Anterior Cruciate Ligament Reconstruction

A Practical Surgical Guide
ACL Two-Stage Revision Surgery: Practical Guide

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36.1 Introduction

Reconstruction of the anterior cruciate ligament (ACL) has become an increasingly common orthopedic procedure. Around 200,000 ACL ruptures per year occur in the United States [16, 17]. The overall incidence has been reported between 36.9 and 60.9 per 100,000 persons per year [12, 34]. Considering surgical treatment, it is estimated that more than 100,000 ACL repairs are performed annually in the United States [5], 34,000 ACL repairs are performed in France [46], and approximately 50,000 ACL reconstructions have been reported in the United Kingdom [41]. This condition thus represents a heavy economic burden with major societal impact. With a success rate for primary reconstruction ranging from 75 to around 90% [47], one must consider that surgery for revision of ACL repair has become a frequent procedure for a knee-dedicated surgeon. Nevertheless, it should not be forgotten that this procedure presents a continuous challenge to knee surgeons in most cases. This is mainly due to a multiplicity of problems that might arise, thus dictating failure of ACL repair [36] and leading to patient- and problem-related treatment options [48].

This chapter will focus only in the subgroup of patients who might be selected for two-stage revision procedure. A review from literature is provided complemented by institutional and personal experience aiming to provide a useful and practical tool.

By its turn, bone tunnel enlargement has been reported after ACL reconstruction surgery [13]. Although the long-term outcome of this phenomenon is not yet well known, tunnel lysis or expansion may be clinically significant in revision surgery. This is mainly due to the fact that the enlarged tunnels may complicate graft placement and fixation [13, 41]. Thus, two-stage revision surgery ensures adequate restoration of bone stock. By this mean, it is possible to ensure the biologic conditions for healing of the bone tunnels, which will then provide a good bed for fixation of the ACL graft [41].

Anatomic (posterior and proximal) placement of the intra-articular exit (apertural) of the femoral tunnel is required since it can provide minimal lengthening of the ACL substitute during range of motion, including when full extension is achieved [29]. A more anterior and distal position of the femoral tunnel within the roof of the notch is a recognized cause of failure, leading to the increase in length of the graft with flexion [6]. Similarly, it has also been stated the need for correct positioning of the tibial tunnel [6, 13]. A tibial tunnel in the anterior half of the anatomic tibial footprint may cause roof graft impingement in extension. In addition, repeated impingements can induce weakening of the graft with subsequent increased risk of failure [1].

Bearing in mind the aforementioned, if a significant void bony defect arises after a primary ACL reconstruction (Fig. 36.1), it will jeopardize the necessary biologic conditions for graft integration. In addition, it will also impair the correct apertural placement of the graft. Even if suspensory fixation could provide pullout stability, it would not be possible to recreate joint kinematics [13]. When this is the case, i.e., if insufficient bone stock impairs adequate apertural fixation of the plasty, primary bone grafting and a two-stage reconstruction are advised.

36.2 Patient Selection for Two-Stage ACL Revision

The radiologist is a strong ally in the diagnosis process. This member of the diagnostic health-care team should be able to recognize the types of primary repair. It must be able to assess for the complications of primary surgery, such as tunnel malpositioning, tunnel widening, and fixation device failure [18]. Nevertheless, when correct bone tunnel position implicates conflict with previous tunnels and/or hardware, consequently all materials should be carefully removed to recreate biologic and biomechanical conditions for adequate graft placement and further graft integration.

Tricks and Pearls

Moreover, if widening of the tunnel is higher than 100% of the original one, or its width measures from 16 to 20 mm on preoperative X-ray or CT, the option for two-stage repair is also suggested [2].
Considering anatomic and technical issues, we have found more frequently such indications involving the tibial than femoral tunnel [41, 42].

### 36.3 Graft Choice and Surgical Technique of Two-Stage Revision

Several graft options exist for ACL reconstruction (primary or revision), and, up to date, surgeons are far from reaching consensus concerning which represents the best option [14, 40].

Choice between autograft and allograft is a matter of continuous debate [27]. Several issues remain, but personal/institutional experience and legal issues play a decisive role. Allograft helps to overcome morbidity of graft harvesting and enables availability of large amount of tissue when it is available (Fig. 36.2). As recently reported, when ACL autografts fail traumatically, they frequently fail near their femoral origin. However, allograft reconstructions are more likely to fail in other locations or stretch [26]. Despite some issues that still remain to be overcome, namely, those related to biologic conditions on allografts, it keeps being a valuable option particularly in re-revision cases or associated to severe tissue damage [35, 42, 44].

