

Single bundle anatomic anterior cruciate ligament reconstruction: Indications, technique and results

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Abstract

Introduction

Anterior cruciate ligament (ACL) is a common injury and more than 100,000 ACL reconstruction procedures are performed in the United States every year. Although widely accepted and investigated, ACL reconstruction still continues to evolve and many technical issues are under debate. They mainly include: 1) graft selection, 2) surgical technique (double versus single bundle) and 3) femoral tunnel drilling in single bundle ACL reconstruction. In this review, the authors describe the indications, surgical technique and results of anatomic ACL reconstruction. The controversies are also discussed, through a recent literature review.

Methodology

After an ACL tear, three possible treatment options are available: 1) conservative treatment, 2) acute ACL reconstruction (within the first six weeks) and 3) chronic reconstruction. Patient's age, profession and activity level need to be carefully evaluated to correctly plan the treatment.

Conclusion

To achieve good results and high satisfaction rates, correct treatment has to be tailored to meet the patient's needs, profession, activity level, age and sports. Considering the literature review, many issues regarding ACL reconstruction are still under debate and need to be clarified with high quality studies.

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Introduction

The anterior cruciate ligament (ACL) reconstruction is the sixth most common orthopedic procedure, with more than 100,000 surgeries performed in the United States every year¹. It is widely accepted that ACL reconstruction improves stability and function of the knee and reduces the risk of chondral and meniscal injuries. In ACL deficient athletes, ACL reconstruction is the only means of achieving pre-injury level of performance.

However, ACL reconstruction does not seem to protect the knee from arthrosis², and conservative treatment can still be indicated in old and inactive patients.

Although widely accepted and investigated, ACL reconstruction still continues to evolve and many technical issues are under debate. They mainly include: 1) graft selection (patellar tendon, hamstring, quadriceps tendon or allografts), 2) surgical technique (double versus single bundle) and 3) femoral tunnel drilling in single bundle ACL reconstruction (transtibial, antero-medial portal and outside-in femoral tunnel drilling). The aim of this review was to discuss the indications, techniques and results of single bundle anatomic anterior cruciate ligament reconstruction.

Methodology

The authors have referenced some of their own studies in this methodology. These referenced studies have been conducted in accordance with the Declaration of Helsinki, 1964, and the protocols of these studies have been approved by the relevant ethics committees related to the institution

in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

Indications

After an ACL tear, three possible treatment options are available: 1) conservative treatment, 2) acute ACL reconstruction (within the first six weeks) and chronic reconstruction. Patient's age, profession and activity level need to be carefully evaluated to correctly plan the treatment.

As mentioned, ACL reconstruction does not seem to protect the knee from arthrosis in ACL deficient knees. However, a higher incidence of meniscal, chondral and ligamentous injuries is reported in ACL deficient knees compared to stable knees. Therefore, sports medicine surgeons have the tendency to indicate ACL reconstruction in young (< 30 years old) and active patients. Authors' indications for conservative treatment, early and chronic ACL reconstruction are summarised in Table 1.

ACL tear in paediatric patients with open physes needs particular mention. The treatment of ACL tears in skeletally immature patients remains controversial and the debated issues mainly concern the surgical timing (early versus delayed reconstruction) and the most reliable operative technique.

Early ACL reconstruction in skeletally immature patients may improve knee function, avoid strict activity modification in competitive athletes and reduce progressive chondral and meniscal injuries³. However, a wide range of growth disturbances have been reported in animal and clinical studies⁴. Therefore, conservative

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Table 1 Authors' indications for the treatment of ACL tears.

