POSTEROLATERAL BUNDLE RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT TO RESTORE ROTATIONAL STABILITY OF THE KNEE

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Only 5-10% of partial tears of the anterior cruciate ligament (ACL) are symptomatic, especially in high demand individuals or in patients practicing sports requiring rotational motion. A certain preoperative diagnosis of this condition is challenging and often needs the combination of clinical examination, magnetic resonance imaging (MRI) and knee-laxity tool measurements. However, the arthroscopic examination of the torn ACL bundle is the most important factor in decision-making. Evidence in various studies has shown that the preservation of the ACL remnant and its surgical augmentation can bring important advantages in terms of vascularity and proprioception, resulting in better outcomes. The purpose of our paper was to describe the surgical technique of arthroscopic posterolateral (PL) bundle reconstruction with the preservation of the anteromedial (AM) bundle for ACL partial tears. Moreover, we reported the current knowledge about rationale, diagnosis and treatment of partial tears of ACL.

Partial tears of the anterior cruciate ligament (ACL) are common in the population, accounting for 10-28% of all ACL tears (1). However, only 5-10% of these lesions are symptomatic, especially in young patients involved in sports requiring jumping or rotational motions (1). The diagnosis of this type of lesion of the ACL is often difficult and still challenging, requiring a combination of careful clinical examination, adequate magnetic resonance imaging (MRI), and knee-laxity tool measurements. However, a certain diagnosis can be achieved only through arthroscopy (2)..

The ACL is made of two bundles, the anteromedial (AM) and the posterolateral (PL) (2). Each bundle contributes separately toward stabilizing the knee and injure separately, depending on the knee flexion angle at the time of trauma and the different reciprocal tension pattern between the two bundles (3).. From a biomechanical viewpoint, the AM bundle fibres are tight between 30 and 130° of knee flexion and are the primary restraint against anterior tibial translation in flexion; PL bundle fibres are completely tight in full extension and play a role controlling rotational stability.. Although both bundles contribute to anterior-posterior stability, only the PL bundle controls the rotational stability of the knee (4).

In case of ACL tear, a standard arthroscopic reconstruction is usually carried out sacrificing the residual portion of the ACL, to avoid intercondylar notch overstuffing and to prevent impingement or extension lag (5).. However, in the last decades, several anatomical and biomechanical studies provided better knowledge about correct knee ligament insertions and the functions of the two ACL bundles (5). Modifications in the technique of ACL reconstruction with the emergence of double-bundle and anatomical reconstruction were then developed. Furthermore, a selective single bundle

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reconstruction with preservation of the intact ACL bundle (selective augmentation technique) in case of partial tears was described (6).. In particular, since the restoration of the biomechanical function is essential for the knee kinematic, keeping ACL intact bundle and reconstructing only the injured bundle could be advantageous in restoring knee stability and maintaining the proprioceptive function of the ligament.. Excellent results have been reported in literature after selective anteromedial (AM) bundle reconstruction but only few studies reported the outcomes of PL bundle reconstruction with preservation of the AM remnant (7, 8)

The purpose of this study was to describe the surgical technique of arthroscopic PL bundle reconstruction with the preservation of the AM bundle for ACL partial tears. Moreover, we reported the current knowledge about rationale, diagnosis and treatment of partial tears of ACL.

Surgical technique

Under spinal anaesthesia, the patient is placed supine on the operating table and a tourniquet is positioned on the proximal region of the thigh. The lower limb is fixed in a leg holder allowing full extension-flexion range of motion of the knee.

Diagnostic arthroscopy

The diagnostic arthroscopy should start performing a standard anterolateral portal close to patellar tendon and a low AM portal.. A careful inspection of the knee can be easily made through these portals using a probe, looking for meniscal/chondral lesions, or capsular deficiencies. A debridement of the anterior fat pad could allow a better visualization of the intercondylar notch with increased knee flexion. The ACL evaluation started confirming the presence of the continuous AM bundle fibres connecting femoral and tibial footprints, and should be done either in a semiflexed position either in a "figure 4" position of the knee while assessing tension of intact AM bundle fibres by palpation with the probe and via clinical tests. The PL bundle has some specific features; often its direct observation through the anterolateral portal is difficult and the best way is to switch the scope to the anteromedial portal to have a direct view of its insertions. The best leg position to explore the PL bundle is in flexion close to 80° and combined to a varus with an external rotation of the hip (Cabot's position) (9)..

