Članki

Articles

Anatomic ACL reconstruction - double bundle

Anatomska rekonstrukcija sprednje križne vezi – tehnika dvojnega snopa

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Abstract

Background. *Complete anterior cruciate ligament (ACL) rupture can lead to recurrent knee instability, meniscal tear, and articular cartilage degeneration. The success rates of traditional reconstruction techniques vary from 69% and 95%, which suggests that there remains considerable room for improvement in ACL reconstruction.*

Methods. *ACL consists of two parts, the anteromedial (AM) and the posterolateral (PL) bundle. These two functional bundles are named by their insertion on the tibial side and are not isometric throughout flexion and extension. In general, the AM bundle tightens in flexion and the PL in extension. Anatomic ACL double-bundle reconstruction seems to reproduce normal in situ forces of the ACL more accurately, and provides better anteroposterior and rotational control. Various double-bundle ACL reconstruction techniques have been described. The approaches used differ in terms of tunnel position, fixation and graft selection. The postoperative management follows the standard ACL rehabilitation protocol.*

Conclusion. *It is important to restore normal knee kinematics in order to prevent long-term degenerative changes, and anatomic double-bundle reconstruction has demonstrated some promise to achieve this goal.*

Ključne besede. *ACL, knee, arthroscopy, double bundle, reconstruction.*

Izvleček

Izhodišča. Popolno pretrganje sprednje križne vezi (ACL) lahko vodi do ponavljajoče nestabilnosti kolena, poškodbe meniskusa in degeneracij na sklepnem hrustancu. Uspešnost običajne rekonstrukcije ACL se giblje od 69 % do 95 %. To nakazuje, da še obstajajo možnosti za izboljšanje same tehnike rekonstrukcije ACL.

Metode. ACL je sestavljena iz dveh snopov: anteromedialnega (AM) in posterolateralnega (PL). Oba funkcionalna snopa se imenujeta glede na položaj, ki ga imata na golenici, in nista izometrična pri fleksiji in ekstenziji. Snop AM se napne v fleksiji, snop PL v ekstenziji. Anatomska rekonstrukcija ACL z dvojnim snopom (double bundle) zagotavlja delovanje križnih sil bolj zanesljivo in omogoča boljšo kontrolo pri pomiku kolena v anterioposteriorni smeri in pri rotaciji. Opisane so različne tehnike rekonstrukcije ACL z dvojnim snopom (double bundle). Razlike v metodah so odvisne od položaja tunelov, fiksacije in izbire transplantata. Pooperativno obdobje vključuje standardni protokol rehabilitacije ACL.

Zaključek. Pomembno je vzpostaviti normalno gibljivost kolena, da preprečimo nadaljnje degenerativne spremembe. Rekonstrukcija ACL z dvojnim snopom (double bundle) se je izkazala za zelo obetavno tehniko, s pomočjo katere lahko to tudi dosežemo.

Ključne besede. Sprednja križna vez, koleno, artroskopija, dvojni snop, rekonstrukcija.

Introduction

Complete anterior cruciate ligament (ACL) rupture can lead to recurrent knee instability, meniscal tear, and articular cartilage degeneration. The ACL does not heal when torn, and surgical reconstruction is the standard treatment (1,2). Reconstruction aims at restoring the kinematics and stability of the injured knee to prevent future degenerative changes (3). Reconstruction of the ACL has become a commonly performed procedure, and good to excellent results have been reported. However, a critical review of the literature reveals that the success rates vary between 69% and 95% (2,5-7). Traditional reconstruction techniques are mostly successful in limiting anterior tibial translation, but may be insufficient in controlling a combined rotatory load of internal and valgus torque (8). A significant portion of ACL reconstructed patients will not return to their previous level of sporting activity, and it has been shown that many ACL reconstructed patients demonstrate long-term degenerative changes on radiographs and bone scans (6-10). This suggests that there remains considerable room for improvement in ACL reconstruction.

