-bundle technique with the AM bundle being reconstructed first, and 20 patients had double-bundle reconstruction with the PL bundle first. Patients were allocated to each group using permutated block randomisation by Random Number Generator Software version 7.0 (Microsoft Corp., Redmond, Washington). The number of patients in the study was determined by a power analysis, which required 20 patients in each group. The minimum sample size required to detect the hypothesised effects was determined as \( n = 60 \), with an effect size of 90%, \( \alpha \)-level 0.05 and power of 0.90 (\( \beta = 0.10 \)).

The inclusion criteria were limited to an ACL lesion combined with a meniscal tear (of either meniscus). All patients with associated injuries to the knee, such as a fracture, posterolateral instability, or injury to the lateral or medial collateral ligaments, were excluded. Any patient with a partially torn ACL confirmed by arthroscopy was also excluded.

Under general anaesthesia, the patient's thigh was secured in a metal holder. A diagnostic arthroscopy was performed to assess the ACL and meniscal injuries, as previously diagnosed by MRI. If the diagnosis of rupture was confirmed, grafts were harvested. Through a 5 cm incision overlying the anterior border of the pes anserinus the gracilis and semitendinosus tendons were identified and separated by hook retractors, and the semitendinosus was removed using a tendon stripper. A graft for the single-bundle technique was folded three times to make it 9 cm long and 9 mm wide, irrespective of the diameter of the femoral attachment of the native ACL. Grafts for the double-bundle technique were taken from the semitendinosus for the AM bundle and the gracilis tendon for the PL bundle. In these cases the graft was adjusted to a size of 9 cm \( \times \) 8 mm for the AM bundle and 8 cm \( \times \) 6 mm for the PL bundle. Both grafts were folded three times and the edges of each graft bundle were whip-stitched at 3 cm from the femoral end and 2.5 cm from the tibial end using Polysorb 2 absorbable suture (Covidien, Mansfield, Massachusetts).

In the single-bundle technique a 9 mm femoral tunnel was drilled into the medial aspect of the lateral femoral condyle between the one and two o'clock positions in the intercondylar notch for the left knees and between 10 and 11 o'clock for the right knees. The tibial tunnel was drilled to pass through the centre of the footprint of the native ACL.

For the double-bundle technique, the 8 mm femoral tunnel for the AM bundle was located behind the lateral bifurcate ridge on the medial aspect of the lateral femoral condyle. The 8 mm tibial tunnel for the AM bundle was located 14 mm in front of the PCL attachment slightly medially, and was drilled at an angle of 55° relative to the anteromedial part of the tibial plateau. The femoral attachment of the PL bundle was drilled between the lateral bifurcate ridge and the lateral intercondylar ridge. This tunnel was 6 mm wide. The tibial tunnel for the PL bundle was located 7 mm in front of the PCL attachment slightly laterally, and drilled at 45° relative to the medial tibial plateau (Fig. 1).

Subsequently, a bicortical screw was drilled percutaneously into the femur for the attachment of a passive marker, 10 cm proximal to the upper pole of the patella, and a second screw was passed into the ventral aspect of the tibia, 15 cm below the distal pole of the patella. Each screw secured the navigation system markers. The optical computer navigation system used was OrthoPilot (Aesculap, Tuttlingen, Germany). It depends on the reception of infrared rays emitted by a stereo-optic infrared camera, which also records the rays reflected by the markers. It evaluates the data and calculates the relative positions of the markers to a resolution of \( \leq 1 \) mm. In order to collect other data, the positions of the tibial tuberosity, anterior tibial cortex and medial and lateral margins of the tibial plateau need to be defined. The positions of the markers on both the tibia and the femur are recorded in 90° knee flexion and in full extension. The kinematics of the markers are recorded when the knee is moved from extension to flexion, permitting measurement of sagittal translation (in mm) and rotation of the tibia relative to the femur (in °).