Graft harvesting

Our chosen graft for the reconstruction of the PL bundle is the semitendinosus tendon (ST) which is harvested by a 4 cm longitudinal incision located 1-2 cm medial to the tibial tuberosity, at the level of the pes anserinum.. The graft is harvested using an open-ended tendon stripper and then is looped in doubled conformation over a traction suture device and the distal ends are whipstitched with no. 2 vicryl or no-absorbable sutures so that over 2 cm of doubled ST graft could lie in the femoral and tibial fixation tunnels. Then, the graft is looped over a 15-25 mm Endobutton CL-ultra (Smith and Nephew Endoscopy, Andover, MA) for femoral fixation, depending on lateral femoral condyle length.

Since ACL remnant augmentation technique may increase the risk for cyclops syndrome, special attention must be paid to the graft size because a large graft can result in a loss of full extension postoperatively and pain due to overstuffing in the intercondylar notch. The goal is to obtain a graft with a diameter of 6-8 mm.

Bone tunnels

Before drilling bone tunnels, tibial and femoral footprints of the PL bundle are carefully identified and debrided while preserving the intact AM bundle. A careful protection of the remnant fibres of the ACL is crucial, and can be easily made using a probe. Then, the bone tunnels are drilled according to the size of the graft in order to obtain a good tendon-to-bone press fit.

We prefer to perform a selective PL bundle reconstruction using transtibial technique for creating the femoral tunnel. First, we perform tibial tunnel using a tibial guide set to 45-48°, placed approximately 3 cm medial to the tibial tuberosity with a tilt of 40-45° to the tibial axis and with the intraarticular tip of the drill guide positioned immediately posterolateral to the fibres of the AM

bundle, at the centre point of the PL bundle and at an average 4 to 5 mm anterior to the posterior root of the lateral meniscus. A 2 mm Kirschner wire is inserted using the drill guide and then advanced by a conventional cannulated reamer to create the tibial bone tunnel, which is then drilled according to the same diameter of the harvested graft. At the same time, intact AM bundle fibres are retracted with a probe or a curette through the AM portal to protect them during the tibial tunnel drilling.

The femoral PL bone tunnel is then marked with the knee at 110° of flexion because in this position the PL bundle insertion is horizontal to the AM bundle, at an average of 4 to 5 mm posterior to the articular cartilage of lateral femoral condyle. At this time, resident's ridge is also outlined. Through the AM portal, a flexible guidewire is advanced at the centre of PL femoral bundle footprint behind the resident's ridge and then exited outside through the distal femur and thigh. In case of PL bundle rupture, the goal is to position the central portion of the femoral tunnel between 9:30 and 10 o'clock (right knee) and between 2 o'clock and 2:30 o'clock (left knee). The length of tunnel is calculated after increasing the diameter to 4,5 mm with the Endobutton drill, then the femoral socket is created using a cannulated reamer of the same diameter of the harvested graft to a depth of approximately 30 mm.

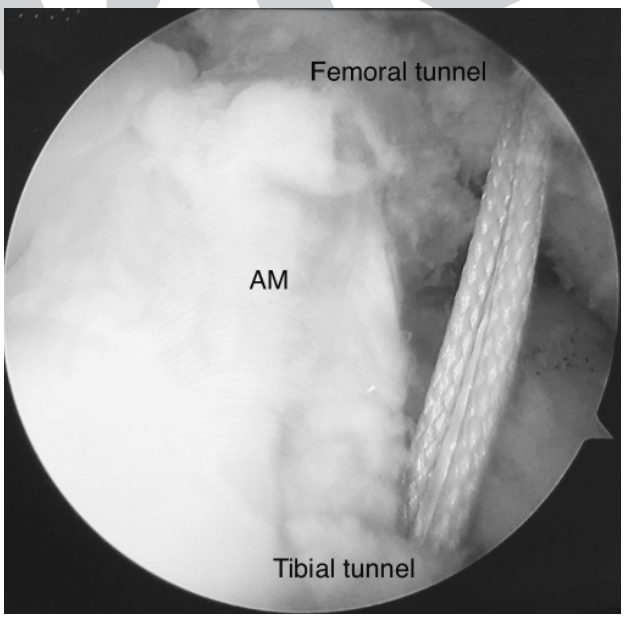

Fig. 1.. *Graft passing through tibial tunnel. **AM**: anteromedial bundle; **PL**: posterolateral bundle).*