It has been well described in the literature that the ACL can be divided into two major functional bundles, the anteromedial (AM) bundle and the posterolateral (PL) bundle (11,12). Biomechanical investigations have indicated that anatomic ACL double-bundle reconstruction restores knee stability closer to normal than conventional single-bundle ACL reconstruction (11,13,14). These anatomical and biomechanical considerations have recently prompted many authors to utilize a double-bundle reconstruction technique (11).

Anatomy of the ACL

The ACL consists of dense connective tissue enveloped in a synovial membrane, which places the ligament in an intraarticular but extrasynovial position (15). The bony attachment is located at the posterior part of the inner surface of the lateral femoral condyle and not, as sometimes presumeed, at the roof of the intercondylar notch. From its femoral attachment, the ACL runs anteriorly, medially and distally to the tibia. Its length ranges from 22 to 41 mm (mean, 32 mm) and its width from 7 to 12 mm (11,12,15-17). The tibial attachment is somewhat wider and stronger than the femoral one.

Functionally, the ACL consists of two parts, the AM and the PL bundle (11,12,15,17). These two functional bundles are named by their insertion on the tibial side. The fascicles of the AM bundle originate at the most anterior and proximal aspect of the femoral attachment and insert at the anteromedial aspect of the tibial attachment. Conversely, the fascicles of the PL bundle originate at the posterodistal aspect of the femoral attachment and insert at the posterolateral aspect of the tibial attachment (18). Some authors have divided the ACL into three functional bundles (AM bundle, intermediate bundle, and PL bundle) (1,18). However , the two-bundle model has been generally accepted as the best representation to understand ACL function (1) These anatomic considerations suggest that it is not possible to reproduce the anatomy of the native ACL with traditional one bundle reconstruction techniques (11).

Physiological function of the two ACL bundles

Biomechanical investigations have demonstrated that the ACL fiber bundles are not isometric throughout flexion and extension. In general, the AM bundle tightens in flexion and the PL bundle relaxes, whereas in extension the PL bundle tightens and the AM bundle relaxes (15,18).

During flexion, there is a slight lateral rotation of the ligament as a whole around its longitudinal axis, and the AM begins to spiral around the rest of the ligament. This relative movement of one bundle upon the other is due to the orientation of the bony attachments of the ACL (1,12,15). Biomechanical studies of the magnitude of in situ forces in response to anterior and rotatory tibial loads in various knee flexion angles for the AM and PL bundles suggest that each bundle may play a separate but equally important role in the overall stability of the knee joint (11). These studies highlight the important role of the PL bundle as a stabilizer against rotatory loads. They also reveal its role as a stabilizer against anterior loads when the knee is in the extended or near extended position (11).

Biomechanics and kinematics of ACL reconstruction: double versus single bundle

Biomechanical studies in cadavers have demonstrated that conventional ACL single bundle reconstructions are relatively successful in limiting anterior translation, but are ineffective in resisting combined rotatory loads (19). Yagi observed that anatomic ACL double bundle reconstructions are more successful at restoring knee stability closer to normal than conventional ACL single bundle reconstructions (11,13). Other biomechanical data from cadaveric investigations suggest that single bundle ACL reconstructions insufficiently restore normal knee stability, independent of the femoral tunnel position. In contrast, anatomic ACL double-bundle reconstruction seems to reproduce normal in situ forces of the ACL more accurately, and provides better anteroposterior and rotational control (11,14)

3D kinematic analysis, which allows for objective evaluation of the functional levels of the knee, showed that in the ACL-deficient knee there is anterior tibial translation and excessive tibial rotation during everyday activities. Conventional ACL reconstruction is successful in restoring these functions when low-demand activities, such as walking are performed. However, during high-demand activities, conventional techniques fail to abolish excessive tibial rotation, which may lead to further degeneration in the medial compartment (1).