Some allograft inherent risks and considerable costs should be considered prior its application [22, 28, 37, 38, 45].

Novel regenerative possibilities include tissue engineering and regenerative medicine principles. These are under intense research and promise to overcome the need for cadaver allografts for future for either bone or ligament replacement [8, 20, 33, 50]. Figure 36.3 shows an example of
the scaffolds that have been developed in the context of bone tissue engineering.

Despite the previously exposed, there are several viable options for ligament autograft [36] in any form of ACL repair (primary or revision). Likewise, autologous bone grafting from iliac crest [41] or other sources (e.g., proximal tibia) [10] can be used. This is also the case when a two-stage revision is to be considered.

Surgeons still lean toward the use of autografts due to technical, biologic, and legal issues. Generally, clinicians lean toward favoring a graft source different from that used in primary reconstruction. That is, if hamstrings were used as primary choice, then bone-patellar tendon-bone (BPTB) is the choice for the revision procedure.

Conversely, if BPTB was firstly used, hamstrings are selected in the revision. This issue is further discussed elsewhere.

Tissue engineering also presents promising new options for future concerning ligament replacement [8]. However, in current practice, prosthetic ligaments as primary grafts lead to some of the most difficult cases with increased intra-articular scarring and more pronounced tunnel widening. Therefore, we do not encourage their use for the time being [41].

### 36.3.1 Graft Fixation

The techniques for graft fixation that have been used during the revision procedure are mainly
dependent on the remaining bone stock and the chosen graft [19, 42].

Initial fixation is critical for the outcome, but it is particularly important until adequate graft integration takes place.

**Tricks and Pearls**

In order to increase primary resistance and obtain stability close to the articular surface, “double fixation” combining complementary devices might be an appropriate option during several “difficult ACL revision” cases [19].

Either suspensory cortical fixation (fixed or adjustable loop) or interference screws might be complemented with interference screws, staples, or post with sutures. Such double fixation might provide additional strength or increase stability close to joint line.

Fixation devices distant from the joint line (e.g., buttons, staples, washers, or post-screws) will provide a less stable reconstruction [7, 11]. This will permit abnormal graft motion within the bone tunnel causing the so-called bungee effect (longitudinal) and/or windshield-wiper effect (transverse). Ultimately, these phenomena might contribute to the enlargement of bone tunnels, and it can jeopardize integration of the graft. Ultimately, it can increase risk for failure, thus posing higher difficulty in subsequent surgeries if that might be the case [7].

Whatever is the chosen technique, it will be mandatory to achieve sufficient bone stock for further primary fixation and integration of the transplant. This is the rationale behind the two-stage revision option in cases of major defects around primary tunnels.

### 36.3.2 Two-Stage Revision Technique

#### 36.3.2.1 Stage I

All patients should be submitted to careful clinical examination under anesthesia and observations recorded. Arthroscopic thorough examination follows using standard arthroscopic portals. Possibility of ongoing infection must be definitely ruled out. Assessment and appropriate treatment of meniscal and chondral injuries should take place. Then, the graft remnant must be removed as well as unwanted osteophytes. Notch assessment and notchplasty when strictly necessary should also occur. Usually one should expect more macroscopic cartilage damage changes than previously suggested by preoperative assessment.

After the soft tissues are debrided and the entrances of the tunnels exposed, the surgeon will have a definitive picture of the defect- and hardware-related issues. Hardware is removed only when it is required.

**Tricks and Pearls**

If the original tunnel interferes with the placement of the new tunnel, it should be inspected with the arthroscope in air medium (osteoscopy) (Fig. 36.4).

![Fig. 36.4 Osteoscopy image with the arthroscope inside the tibial tunnel. This enables inspection of macroscopic aspects of the bone of tunnel walls. Notice the oval aspect of the tunnel in the articular surface. Yellow arrow represents the location of femoral tunnel](image-url)
The sclerotic walls of the tunnel should be drilled with a fine 2 mm drill, and the tunnel curetted and rapped until the tunnel walls had been taken back to clean bone. Bone in the form of dowel grafts must be then harvested from the iliac crest, placed into the tunnel, and carefully impacted. Bone graft from the ipsilateral iliac crest can be used.

Compression is a critical point once extreme care is required to avoid additional damage. For tibial tunnel, we must avoid to breach the exit point within the joint, which is achieved by viewing the relevant articular surface of the tibial plateau with the arthroscope during bone graft compression.