Conservative treatment (mainly focused on muscle strengthening and proprioception):
Non-active patients > 45 years of age
Absence of giving away episodes
Early ACL reconstruction:
High level athletes
Associated meniscal injury requiring repair in young patients (< 45 years old)
Associated peripheral ligament injuries requiring acute repair: 1) Grade III postero-lateral corner injuries; 2) Grade III postero-medial corner injuries with valgus alignment of the knee
Knee dislocation (according to the surgeon's preference). ACL reconstruction can also be performed in a second procedure, after posterior cruciate ligament, postero-lateral corner and medial collateral ligament reconstruction
Delayed ACL reconstruction:
Severe knee instability with recurrent giving away of the knee
When surgical procedures requiring a good knee stability are required (meniscal suture, meniscal transplant, cartilage resurfacing procedures and postero-lateral/postero-medial corner reconstruction)

management with ACL reconstruction at skeletal maturity should always be mentioned as a possible treatment, most of all for inactive patients. Surgery is recommended when: 1) the conservative treatment fails (persistent effusion, pain and recurrent episodes of instability), 2) the patient is unwilling or unable to modify the activity level and 3) meniscal tears amenable to repair are associated with the ACL tear. Many techniques have been described for paediatric ACL reconstruction and they include: 1) physeal-sparing techniques (intra-articular, extra-articular and combined intra-/extra-articular), 2) partial transphyseal techniques and 3) complete transphyseal techniques. For this topic, the authors refer to specific readings⁵.

When ACL reconstruction is indicated in adult patients, graft selection is an important step in pre-operative planning. Different grafts have been proposed in the literature, and they include: autografts (bone patellar-tendon bone, hamstrings, quadriceps

tendon, fascia lata); allografts (bone patellar-tendon bone, hamstrings, quadriceps tendon, tibialis anterior or posterior tendon, Achilles tendon, fascia lata, peroneal tendons) and synthetic grafts (scaffolds, stents, prostheses). Although new materials

are being investigated, synthetic grafts reported a higher rate of complications compared to autograft and allograft⁶.

Autologous bone patellar-tendon bone (BPTB) and hamstrings (HS), as well as allografts are the most commonly used grafts. Although similar results have been described for these grafts⁶, the authors strongly believe that it is important to individualise the graft choice for each patient's need. The authors' indications for the graft choice are summarised in Table 2.

Surgical technique

The patient is administered spinal or general anaesthesia and positioned supine on the operating table. A tourniquet is positioned on the proximal thigh. Intravenous antibiotic prophylaxis is performed. The operative leg is stabilised with an arthroscopic leg holder and the distal extremity of the bed is dropped. At least 120° of knee flexion needs to be achieved. A thorough examination under anaesthesia is essential to confirm ACL tear and rule out concomitant ligament injuries. The tourniquet is inflated after leg elevation.

Table 2 Authors' indications for the graft selection.

Bone Patellar Tendon Bone (BPTB)
– When a prompt return to play is required
– In athletes subjected to hamstrings lesions (football, sprinting sports)
– In patients not compliant with rehabilitation and restrictions
– If physical examination reveals hyperextension of the knee
Hamstrings (HS)
– In patients with open growth plates
– In women with esthetic issues
– In patients with kneeling activities
– In athletes subjected to patellar tendon pathologies (basketball, volleyball, tennis)
– In double bundle ACL reconstruction
Allograft
– In ACL reconstruction revisions
– In multi-ligamentous knee injuries
– When all-inside technique is required by the patient with esthetic issues
– In patients more than 40 years old, with low activity level

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Graft harvesting

When using a BPTB autograft, a 7–8 cm anterior/antero-medial incision is performed from the inferior patellar pole to the superior aspect of the tibial tubercle (Figure 1). The incision is usually slightly medial to the midline of the knee in order to facilitate the tibial tunnel drilling through the same incision. After incising the paratenon, the central third (around 10 mm) of the patellar tendon is harvested with trapezoidal patellar and tibial bone plugs (usually around 9×22 mm). Two of No. 2 non-absorbable braided traction sutures are inserted in each plug (Figure 1). The length of the tendon and the bone plugs are measured (Figure 1).