Graft passing and fixation

Once completed both bone tunnels, the graft is routed from the tibia to the femur (Fig.. 1). On the tibial side, graft fixation is performed using a bio-absorbable interference screw in 20° of knee flexion, because it has been shown that both bundles carry the same load within this degree of motion (10).. After selecting the appropriate size of Endobutton CL-ultra for the femoral side, the graft is passed through the tibial tunnel and femoral tunnel, fixed to the lateral femoral cortex by flipping the Endobutton and pulling the graft distally (Fig. 2). Finally, the graft is tensioned on the femoral side and cycled through several flexion-extension movements. Once stable fixation is confirmed, the excess distal ends of the graft are sharply dissected..

DISCUSSION

The reconstruction of ACL is a very common procedure with good to excellent results reported over the years (11). The primary purpose of performing an ACL reconstruction is to restore the biomechanical stability of the knee, therefore reducing the incidence of associated lesions such as meniscal tears, collateral ligaments injuries or cartilage damage (11). Standard ACL reconstruction often involves the resection of the remaining ligament fibres from both the tibial and femoral footprint, to avoid overstuffing into the intercondylar notch and to prevent impingement of soft tissues, which can produce decreased range of motion and extension lag (12).. However, it was shown that the preservation of the ACL remnant and of the intact bundle could bring advantages in terms of vascularity and proprioception (12), resulting in improved recovery of joint stability and position, enhanced revascularization, integration and remodelling of the graft (13)..

From a biological viewpoint, remnant ACL fibres can maintain blood supply preserving the synovial sheet, and providing support to the healing process of the graft (14). Consequently, preserving ACL remnants and any eventual uninjured bundle

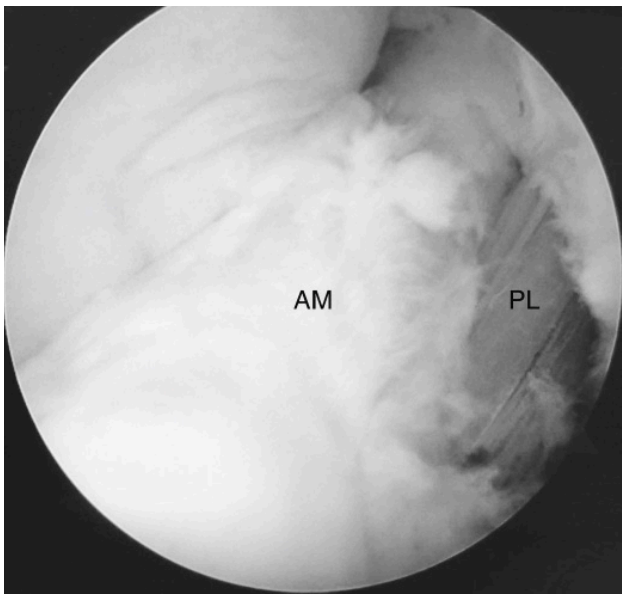

Fig. 2.. *Final result of selective posterolateral.* ***PL****: bundle reconstruction* ***AM****: anteromedial).*

during an ACL reconstruction is very important and can lead to significant biomechanical, vascular and proprioceptive advantages (15). Moreover, these ACL remaining fibres may serve as a guide and landmark for ensuring a better placement and orientation of the graft at the ACL native insertion sites, adding biomechanical strength and stability to the reconstructed bundle in the immediate postoperative period (15).