Arthroscopic bone grafting of femoral tunnel is a demanding procedure. Several options have been proposed either sliding graft through a guidewire [30] or using a tube harvester similar to osteochondral autograft transfer system (OATS) procedure and a press-fit technique [10].

It should be highlighted that additional difficulties are to be expected if the primary ligament used is a synthetic one. In our experience, the first-stage revision surgery is more demanding and time-consuming given the higher synovitis. Besides, it can increase intra-articular scarring associated to the synthetic graft. Tunnel widening also tends to be higher after the foreign body reaction. Extra care is often required to identify the posterior cruciate ligament (PCL) before clearing the intercondylar notch.

### 36.3.2.2 Stage II

The second stage procedure might be summarized in five steps: (1) examination under anesthesia, (2) macroscopic arthroscopic assessment, (3) relevant meniscal and chondral surgery, (4) graft harvesting, and (5) revision ACL reconstruction.

After minimizing bone voids in stage I, the revision procedure itself becomes “similar” to a primary procedure. The main focus is now given for achieving the correct anatomic placement of the tunnels.

Because the landmarks were often less distinct than those in a primary procedure, the tibial tunnel was referenced off the PCL on the medial side of the midintercondylar point. Moreover, the femoral tunnel was referenced from the over-the-top position using appropriate tools. Perioperative radioscopic imaging using an image intensifier is occasionally required to ensure optimal placement (see also Chap. 34).

### 36.4 Timing for Revision ACL Reconstruction After Spongiosaplasty

After stage I procedure, one might predict a period of 4–6 months until stage II might take place.

Many approaches are used to repair skeletal defects in reconstructive orthopedic surgery.

Autogenous cancellous bone graft, with its osteogenic, osteoinductive, and osteoconductive properties, remains the gold standard [23]. Neovascularization takes place within the bone graft as early as 2 days after implantation. With time, there is a repopulation of the marrow spaces with primitive MSCs.

Despite autogenous cancellous bone grafts lack mechanical strength, their favorable biologic activity (osteoinduction, osteoconduction, and new bone formation) provides early stability at the recipient site [23]. The biology of the graft and the mechanical environment of the host-graft interface are critical for the successful graft integration. Besides graft integration, minimal biomechanical features must be achieved prior to final ACL reconstruction. Bone maturation will continue up to several years after surgery [4, 23].

Compared with autograft cancellous bone, allograft bone of any source is a poorer promoter of bone healing [23]. Cancellous chips are the most common type of allogeneic cancellous graft used.

When revision requires a two-stage procedure with bone grafting of the tunnels prior to the definitive ligament repair, radiologists might play an important role in order to assess for adequate bone graft incorporation [18]. X-ray analysis and more relevantly computed tomography (CT) have proven to be powerful tools in this subject (Figs. 36.5 and 36.6).
Fig. 36.5 3D CT reconstructions from a case of re-revision after BPTP ACL repair. Notice the placement of two separate tibial tunnels (red and yellow arrows) and bone loss due to graft harvesting.

Fig. 36.6 CT images representing severe bone loss around femoral tunnel (yellow arrows)
A CT scan obtained at 4 months should be used to assess healing of the bone graft. Blurring of the tunnel margins, reactive sclerosis, and the presence of bone within the tunnel are signs of adequate healing.

In upcoming future, we envision that tissue engineering and regenerative medicine strategies can provide an adequate grafting material mimicking bone tissue. The main challenge for scientists in manufacturing bone graft substitutes is to obtain a scaffold that has sufficient mechanical strength and bioactive properties and can be vascularized in order to promote a viable new tissue [24, 39]. Such approach would overcome the morbidity of autologous bone harvesting and possibly achieving a faster maturation of implanted material. Our study group has been working thoroughly on development of several possibilities for bone replacement on orthopedic application combining scaffolds, cells, and nanotechnologies [31–33] (Fig. 36.3). One additional feature would be to provide a more user-friendly method for arthroscopic implantation [25] and furthermore combining bioactive molecules (e.g., growth factors) or medications [49, 50] to enhance and/or fasten tissue maturation.