During HS harvesting, a 3 to 4 cm longitudinal skin incision is made on the antero-medial aspect of the tibia (Figure 2). The incision is placed 2 cm medial to the tibial tubercle, started 3 cm below the joint line and prolonged distally. The sartorial fascia is incised proximally and parallel to the tendons with a No. 15 blade first and then with Metzenbaum scissors. Deep to the retracted sartorial fascia, the gracilis tendon is visualised proximally and the semitendinosus tendon distally. The semitendinosus tendon is then pulled out with a blunt hook. The vinculum to the medial head of the gastrocnemius and all other minor vincula of the tendon should be released proximally, distally, medially and laterally. When the distal insertion of the tendon is left intact, like in this technique, an open tendon stripper is used (Figure 2). Alternatively, the tendon can be distally detached, armed with a leading suture and harvested with a closed tendon stripper. The gracilis tendon is harvested in the same fashion. The tendons are then distally detached and taken to the back table for preparation.

ACL reconstruction

A complete diagnostic arthroscopy is performed through standard antero-medial (AM) and antero-lateral (AL)

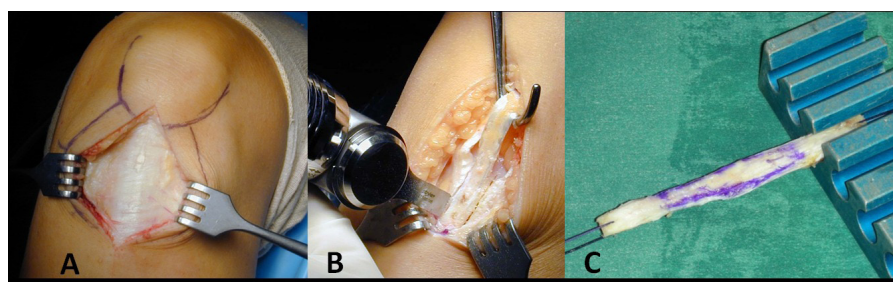


Figure 1: Bone patellar tendon bone (BPTB) harvest. A) Anterior incision. B) Harvesting of the central third of the tendon with tibial and patellar bone plugs. C) Graft on the back table for sizing after preparation.

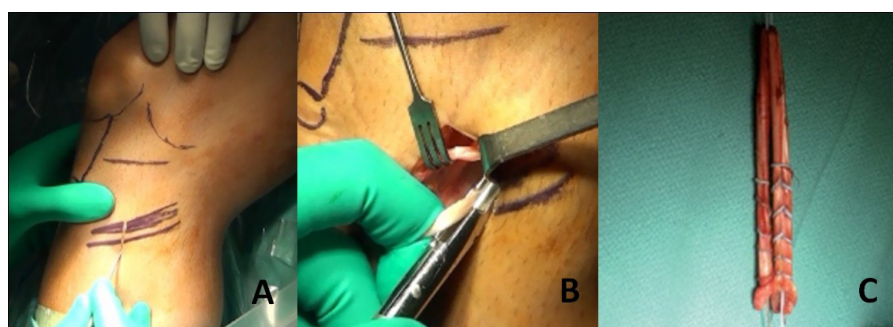


Figure 2: Hamstring (HS) harvest. A) Antero-medial incision. B) Harvesting of the gracilis and semitendinosus tendons with an open tendon stripper. C) Graft on the back table for sizing after preparation.

portals. Any associated pathologies (meniscal or chondral injuries) are identified and treated at this point. The remaining ACL stump is removed with a mechanical shaver until the tibial and femoral footprints are well visualised. No notchplasty is required, unless osteophytes are visualised in the intercondylar notch.

When performing anatomic ACL reconstruction with AM portal femoral tunnel drilling, either the tibial (Figure 3) or the femoral tunnel (Figures 4, 5) can be drilled first, according to the surgeon's preference. The authors usually prefer to drill the femoral tunnel first.