The KT-1000 arthrometer (MEDmetric, San Diego, California) was used to measure the ventral translation in the knee joint (with a constant force of 133 N) in 30° flexion, which was controlled with reference to the navigation system. In order to measure rotation of the tibia in relation to the femur, the patient’s leg was stabilised in a customised boot, so that the ankle was held in 10° dorsiflexion, in order to eliminate unintentional rotations of the ankle. A rolimeter (Aesculap) was attached to the boot as an extension of the tibial axis, allowing rotation of the tibia with a constant force of 2.5 Nm (Fig. 2).

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Fig. 1

Intra-operative arthroscopic photograph of the anteromedial (AM) and posterolateral (PL) bone tunnels for the placement of grafts in the femur.
Next, the KT-1000 arthrometer was used to apply force (133 N) to the ACL-deficient knee after the tendon harvest in order to measure the anterior translation of the tibia. This movement was also measured using the navigation device and repeated three times in this position by the same senior orthopaedic surgeon (RH). Subsequently, the tibia was internally rotated using the rolimeter using a force of 2.5 Nm and the measurements were repeated. The same process was finally repeated for external rotation.

The grafts were placed into the prepared tunnels and secured with interference screws. The AM bundle was tensioned using a tonometer set to 85 N in 45° of knee flexion. The PL bundle was tensioned at 10° flexion with the same force applied. In single-bundle technique, the graft was tensioned by 85 N in 30° flexion. After securing one bundle during the double-bundle technique, the same data as in the ACL-deficient condition were collected three times from the navigation device with forces of 133 N or 2.5 Nm applied in 30° flexion. This was repeated after securing the second bundle. For the single-bundle technique data collection was done only once.

After collecting all the values of both the AP tibial movement relative to the femur (in mm) and internal and external rotation (in °) for the 30° flexed knee joint, the post-operative values for the stability of both single-and double-bundle techniques were compared with those of the ACL-deficient pre-operative knee joint. For the double-bundle technique, the influence of individual portions of the ACL was also compared with the ACL-deficient situation. The two techniques were also compared.

Statistical analysis. All results were analysed using STATISTICA 9.0 software (StatSoft, Prague, Czech Republic). The recorded movements (in mm or °) were examined as means, standard deviations (SD) and ranges. Analysis of variance (ANOVA) and unpaired Student’s t-tests were used to compare the AP translation and rotational stability in the knee joint for ACL-deficient, AM or PL-bundle reconstructed knee joint (DB technique), isometric SB reconstruction and for DB reconstructed knee joint (ACL-intact). A p-value < 0.05 was considered statistically significant.

Results

Anteroposterior translation. There was no statistically significant difference in AP translation of the knee after insertion of the graft in the single-bundle technique or the AM bundle in the double-bundle technique (p = 0.85, Student’s t-test). When only the PL bundle was inserted, the AP translation reduced by a mean of 5.8 mm, demonstrating a smaller influence of the PL bundle on AP translation compared to the AM reconstruction and the single-bundle technique (p = 0.003, ANOVA). Similarly, the difference in mean AP translation between the double-bundle technique and the single-bundle technique remained statistically significant (p = 0.02, Student’s t-test) (Table I).

Internal rotation. The double-bundle technique reduced internal rotation more than the single-bundle technique (p = 0.01, Student’s t-test). When the PL bundle was inserted first, internal rotation was reduced to a mean of 15.3° compared with the ACL-deficient knee. After adding the AM bundle, the mean internal rotation was 13.9°. There was no statistically significant difference between the results of single- and double-bundle techniques regardless of which bundle was secured first (p = 0.51, ANOVA). However, reconstruction of the AM bundle had a greater effect on reducing internal rotation than did the PL bundle. Reconstruction of the AM bundle restores internal rotation to the same extent as does isometric single-bundle reconstruction of the ACL (p = 0.89, Student’s t-test) (Table II).
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External rotation. No significant difference was apparent for the extent of external rotation between the single- and double-bundle techniques ($p = 0.25$, Student’s $t$-test), and with the double-bundle technique no difference was found whether the AM or the PL bundle was reconstructed first ($p = 0.43$, ANOVA) (Table III).