### 36.5 Pitfalls and Complications of Two-Stage Revision

As aforementioned, the complications and pitfalls of two-stage revision must consider the additional morbidity of bone harvesting. Anterior iliac crest should be regarded as a good site for bone harvesting, i.e., considering its relatively low morbidity rate, early ambulation, and hospital discharge [9]. However, up to 28% postoperative pain and nearly 5% sensory disturbances have been reported [9]. The safe zone on the proximal tibia (anterior tibial metaphysis) has recently been described [43] for this propose with minimal complications noticed: 1.7% transitory sensory disturbances and one case over thirty with hypoesthesia at a five-year follow-up causing no particular limitation [10]. Allografts constitute a valid option but present lower biologic activity and inherent risks [45], while tissue-engineered implants are giving the first steps toward clinical application [33].

Preservation of tunnel’s bone walls is sometimes difficult to achieve, and it requires extreme care during bone impaction with appropriate arthroscopic control of apertural limits of tibial tunnel. Given the risk of wall breakage during surgery, surgeons should “expect the unexpected” and must be prepared for the worst-case scenario. Ultimately, it is required a complete surgical set with several distinct and complementary fixation options, i.e., besides surgical tools to prepare “bone beds” or additional fixation strategies.

Surgical time might be on the upper limit of the globally expected for ACL surgery which might predispose to vascular issues despite no evidence has been provided in this matter [15].

Complications inherent to any elective knee arthroscopy should also be considered [3].

Further possible complications are parallel to any ACL revision procedure which is described in detail on a specific chapter (see also Chap.34).

However, it must be bear in mind that most cases selected for two-stage revision are among the most difficult patients requiring ACL repair. So being, expectations for outcome must be realistic, adequate to the specific condition, and previously discussed with the patient.

### 36.6 Literature Results of Two-Stage Revision

There are limited reports from literature focused on patient selection, technical issues, or outcome from two-stage ACL revision procedures.

Patients having revision ACL reconstruction after a failed repair had improvement in their functional status as compared with pre-revision status. However, they did not achieve the same level of satisfactory results as primary ACL reconstruction [21, 48]. Outcome of repeat revision has been reported as excellent or good in 70% of the cases, although decreased after the second revision [46]. The main causes of failure have been recurrent trauma and surgical technical errors [46, 48].
A case-control clinical study has reported technical aspects and results of two-stage ACL repair with bone grafting of the tibial tunnel and the use of a different femoral tunnel [41]. Comparing to primary ACL repair, ACL revision cases presented a higher incidence of chondral and meniscal lesions. At final follow-up, IKDC scores of 61.2 ± 19.6 were obtained in the two-stage revision group compared to 72.8 ± 10.2 for primary ACL repair. No significant differences were found between laxity measurements using KT-2000 arthrometer [41].

Considering two-stage revision requiring bone grafting of femoral tunnel, a recent study considering autologous hamstring tendon graft by a single-bundle transtibial ACL reported very good results at mean 6.7-year follow-up [10]. At the last follow-up, IKDC scores significantly improved from 18 class C and 12 D to 27 patients A and B plus 3C. Mean Lysholm score improved from 65.4 (48–82; SD, 7.9) to 90.2 (72–100; SD, 7.9). Twenty-four of 30 patients (80%) were able to hop 90–100 % (grade A) as compared to the uninjured side. Significantly improved outcome concerning KT-1000 side-to-side difference and Lachman and pivot-shift measures was also registered. At a 24-month follow-up, 20 of 30 patients (66.7 %) had returned to the preoperative sport activity level (9 elite athletes, 11 county levels); 9 patients had changed to lower nonimpact sports, and 3 had to quit sports activities. All patients were able to undertake the knee-walking test without significant complaints [10]. Minor complaints related to graft harvesting were reported.

A short clinical experience of four cases that required bone tunnel repositioning and two-stage technique by means of sliding the structural iliac crest bone graft through a guidewire reported no complications from either the intra-articular bone grafting procedure or the bone graft harvesting [30].

Prospective controlled studies would be desirable in order to increase evidence level concerning two-stage ACL revision. However, it must be assumed that this is a difficult task considering the somewhat low incidence and multifactorial aspect of this condition. However, it can be concluded that in properly selected cases, two-stage revision is an adequate and feasible option while enabling good results however generally lower than primary ACL reconstruction. Ongoing research and upcoming new options might provide improved outcome particularly by diminishing the morbidity associated to graft harvesting and fasten the process of bone formation.

**Memory**

Two-stage revision after failed ACL repair must be understood as a challenging multifactorial entity. Preoperative planning is mandatory, and one should be prepared even for the unexpected. Surgeons must be experienced in primary ACL procedures and be aware of multiple options and devices to enable choosing the best approach in each specific case. In properly selected cases, good/fair results might be achieved. However, poorer outcome comparing to primary repair should be expected.

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