An arthroscopic offset guide is inserted into the joint through the AM portal. If the medial wall of the lateral femoral condyle is not adequately visualised through the AL portal, an accessory AM portal can be established to introduce the femoral

guide. Over the top guides are available with different offsets (Figure 5). The appropriate offset should be decided to preserve a 2 mm posterior wall. For example, if a 10 mm diameter (5 mm radius) femoral tunnel is planned, a 7 mm offset guide is used to maintain 2 mm of the posterior wall ($7 - 5 = 2$ mm). With the knee at 120° flexion, a guide pin is drilled around the 10 o'clock (right knee) position on the coronal plane. The exit point of the pin through the skin of the lateral thigh should be evaluated. If the pin is exiting too posterior with respect to the femoral shaft, it should be repositioned to minimise the risk of posterior wall disruption. A cannulated reamer of the same size of the graft diameter is used to create the femoral tunnel. The femoral tunnel length usually varies from 25 to 30 mm, according to the length of the bone plug or the proximal fixation

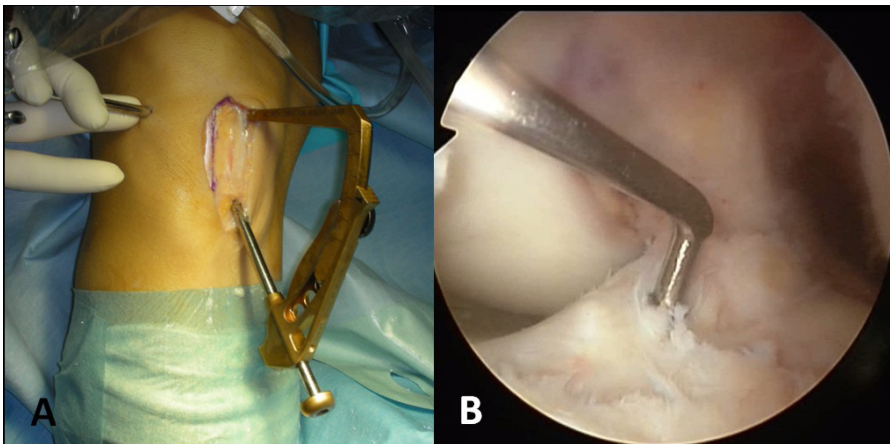


Figure 3: Tibial tunnel preparation. A) An ACL guide is positioned on the anatomic tibial footprint of the native ACL through the antero-medial portal. B) Arthroscopic view of the guide positioning.

device. A No. 2 braided shuttling suture is looped and passed through the eyelet of the guide pin. The guide pin is pulled from the lateral side of the thigh, retrieving the two free ends of the suture proximally and keeping the loop outside the AM portal. The free ends are secured with a Kelly clamp.

Then an ACL tibial guide is inserted into the joint through the AM portal (Figure 3). Landmarks for the correct positioning of the tibial tunnel are: the posterior cruciate ligament (PCL), the anterior horn of the lateral meniscus and the tibial spines. The ACL guide is positioned about 7 mm anterior to the PCL, posterior to the anterior horn of the lateral meniscus and on the lateral wall of the medial tibial spine. When using a BPTB graft, the length of the tibial tunnel is important. This is determined by measuring the length of the graft and subtracting the femoral bone plug and the intra-articular portion of the graft (usually 30 mm). A guide pin is drilled into the proximal tibia from a point located half way between the tibial tubercle and the postero-medial corner of the tibia. The length of the tibial tunnel can be measured with the guide pin. A cannulated reamer with the same diameter of the graft is used to drill the tibial tunnel.

An arthroscopic grasper is inserted into the tibial tunnel and the loop of the suture, previously positioned in

the femoral tunnel, is then retrieved out of the tibial tunnel distal aperture. The graft is then inserted into the joint and fixed.

Fixation of the graft and post-operative rehabilitation

The authors' preferred fixation for the ACL is as follows: When using a BPTB graft, fixation is achieved with two interference screws on both the femoral (first) and tibial sides. When using a soft tissue autograft or allograft, fixation is achieved proximally with an extracortical flip button device and distally with an interference screw.

Discussion

Autograft vs. Allograft

During the decision-making process regarding a patient undergoing ACL



Figure 4: Transtibial femoral tunnel drilling (non-anatomic reconstruction). A) Anatomic specimen showing the femoral position that can be reached with transtibial technique (compare with Figure 5A). B) Arthroscopic view of the femoral offset (compare with Figure 5B). C) Position of the neoligament in a more vertical position compared with Figure 5C.