Surgical concepts of anatomic ACL double-bundle reconstruction

Over the past several decades, various double-bundle ACL reconstruction techniques have been described in the literature. Differences in approach include tunnel position, fixation, graft choice, and more recently, single vs. double tunnel approach. Recently, the anatomic concept has emphasized the restoration of the normal footprint anatomy, regardless of single tunnel vs. double bundle approach. However, it is difficult to recreate the full anatomic insertion of the normal ACL with a single tunnel. The following is a description of the technique used at our institution utilizing two tibial and two femoral tunnels (20-23).

Surgical technique

After identifying and marking the operative leg in the holding area, the patient is taken to the operating room and placed on the operating table in the supine position. The non-operative leg is wrapped and placed in a well-leg holder. Following an examination under anaesthesia, the operative knee is shaved and a pneumatic tourniquet is applied to the upper thigh. The leg is placed in a knee holder, and the foot of the operating table is fully retracted to allow for a range of motion between 0° and 120° (Fig. 1). Correct intra-operative assessment of the knee flexion angle is essential to correct positioning of graft tunnels. Next, the knee is prepped and draped in the standard fashion, and arthroscopic portals are established. The anterolateral portal is placed at the level of the inferior pole of the patella at the lateral border of the patella tendon. The anteromedial portal is placed just below the inferior pole of the patella, approximately 1 cm lateral to the medial edge of the patella tendon. Finally, an accessory inferior medial portal is marked medial and distal to the inferomedial portal, slightly above the meniscus, and is established later during the procedure (Fig. 2).

Graft preparation is initiated on the back table during the patient positioning and portal establishment. We prefer the use of two tibialis anterior or posterior tibialis allografts, which are typically between 12 and 15 cm in length after being doubled over (Fig 3). Each graft is trimmed to the appropriate diameter, typically 7 mm for PL, and 8 mm for AM. The ends of each graft are sutured using a “whip-stitch” and No. 2 Ticron sutures. Prior to graft passage, an EndoButton™ CL (Smith and Nephew, Andover, MA) is attached, with a loop length based on the measurements of tunnel lengths. It is also possible to use soft tissue autografts, such as semi-tendinosis/ gracilis. However, these require triple or quadruple strands for adequate diameter, and in some cases may not be of adequate length (a minimum of 6-7cm).

Prior to the assessment of the ACL, any meniscal or chondral pathology is addressed. Next, the rupture pattern of the AM and PL bundle is carefully evaluated using a thermal device. Special attention is given to the remaining fibers of each bundle, and the insertion sites of AM and PL bundles are marked on both the femoral and tibial surfaces, corresponding to their positions in the normal ACL (Fig. 4). The tibial footprints are partially preserved for their proprioceptive and vascular contributions.

Next, the accessory medial portal is established using an 18-gauge spinal needle under direct visualization. This portal is essential to allow improved visualization of the lateral wall of the intercondylar notch and correct placement of the PL femoral tunnel. With the scope in the medial portal, a 3/32 Steinman pin is introduced through the accessory medial portal, and placed at the center of the PL femoral insertion site, approximately 5 mm posterior to the anterior articular cartilage border, and 3 mm superior to the inferior border (Fig. 5). Importantly, the knee is held in 90° flexion for this step, since the position of the femoral insertion sites changes with the knee flexion angle. With the knee at 0°, the PL femoral insertion is vertically oriented with the AM insertion, while with the knee in 90° flexion, the insertion sites are oriented horizontally. After verifying the correct pin position, the knee is flexed to 110°, and the pin is malleted into place. A 7-mm acorn reamer is inserted over the guide wire, with special attention taken to avoid injury to the articular surface of the medial femoral condyle. The PL tunnel is drilled to a depth of 25 mm; depending on the overall tunnel length it may later be hand-drilled to a final length of 30 mm. The far cortex is breached using a 4.5-mm EndoButton drill (Smith and Nephew, Andover, MA) and total tunnel length is measured with a depth gauge.