A preoperative diagnosis of partial tears of the ACL is often challenging and the decision of whether the ACL tear is partial or complete is made based on clinical, MRI and final arthroscopic evaluation. Siebold and Fu (16) pointed out that clinical presentation of partial ACL tears shows significant variations according to the injury pattern of the AM and PL bundles. Depending on the injury mechanism, there is a wide range from asymptomatic to symptomatic elongation or rupture of 1 or 2 bundles. Zantop (17) et al. focused on the correlation between injury mechanism and the injury pattern of the 2 ACL bundles and showed that an AM bundle tear seems to involve a more explosive type trauma to the knee, predominantly in the anterior direction, whereas an injury to the PL bundle might involve a less energetic pivoting injury, with a predominantly rotational component. Patients with symptomatic PL bundle tears usually tend to complain of rotational instability with pivoting sports showing only slightly positive anterior drawer and Lachman test while presenting a positive pivot shift test. On the other hand, patients with AM bundle tears show an accentuated anterior instability with a significantly increased anterior drawer at 90° and Lachman test at 30° of knee flexion.

Besides clinical examination, instrumental exams could also make a valuable contribution to getting accurate diagnosis; however, conventional MRI is not sensitive enough to diagnose a partial ACL tear (18). The double bundle structure of the intact ACL and its specific injury pattern is usually seen on T1 and or T2 weighted 0,2 T MRI on standard views in the sagittal and coronal planes but a clear definition of the two bundles remains often very difficult. Starman et al (18) reported that the AM bundle was detected in most standard viewing planes with high frequency and reliability, while the PL bundle identification was less frequent and had a lower associated reliability in MRI. These data confirmed the difficulty to reliably detect both bundles using a low-field strength 0.2 T MRI with standard planes of view..

We have already demonstrated that partial tears of ACL can predictably be recognized on oblique sagittal (in case of AM bundle tear) and oblique coronal planes (in case of PL bundle tear) using a 3T MRI, allowing a more precise description of ACL rupture patterns and consequently a more distinctive approach for reconstructive surgery (19)..

Nevertheless, since the use and the development of better adapted MRI protocols may allow a certain diagnosis of this type of lesion, direct arthroscopic examination of the preserved fibres remains the most important factor in the surgical decision (19). The evaluation of the quality of the PL bundle fibres is better done with the knee in the "figure four" position (Cabot's position) because in this setting a stretched-out PL bundle cannot show an increase in tension normally seen (9). Moreover, an isolated PL bundle rupture can be easily missed when viewing from standard anterolateral portal and because the presence of the AM bundle which overlies the PL bundle.

Mott et al. (20) were the first to describe an ACL augmentation surgery in acute ACL tear, pointing out that this type of reconstruction gives back an optimal ligament strength compared to normal ACL. Other authors have reported good clinical outcomes in terms of reduced laxity and better joint stability and proprioception after partial reconstruction of either the AM bundle or the PL bundle (21).. Adachi et al (22) described that the remnant preservation during reconstruction may contribute to improve postoperative proprioceptive function of the knee joint, better restoration of knee kinematics and the potential enhancement of graft biological integration. Ochi et al (23) demonstrated that proprioception and healing was effective after single bundle reconstruction in a series of 45 patients who underwent selective augmentation reconstruction with a follow-up of 2 years.. Buda et al (24) reported good or excellent clinical outcomes correlated with integration of the graft with the remaining fibres and with the presence of a signal on postoperative magnetic resonance imaging, while Pujol et al (25) rated a better control on anterior laxity test in patients who underwent selective single bundle augmentation on a prospective, randomized multicentre study.

In conclusion, the reconstruction of the PL bundle of the ACL is a challenging procedure requiring an experienced arthroscopic surgeon and a reproducible technique to place the PL bone tunnel in the anatomic insertion while preserving the AM remnant. Correct tunnel placement and a careful preservation of the intact bundle are critical for achieving successful short and long-term outcomes after this type of ACL reconstruction.

Based on literature evidence and our experience, we recommend this surgical technique that proves to be effective and shows good to excellent clinical outcomes, especially regarding joint proprioception and stability. However, more prospective and randomized controlled studies including large sample of patients and with objective methods of outcome assessment are necessary to evaluate the outcomes about healing, remodelling of the graft, proprioception and biomechanics of the knee, after augmentation surgery for partial ACL tears.

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