Figure 5: Antero-medial portal femoral tunnel drilling (anatomic reconstruction). A) Anatomic specimen showing the femoral position that can be reached with antero-medial portal technique (compare with Figure 4A). B) Arthroscopic view of the femoral offset (compare with Figure 4B). C) Position of the neoligament in a more horizontal position compared with Figure 4C.

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reconstruction, the first step is defining the type of graft. The use of autograft (mostly BPTB and HS) is widely accepted. The use of readily available allografts has recently grown in popularity, in order to reduce donor-site morbidity and expedite post-operative rehabilitation compared to autografts. However, some tissue banks irradiated or chemically treated the grafts as a means of sterilisation or preservation. This led to inferior outcomes of allograft ACL reconstruction compared to autograft. Although sterilisation and preservation have considerably improved over the years, tissue-processing techniques are not currently standardised yet. Potential disadvantages of allograft tissue include disease transmission, autoimmune response, delayed or incomplete biological incorporation and increased costs. In a recent systematic review, the authors compared the results of ACL reconstruction with autografts and non-irradiated, non-chemically treated allografts⁷. The authors found that no statistically significant differences existed between autografts and non-chemically processed non-irradiated allografts in Lysholm scores, International Knee Documentation Committee (IKDC) scores, Lachman examinations, pivot-shift testing, KT-1000 measurements or failure rates. However, the authors included only 11 papers in their systematic review and warn the readers that further large-scale, well-designed studies are required to confirm these findings.

In another meta-analysis of 5182 patients, the authors compared the results of BPTB autograft versus allograft in ACL reconstruction. Data from both fresh-frozen and irradiated allografts were used. The authors found that outcomes on subjective IKDC, Lysholm, Tegner, single-legged hop and KT-1000 arthrometer were significantly better in autografts. Alternatively, return to pre-injury level, overall IKDC, pivot shift and anterior

knee pain were significantly in favour of allografts. Allograft BPTB demonstrated a three-fold increase in re-rupture rates compared to autograft (12.7% and 4.3%, respectively). The authors concluded that patients undergoing ACL reconstruction with autologous BPTB grafts demonstrated lower rates of graft rupture, lower levels of knee laxity, and improved single-legged hop test results and, in general, were more satisfied than patients who received allograft BPTB reconstruction⁸.

Considering the long-term follow-up and larger case series with autografts, the authors strongly believe that autologous BPTB and HS grafts still represent the gold standard in ACL reconstruction. Allograft is a valuable alternative option in selected cases, as described in Table 2.

Bone-patellar tendon-bone vs. hamstring

Controversy also exists regarding the outcomes of BPTB and HS autografts. In a recent Cochrane review, Mohtadi and colleagues included randomised and quasi-randomised controlled trials comparing outcomes (minimum two year follow-up) following ACL reconstruction using either BPTB or HS autografts in skeletally mature adults, irrespective of the number of bundles, fixation method or incision technique. The authors found that pooled data for primary outcomes showed no statistically significant differences between the two graft choices for functional assessment (single leg hop test), return to activity, Tegner and Lysholm scores and subjective measures of outcome. There were also no differences for re-rupture or IKDC scores. All tests (instrumental, Lachman, pivot shift) for static stability consistently showed that BPTB reconstruction resulted in a more statically stable knee compared to HS. However, patients experienced more anterior knee problems, especially with kneeling, after BPTB reconstruction. BPTB

reconstructions resulted in a statistically significant loss of extension range of motion. Alternatively, HS reconstructions demonstrated a trend towards loss of flexion range of motion and a statistically significant loss of knee flexion strength. The clinical importance of the range of motion losses is still unclear⁹.

In the light of these findings, the authors believe that BPTB and HS autografts are equally valuable options in ACL reconstruction. The surgical technique, in terms of graft choice, should be tailored to the patient's needs, profession, activity level, age and sports.