Next, attention is turned to the tibial tunnels. A 4-cm skin incision is made along the anteromedial tibia, at the level of the tibial tubercle. An ACL tibial tunnel director guide (Smith and Nephew, Andover, MA) set at 55° is placed in the insertion site of the PL bundle, based on the anatomic landmarks and previous marking. The position of the director guide on the tibial cortex is anterior to the superficial fibers of the medial collateral ligament. Following the PL guide pin placement, the guide is set to 45° and positioned in the AM tibial footprint (Fig. 6A). The starting point of the AM tunnel on the tibial cortex is more anterior, central, and proximal than the starting point of the PL tunnel. The AM tibial guide pin is placed, and both pin positions are verified prior to tunnel drilling. The tibial tunnels are overdrilled with 7-mm and 8-mm compaction drill reamers for the PL and AM tunnels, respectively (Fig 6B).

Finally, the AM femoral tunnel is established. Again, it is important to hold the knee in 90° flexion while determining pin position to ensure correct tunnel placement. The AM femoral tunnel guide pin is referenced approximately 3 mm posterior to the posterior rim of the PL tunnel, in a horizontal or slightly superior position (Fig. 7). A trans-tibial approach is used in the majority of cases, but in some patients an accessory medial approach may be necessary to achieve correct position to avoid a more vertical AM tunnel position. After verifying the tunnel position, the knee is flexed to 110°, the guide pin is malleted into place, and an 8-mm acorn reamer is used to drill to a depth of 35-40 mm. A 4.5-mm Endo-Button drill is used to breach the far cortex, and a depth gauge is used to measure tunnel length.

For the PL graft passage, a Beath pin with a long loop suture is passed through the accessory medial portal, femoral PL tunnel and lateral thigh, with the knee hyperflexed to protect the peroneal nerve. The suture is retrieved through the PL tibial tunnel using an arthroscopic suture grasper. The PL graft is passed and the EndoButton is flipped in the standard fashion to achieve femoral fixation (Fig. 8A). The AM graft sutures are passed in a similar fashion. The crossing pattern of the two bundles of the ACL can be observed by taking the knee from flexion to extension (Fig 8B). The AM graft is then passed and the Endo-Button is flipped in the standard fashion for femoral fixation (Fig 9).

The knee is cycled from 0° to 120° approximately 25 times for pre-conditioning of grafts. Each graft is fixed using a bioabsorbable interference screw and staple for secondary fixation. The PL graft is tensioned with the knee held in 0°, and the AM graft is tensioned with the knee in 60° flexion. Following fixation, the knee is tested for the range of motion and stability, and the wounds are closed in the standard fashion. A Cryocuff (Aircast, Summit, NJ) is applied, and the leg is placed in a hinged knee brace locked in full extension (24,25).

Rehabilitation

Postoperative management follows our standard ACL protocol. The patient wears a leg brace for six weeks, and continuous passive motion stretching is initiated on the first postoperative day. Crutches are used for 4-6 weeks, but patients are allowed to bear weight as tolerated. Return to full activities is allowed at 6 months postoperatively.

Conclusion

The ACL consists of two functional bundles, AM and PL. Biomechanical and cadaveric data suggest that a reconstruction technique which closely restores the normal anatomy may yield better results than conventional techniques. It is important to restore normal knee kinematics in order to prevent long-term degenerative changes. Anatomic double bundle reconstruction has demonstrated some promise of achieving this goal, yet further studies will be needed. However, the anatomic concept in ACL reconstruction can be applied to any surgical technique, regardless of whether a two tunnel approach is used, and may lead to improved outcomes following surgery.

Figure 1
Position knee to allow for full range of motion between 0 and 120 degrees

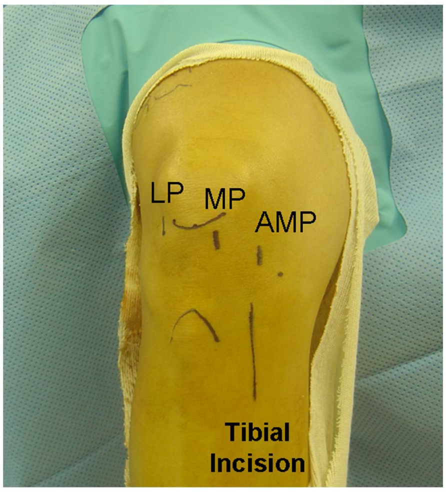

Figure 2
Arthroscopic portal placement: LP = lateral portal; MP = medial portal; AMP = accessory medial portal