Discussion

The main purpose of this study was to examine the role of the AM and PL bundles of the ACL on kinematic changes in the knee joint, especially rotational stability. The kinematic function of the ACL has been studied extensively under experimental conditions, after dividing the ACL partially or totally, after the reconstruction of the ACL in a cadaver, and intra-operatively after reconstruction.

Ishobashi et al undertook an investigation similar to our own in which the improvement in the AP and rotational stability of the knee was studied while using a navigation system. The authors evaluated the kinematics of 125 knees in 125 patients (80 treated by the double-bundle technique, 45 by the single-bundle technique) in an ACL-deficient knee, after reconstructing the AM or PL bundles and in an ACL-intact knee. The internal rotation of the tibia before the reconstruction was a mean 39.0°. After reconstruction of the PL bundle, the rotation improved to a mean of 35.0° and after reconstruction of the AM bundle separately, the mean tibial rotation was 35.3°. After the double-bundle reconstruction, the rotation decreased to a mean of 34.5°. The authors concluded that ‘the posterolateral bundle has a more important role in controlling rotation of the tibia than the anteromedial bundle’. Robinson et al also concluded that the PL bundle contributed more to reducing internal rotation than the AM bundle. However, we found a greater decrease in internal rotation after reconstruction of the AM bundle than after PL bundle reconstruction, but the difference was not statistically significant ($p = 0.61$). The difference between the ACL-deficient knee joint and after PL bundle reconstruction was a mean of 3.5°, and after AM reconstruction was a mean of 4.9°. In clinical practice such a small difference has little relevance, which indicates a very similar role for both AM and PL bundles in controlling internal rotational stability in the knee joint.

The hypothesis that the AM bundle is the most important for controlling internal rotation was confirmed in a study by Monaco et al using navigation. They showed that internal rotation decreased from a mean of 19.8° in ACL-deficient knees to a mean of 17.0° after AM reconstruction only, and to 16.2° after further reconstruction of the PL bundle.

In a study in cadavers Lorbach et al showed the PL bundle to have a greater influence on controlling external rotation than the AM bundle. They produced rotation by applying a force of 5 Nm using a rotameter attached to the...
tibia. External rotation in the ACL-intact knee was a mean of 19.4°; after dividing the PL bundle it increased to a mean of 22.2° and after dividing the AM bundle it increased to a mean of 24.4°. The difference in the increased external rotation between when the PL bundle was divided and when the entire ACL was divided was only 0.6°. In our study this difference was 0.4°. Consequently, we agree with Monaco et al9 that the AM bundle has a greater role in controlling external rotation than the PL bundle.

In experimental conditions double-bundle reconstruction has been shown to reduce rotational movement better than the single-bundle technique.15 Hofbauer et al,11 in an in vivo study, showed greater control of internal rotation in the knee after double-bundle reconstruction than after single-bundle reconstruction. Song et al10 reported similar findings.

The strength of our study is the randomisation of the method of reconstruction of the ACL bundles, allowing the influence of individual bundles on AP translation and both internal and external rotation to be studied. Additionally, the application of force to the knee with the rolimeter and the KT-1000 allowed reproducibility in testing.

In summary, in the anatomical position during double-bundle reconstruction of the ACL, AM bundle restores rotational stability of the knee joint to the same extent as the isometric single-bundle reconstruction of the ACL and to a greater extent than the PL bundle (although in the latter case without reaching statistical significance). Adding the PL bundle increases the rotational stability of knee joint, primarily in internal rotation. The double-bundle technique reduces AP laxity in a statistically significant manner to a greater extent than does the single-bundle technique, irrespective of whether the AM or the PL bundle was tensioned first. The rotational stability of the knee joint is also greater after the double-bundle technique, with statistical significance for internal rotation but not for external rotation.

**Supplementary material**

A table summarising the literature on relative laxity in the knee after division and reconstruction of the anterior cruciate ligament is available with the electronic version of this article on our website www.bjj.boneandjoint.org.uk

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**References**