Antero-medial portal vs. transtibial femoral tunnel drilling

Traditionally, the femoral tunnel has been drilled through the tibial tunnel (transtibial technique) (Figure 4). However, this procedure poses the risk of a high/vertical placement of the femoral tunnel in the intercondylar notch and a posterior tibial tunnel placement on the plateau¹⁰. This usually results in a non-anatomic ACL reconstruction (Figures 4, 5, 6, 7). The trans-tibial technique achieves good-to-excellent results in only 60% of patients¹¹, and 20%–30% of athletes do not regain their previous level of performance¹². For these reasons, surgeons started creating two independent tunnels, by drilling the femoral tunnel from the antero-medial portal (Antero-medial portal technique). In this fashion, the surgeon can place the tunnels anatomically and with more freedom compared to the transtibial technique. Antero-medial portal technique allows for anatomical tunnel placement (Figures 4, 5, 6, 7) and improved knee biomechanics^{12,13}. However, in a recent retrospective study carried out from the data of the Danish Knee Ligament Reconstruction Register, an increased risk of revision after antero-medial compared with transtibial technique during primary ACL reconstruction has been described. The authors



Figure 6: Post-operative antero-posterior views after anatomic and non-anatomic ACL reconstruction. Note the more horizontal position of the femoral tunnel in the anatomic reconstruction, compared with the non-anatomic reconstruction.

stated that their findings could be explained by technical failures resulting from introduction of a new and more complex procedure or by the hypothesis that compared to non-anatomic techniques, a greater force is carried by the anatomic ACL reconstruction and, hence, there is a concomitant higher risk of ACL rupture¹⁴.

According to the data presented and their clinical experience, the authors believe that a sports medicine surgeon should consider both the techniques. However, antero-medial portal technique allows for more anatomic tunnel positioning and better biomechanical results compared to transtibial technique.

Single vs. double bundle ACL reconstruction

Another controversy regarding ACL reconstruction is about single versus double bundle reconstruction. The double bundle technique, popularised by Dr. Fu, was developed from a good understanding of the native ACL anatomy and its two functionally different bundles (antero-medial and postero-lateral). The double bundle

techniques allows for both bundle reconstruction through four different tunnels. In a recent meta-analysis, double bundle technique apparently resulted in significantly better anterior and rotational stability and higher IKDC objective scores compared to single bundle reconstruction. However, the meta-analysis did not detect any significant differences in subjective outcome measures between double bundle and single bundle reconstruction, as evidenced by the Lysholm score, Tegner activity scale and IKDC subjective score¹⁵.

Alternatively, in a recent Cochrane review, the authors stated that there is insufficient evidence to determine the relative effectiveness of double bundle and single bundle ACL reconstruction in adults. However, the authors found limited evidence that double bundle ACL reconstruction has some superior results in objective measurements of knee stability and protection against repeat ACL rupture or a new meniscal injury¹⁶.

Conversely, a meta-analysis regarding in vitro and intraoperative

laxities after single bundle and double bundle ACL reconstructions demonstrated that both techniques result in similar antero-posterior knee joint laxity at time 0. Therefore, no conclusive evidence on the superiority of one reconstruction technique over the other in terms of rotation laxity could be obtained¹⁷.

In the light of these data, the authors do not commonly perform double bundle ACL reconstruction, due to the more complex and expensive surgical technique.

Conclusion

ACL reconstruction is a common procedure in orthopedic surgery. However, this surgery needs to be done by experienced surgeons, with experience in many different reconstruction techniques. To achieve good results and high satisfaction rates, correct treatment has to be tailored to meet the patient's needs, profession, activity level, age and sports. Considering the literature review, many controversies regarding ACL reconstruction are still under debate and need to be clarified with high quality studies.

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Figure 7: Post-operative lateral views after anatomic and non-anatomic ACL reconstruction. Note that, in the anatomic reconstruction, the femoral tunnel is lower and the tibial tunnel is more anterior than in the non-anatomic reconstruction.

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