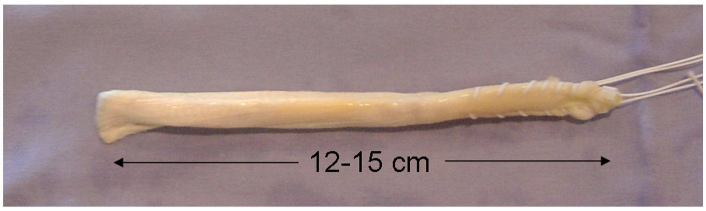

Figure 3
Tibialis anterior allograft. Grafts sized to 7 mm diameter for PL, 8 mm diameter for AM

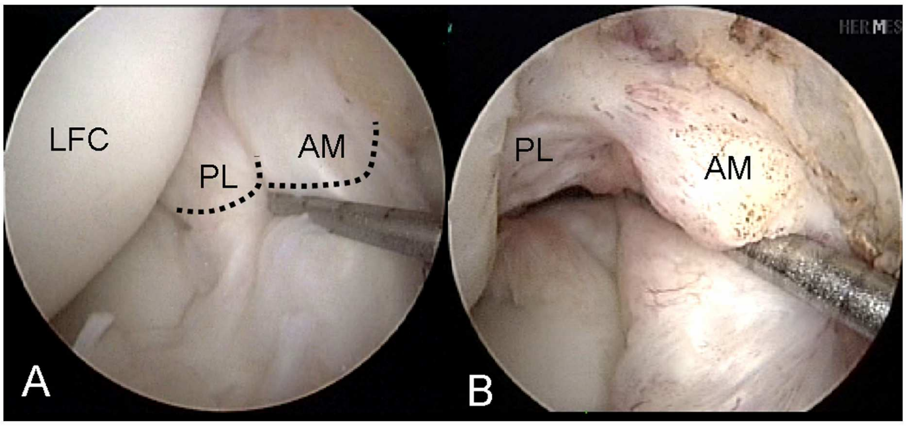

Figure 4
(A) Normal ACL demonstrates double bundle anatomy of AM and PL. (B) Arthroscopic rupture pattern of AM and PL bundle. Remaining fibers used to mark insertion sites with thermal device

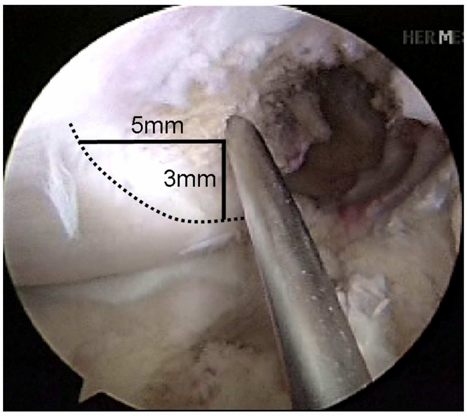

Figure 5
Spinal needle in accessory medial portal demonstrating anatomic position for PL femoral pin

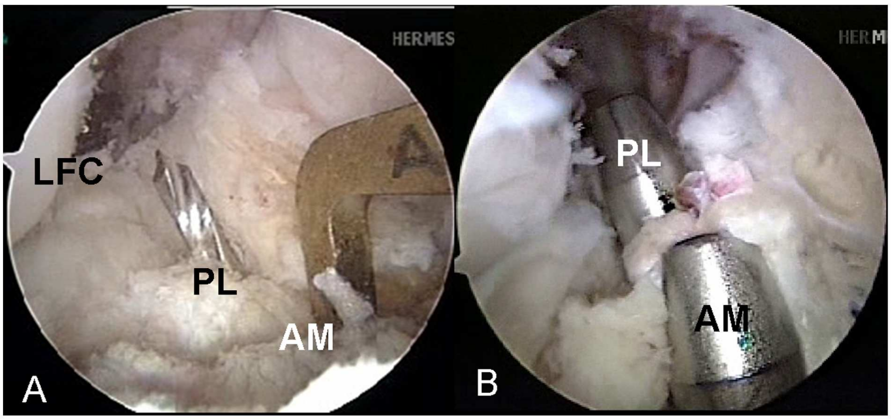

Figure 6
(A) AM tibial guide in position, PL tibial pin in place. (B) Tibial tunnels for AM (45 degrees) and PL (55 degrees)

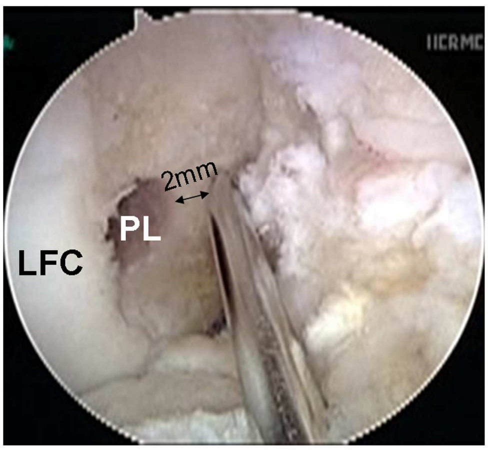

Figure 7
AM femoral pin placement, using trans-tibial technique. Accessory medial port approach may be needed to achieve correct position in some cases.

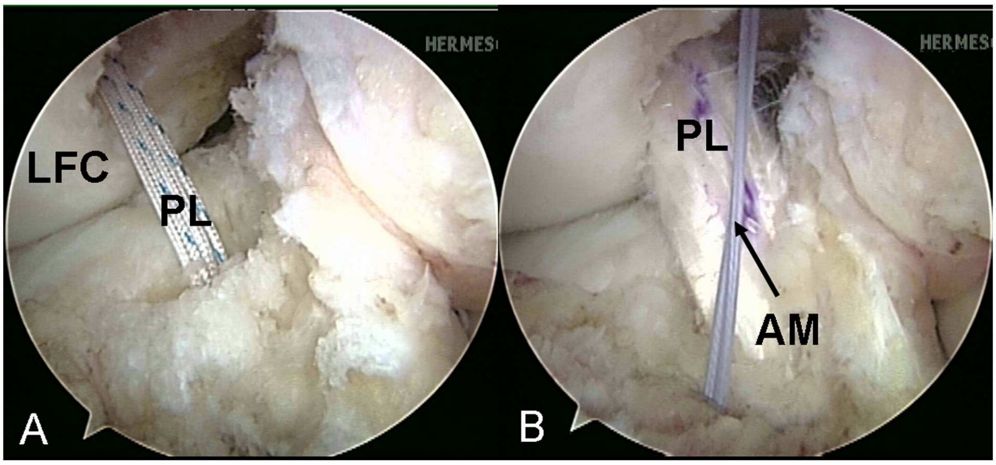

Figure 8
(A) PL suture passage. (B) AM suture passage, PL graft in position. AM and PL are crossed with the knee held in 90 degrees flexion

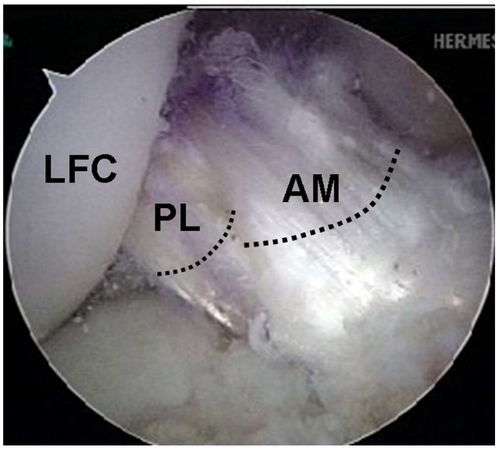

Figure 9
AM and PL grafts in position. PL partially obscured by AM.

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